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ECONOMIC IMPACTS OF RAILROAD ABANDONMENT ON RURAL KANSAS COMMUNITIES

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16. Abstract

Increasing railroad abandonment and other changes in the Kansas grain transportation system have lead to increased trucking of grain. Further losses of shortline railroads would have negative effects on rural Kansas communities, including increased road damage costs and reduction in farm income.

The research measured quantifiable impacts of shoreline railroad abandonment in Kansas through the following four research tasks. First, an assessment of Kansas county road conditions and financing was conducted to determine the ability of counties to absorb the resulting incremental heavy truck traffic. Second, the changes in wheat handling and transportation costs were computed. Third, the increase in truck-attributable road damage costs to Kansas county and state roads was computed. Fourth, the additional highway accident benefits and costs attributable to the resulting incremental truck traffic were calculated.

The western two-thirds of Kansas was selected as the study area. County road officials were interviewed and surveyed to assess county road conditions and finances. GIS routing software was used to model the wheat handling and transportation costs with and without shortline railroads. Using the results of the GIS transportation model and an existing pavement damage model, the additional damage costs to county and state roads are calculated. Finally, the safety cost was calculated using the estimated increased truck miles driven, accidents per mile traveled data and costs per accident. Benefits accruing from elimination of on-grade rail-crossing accidents were subtracted from the safety costs to calculate the net annual safety impact of shortline railroad abandonment.

If the four shorelines serving the study area are abandoned there will be a large diversion of wheat shipments from railroads to trucks and traffic will increase beyond the counties' capacity. Transportation and handling costs of grain would increase by $0.056 per bushel, for a total income loss to Kansas farmers of $20.5 million. The shortline railroad system in the study area annually saves the state of Kansas $57.8 million in road damage costs. A small net safety benefit would be realized from shortline abandonment as railroad-highway crossings are eliminated.

Finally, changes to rail service improvement funding programs are suggested.

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FINAL REPORT

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DISCLAIMER

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Kristi Smith typed the final report. Special thanks go to the county engineers and road supervisors in the study area. Without their cooperation, this study would not have been possible.

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

CHAPTER 2
LITERATURE REVIEW

CHAPTER 3
STUDY AREA COUNTY ROAD CONDITIONS AND FINANCES

CHAPTER 4
TRANSPORTATION AND HANDLING COST ANALYSIS

CHAPTER 5
ROAD DAMAGE COST ANALYSIS

CHAPTER 6
HIGHWAY SAFETY ANALYSIS

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Railroad abandonment has been increasing in the state of Kansas in recent decades. In the 1970-1979 period, 415 miles were abandoned; however, abandonment in the 1980-1989 period was 815 miles, nearly double the miles abandoned in the 1970s. Abandonment continued to accelerate in the 1990-2000 era with 1246 miles abandoned. Of this total, 48% (605 miles) was abandoned by shortline railroads. In 2001, a total of 335 miles were abandoned and 86% of the total miles were abandoned by shortlines.

Following passage of the Staggers Rail Act in 1980, U.S. 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 shortline railroads. In Kansas, shortlines operate 2145 miles of track which is about 44% of total Kansas railroad mileage. Thus the economic viability of these railroads is an important issue for Kansas rural area shippers.

Since the early 1990s, an increasing amount of Kansas grain tonnage has been diverted from shortline 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 (subterminals) on their main lines. Previous research has found that Kansas farmers will truck their grain a much greater distance to obtain the higher grain price at the subterminal location. Farmers will bypass the local grain elevator, and the shortline railroad serving it, and truck the grain to the subterminal.

Agriculture has consolidated into fewer, larger farms. With the increased scale of operations, farmer ownership of semi-tractor trailer trucks has increased. With these trucks, farmers can bypass the local elevator, and the shortline railroad serving it, and deliver grain directly to more distant markets.

Research has discovered that grain is the principal commodity of most Kansas shortlines, and that the most important determinant of shortline railroad profitability is carloads per mile of track. Thus increased grain trucking threatens the economic viability of shortlines, possibly resulting in the abandonment of these railroads.

The increasing size of grain railcars has important implications for the economic viability of Kansas shortline railroads. The 286,000 pound railcar is replacing the 263,000 pound car for moving grain. Thus shortlines in Kansas will need to upgrade their tracks and bridges to handle the larger railcar. These railroads face higher costs to maintain their tracks and bridges as more heavy axle load (HAL) cars move on their lines. If shortlines are unable to handle the HAL cars, the share of grain moved by truck would continue to rise, threatening the long term viability of Kansas shortline railroads.

In the K-TRAN study *Impact of Kansas Grain Transportation on Kansas Highway Damage Costs* (2002), the authors interviewed shippers located on Kansas shortline railroads to discover the reasons for increased grain trucking. In general, the shippers as a group have increased their grain trucking because they view truck service and prices as better than that offered by railroads. The authors also interviewed executives of Kansas shortline railroads to obtain their views on the reasons for increased grain trucking. A majority of the executives cited construction of shuttle train stations (subterminals) on Class I railroads as a significant cause of increased grain trucking in Kansas. Other contributing factors cited by the shortline executives were, (a) truck rates are lower than rail rates, and (b) Class I rail rates are uncompetitive.

The negative impacts on Kansas shortlines of increased grain trucking have been serious. The authors of the K-TRAN study found that based on estimates of executives of four shortlines serving the western two-thirds of Kansas, the combined 1998 and 1999 grain carloadings of these railroads would have been 22% higher if increased grain trucking had not occurred. The four executives estimated that increased grain trucking reduced their profits by 11 to 20%. Thus as grain trucking increased, Kansas shortline railroads have lost market share in their most important commodity market, eroding their profits and threatening their long term viability.

Loss of shortline railroad service would have several negative impacts on rural Kansas communities. Abandonment of these railroads would cause a large diversion of grain traffic to county roads and state highways with a concomitant increase in road damage costs. This could be a significant financial burden for counties where the roads are not engineered to withstand constant, heavy truck traffic.

Abandonment of shortlines would have additional negative effects on Kansas rural areas. The price paid to farmers by grain buyers is obtained by subtracting the cost of transportation from the market price. With abandonment and lack of rail transport competition for trucks, grain shippers would have 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 the market is $3.00 per bushel and the transport cost to the market is 30 cents per bushel, the net price paid to the farmer is $2.70 per bushel ($3.00-$0.30). If the transport cost to the market rises to 40 cents per bushel, the farmer receives only $2.60. Of course, the loss of rail service may increase transport cost and reduce profits of other rural shippers as well.

In addition to higher transport costs, abandonment of shortline railroads would result in a reduction of market options for Kansas rural shippers. Markets that are best served by rail (i.e., large volume shipments over long distances) are no longer available to the rural shipper after abandonment. Instead, shippers are limited to local truck-served markets. 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 local 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.

Abandonment of shortline railroads 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 cost, then other highway users and the state government are no worse off. However, previous research has 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 motor carrier user fees will cover the increase in road damage cost.

Given the potential negative effects of shortline railroad abandonment on rural Kansas communities it is important that Kansas policymakers know the effects of railroad abandonment in order to develop a state rural transportation plan that effectively deals with the potential impacts. Rural Kansas counties need to know the impacts related to the loss of shortline rail service. Since some of the incremental truck traffic will occur on county roads, county road officials need to be able to determine the direct costs of increased road maintenance and the cost of increased safety risks from additional heavy truck traffic on county roads. Given the increased trend of shortline railroad abandonment in Kansas, the objectives of this research are to measure several quantifiable impacts of shortline railroad abandonment. Accordingly the objectives of this research are:

Objective 1 - Conduct an assessment of Kansas county road conditions and financing to determine the ability of counties to absorb incremental heavy truck traffic resulting from shortline railroad abandonment.

Objective 2 - Compute the changes in wheat handling and transportation costs due to abandonment of Kansas shortline railroads.

Objective 3 - Compute the increase in truck attributable road damage costs to Kansas county and state roads as a result of abandonment of Kansas shortline railroads.

Objective 4 - Calculate additional highway accident benefits and costs attributable to incremental truck traffic resulting from abandonment of Kansas shortlines.

The study area corresponds to the western two-thirds of Kansas encompassing the three central and three western Kansas crop reporting the districts. 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.

Four shortline railroads serve the study area. The Kansas and Oklahoma Railroad 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 operates over 971 route miles in Kansas. The Kyle Railroad serves the northern part of the study area operating over a 482 mile system. The Cimarron Valley Railroad has 260 route miles, with 186 miles in southwest Kansas. The Nebraska, Kansas and Colorado Railnet 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 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 1072 miles of main line track in Kansas, 188 branchline miles, and 449 miles of trackage rights. The UP has 1378 main line miles, 127 branchline miles, and 835 miles of trackage rights.

Objective 1 (an assessment of study area county road conditions and finances) was accomplished through personal interviews of County Engineers and County Road Supervisors in the 66 county study area. A questionnaire was also distributed to these individuals, and 55 of them returned completed questionnaires, for a return rate of 83%.

Objective 2 is achieved by computing the minimum transportation and handling costs 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 (GIS) software, wheat is routed through the logistics system so as to achieve minimum total transportation and handling costs. This analysis is performed with and without study area shortline railroads in the wheat logistics system. The difference in the two scenarios is the impact of shortline abandonment on Kansas wheat transportation and handling costs.

Objective 3 is achieved using the following three step general approach:

1. The transportation cost model developed to achieve Objective 2 reveals how many wheat carloadings occur at each station on each of the four shortline railroads in the study area.
2. Abandonment of the four shortline railroads is assumed, and the shortline railroad carloadings at each station are converted to truckloads at a ratio of one carload equals four truckloads.
3. 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 county and state roads attributable to the increased grain trucking following shortline abandonment.

Objective 4 is accomplished through the use of a safety cost-benefit model. When shortline railroad abandonment is assumed, wheat that would have moved by rail is trucked to market. Since accidents are proportional to the number of vehicles on the road and vehicle miles, the additional trucks on the county and state highway system will result in safety costs as measured in the following equation:

Safety Cost = (Increased Truck Miles) (Accidents Per Mile Traveled) (Cost Per Accident)

There is also a safety benefit since shortline abandonment will result in fewer highway-rail crossing (HRC) accidents. Thus the safety benefit of shortline railroad abandonment is measured by the following equation:

Safety Benefit = (HRCs Eliminated) (Accidents Per HRC) (Cost Per Accident)

The net annual safety impact of shortline abandonment equals annual safety costs minus annual safety benefits.

The major conclusions (results) of the study include the following:

1. If the four shortlines serving the study area are abandoned there will be a large diversion of wheat shipments from railroads to trucks. Much of this additional traffic would move over county roads that are not built to handle a large increment in five axle 80,000 pound trucks. To document the potential challenge facing counties, a survey of study area county road conditions and finances was conducted in the summer of 2001. The principal results of the survey are summarized below.

For counties with cement roads, 22% of the miles were rated in the poor or very poor categories, 38% were characterized as good or very good, and 40% were rated as fair. For the counties with asphalt roads, 18% of the miles were rated poor or very poor, 55% were classified as good or very good, and 27% were rated as fair. A total of 29% of the 55 sample county representatives rated the condition of their roads as worse than five years ago, 44% said their roads were better or much better, and 27% rated the condition of their roads as unchanged.

If the overall condition of the county's roads had declined in the previous five years, the respondents were asked to specify the reasons for the deterioration. Increases in the number of heavy trucks on the county's roads was ranked as the most important reason for the decline in road conditions. The second most important factor was increase in the cost of road maintenance.

The average expenditure of the sample counties for road and bridge maintenance in year 2000 was $1.6 million and the principal revenue source was the property tax. A total of 74% of the sample county representatives said that the current budget for road and bridge maintenance is insufficient to maintain an adequate level of service on the county's roads. Nearly 68% of the county engineers or road supervisors that indicated that the budget was inadequate said the budget shortfall was between 11 and 30%. Another 25% of the respondents in this group said the budget shortfall was greater than 30%.

To deal with the budget shortfall, one-third of the sample counties had abandoned some roads which collectively amounted to 234 miles. About one-fourth of the county representatives indicated that they had recently considered abandoning a collective total of 421 miles.

For counties that recently experienced a decline in the condition of the county's roads and bridges, the respondents were asked what changes would help restore the condition of the county's roads and bridges. The most frequently mentioned suggestion was an increase in state and federal aid for county roads. Most of the other suggestions related to the financing of state and federal aid programs for county roads and bridges.

In general, a substantial number of county road miles in the study area are not in good condition. Current road and bridge maintenance budgets are inadequate in the majority of counties even to maintain the current level of service. The counties are not equipped to deal with a large increment in heavy truck traffic triggered by abandonment of shortline railroads.

2. Changes in Transportation and Handling Costs Due to Shortline Railroad Abandonment

The analysis simulated the transportation and handling costs of shipping 365.5 million bushels of wheat (the 1998-2001 average wheat production of the study area) through the wheat logistics system to Houston, Texas. After simulated abandonment the number of truck-miles doubles from 7,771,552 to 15,850,420. Shortline car-miles fall from 3,665,988 in the no-abandonment scenario to zero in the post-abandonment scenario. The number of Class I railroad car-miles (76,438,797) is unaffected by shortline railroad abandonment.

After simulated abandonment all the wheat that was shipped by shortline railroad is transported by truck. Total truck costs rise from $34,336,869 in the no-abandonment scenario to $43,498,306 in the post-abandonment case, an increase of $9,161,437. Total shortline railroad costs fall from $10,863,532 in the pre-abandonment case to zero after abandonment. The strong competition between trucks and shortlines for the relatively short-haul intra-Kansas movements of wheat is revealed by comparing the increase in truck costs to the decline in shortline costs. That is, truck costs rise by $9.16 million after abandonment compared to a decline in shortline costs of $10.86 million. Thus the net change is a decrease of $1.7 million ($9.16 million minus $10.86 million). Since Class I railroad costs are not affected by abandonment ($81,390,227 in either case), the total wheat logistics system costs actually fall by $1.7 million after abandonment. However, it should be noted that the total transport cost of the no-abandonment scenario ($126.6 million) is only 1.4% higher than the total transport cost of the abandonment scenario ($124.9 million).

While there is no difference in the total wheat logistics system transport costs in the two scenarios, this is not the case for wheat handling costs. Wheat shipped by truck has to be trans-shipped twice compared to only once for shortline rail shipment. Wheat is assessed an unload cost when it is received from farmers and a loadout cost when it is subsequently shipped from the country elevator by truck. When the wheat arrives by truck at the shuttle train station or terminal elevators it is assessed an unload cost. Then the wheat is assessed a loadout cost when it is loaded into unit trains for shipment to Houston. In contrast, wheat shipped by shortline is not unloaded into a terminal elevator and thus has less handling costs.

Wheat handling costs increase from $74,769,192 in the no-abandonment case to $97,132,794 in the post-abandonment scenario, an increase of $22,363,602.

When transport and handling costs are combined, the total wheat logistics system costs rise from $201,359,820 in the pre-abandonment scenario to $222,021,327 in the post-abandonment case, an increase of $20,661,507. The increase in total transport and handling cost of $20.7 million in the after abandonment case is the net effect of an increase of $22.4 million in wheat handling costs and a $1.7 million decrease in transport cost.

The total wheat logistics system cost per bushel rises from $0.551 in the no-abandonment case to $0.607 in the after abandonment situation, a net increase of $0.056 per bushel. If Kansas farmers absorb all the increase in wheat logistics system costs, their income would fall by $20.5

million. This figure is obtained by multiplying study area average wheat production of 365.5 million bushels by the $0.056 increase in cost per bushel.

3. Shortline Abandonment and Road Damage Cost

The shortline railroad system in the study area annually saves the state of Kansas $57.8 million dollars in road damage costs. When this figure is reduced by incremental fuel tax revenue due to additional trucking in the post-abandonment scenario, the net road damage cost is $57.5 million. As expected, the road damage costs avoided are proportional to the size of the shortline systems. The Kansas and Oklahoma saves the state $30.6 million in road damage cost, 52.9% of the total savings. The Kyle Railroad saves $15.8 million (27.3% of the total), the Cimarron Valley Railroad $8.5 million (14.8% of the total), and the Nebraska, Kansas and Colorado Railnet $2.9 million or 5% of the total road damage cost savings.

4. Highway Safety Costs and Benefits of Shortline Railroad Abandonment

Abandonment of shortline railroads will increase highway safety costs due to increased truck traffic density and vehicle miles traveled. The safety costs of the additional truck miles consists of $649,196 for fatalities, $622,380 for non-fatal injury accidents, and $23,735 for property damage only accidents, resulting in a total safety cost of $1,295,361. The safety benefit from fewer highway-railroad crossing accidents after abandonment is $2,698,604. Therefore, abandonment results in a net safety benefit of $1.4 million ($2.7 million minus $1.3 million). There is a small net safety benefit after abandonment because the accidents are predicted to be less severe. That is, transporting study area wheat on shortlines (no-abandonment scenario) will annually result in 0.64 fatalities and 3.93 non-fatal injuries, whereas transporting wheat by truck (abandonment scenario) will annually result in 0.20 fatalities and 3.9 non-fatal injuries.

5. Summary of Shortline Railroad Abandonment Impacts

The abandonment of shortline railroads in the study area results in an additional $57.8 million in road damage cost, $20.7 million in additional transportation and handling cost, and $1.3 million in incremental highway safety costs. If Kansas farmers absorb all the increase in wheat logistics system costs, Kansas farm income would decline by $20.8 million.

Since shortline railroads annually save the state of Kansas nearly $58 million in avoided road damage cost, and county road and bridge maintenance budgets are not equipped to cope with the road damage impacts of additional heavy truck traffic, the following policy recommendations should be considered.

Kansas has two shortline railroad assistance plans which are the Federal Local Rail Freight Assistance to States (LRFA) and the State Rail Service Improvement Funds (SRSIF). In 1990, the Kansas legislature granted KDOT the authority to loan Federal Railroad Administration (FRA) funds to shortline railroads through the LRFA program, which provides low interest revolving loans below the prime rate to shortlines. The SRSIF was established in 1999 to provide shortline railroads operating in Kansas with low interest, 10 year revolving loans or grants to be used primarily for track rehabilitation. For SRSIF projects the shortline must pay 30 percent of the cost of the project and the state provides a combination of grants (30 percent) and loans (40 percent) for the remaining 70 percent. The interest rate on the loan portion does not exceed 3 percent.

In order for Kansas shortline railroads to be able to safely and efficiently handle HAL cars and provide better service, the funds in the SRSIF program need to be greatly increased. In order to reduce the impact of SRSIF on debt burdens of shortlines, the state's 70 percent share of track rehabilitation projects should be increased to 80 percent with the grant portion at 40 percent and the loan portion at 40 percent, if SRSIF funds are increased.

The federal government needs to change the Railroad Rehabilitation and Improvement Financing (RRIF) program which has not been used at all in Kansas. The program provides for up to one billion dollars in direct loans and loan guarantees for projects benefitting freight railroads other than Class I carriers (i.e., shortline railroads). Eligible projects include (1) acquisition, improvement or rehabilitation of intermodal or rail equipment or facilities (including tracks, components of tracks, bridges, yards, buildings, and shops); (2) refinancing of outstanding debt incurred for these purposes; or (3) development or establishment of new intermodal or railroad facilities. The maximum repayment period is 25 years and the current interest rate is about 6 percent. One unique feature of the RRIF program is the payment of a credit risk premium prior to an appropriation of funds. The credit risk premium is a cash payment to be provided by the loan applicant or a non-Federal infrastructure partner on behalf of the loan applicant.

The RRIF program could provide a source of loans for Kansas shortline railroads to improve their system infrastructure to accommodate HAL cars and attract more traffic. Currently there are no RRIF loan applicants in Kansas. The federal government needs to modify the provisions of RRIF in order to make it attractive to shortlines. The maximum repayment period could be extended to 30 years and the interest rate reduced to 3 percent to conform to the interest rate available on LRFA and SRSIF loans. The credit risk premium should be modified to be more user friendly since, as noted above, there are currently no RRIF loan applicants in Kansas.

It is recommended that Port Authorities, as an economic development goal, purchase covered hopper cars, new or used, and lease them to shortline railroads for use in Kansas. Given periodic car shortages and railroad congestion, the Class I railroads can not always supply shortline railroads with covered hopper cars in a timely manner. Having an adequate covered hopper car supply to move Kansas grain to market is paramount to the continued success of shortline railroads operating in the state.

CHAPTER 1

INTRODUCTION

1.1 The Research Problem

Railroad abandonment has been increasing in the state of Kansas in recent decades. In the 1970-1979 period, 415 miles were abandoned; however, abandonment in the 1980-1989 period was 815 miles, nearly double the miles abandoned in the 1970s. Abandonment continued to accelerate in the 1990-2000 era with 1246 miles abandoned. Of this total, 48% (605 miles) was abandoned by shortline railroads. In 2001, a total of 335 miles were abandoned and 86% of the total miles were abandoned by shortlines.

Following passage of the Staggers Rail Act in 1980, U.S. 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 shortline railroads. In Kansas, shortlines operate 2145 miles of track which is about 44% of total Kansas railroad mileage. Thus the economic viability of these railroads is an important issue for Kansas rural area shippers.

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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 (subterminals) on their main lines. According to Rindom, Rosacker, and Wulfkuhle (1997, p. ii) Kansas farmers will truck their grain a much greater distance to obtain the higher grain price at the subterminal location. Farmers will bypass the local grain elevator, and the shortline railroad serving it, and truck the grain to the subterminal.

Agriculture has consolidated into fewer, larger farms. With the increased scale of operations, farmer ownership of semi-tractor trailer trucks has increased. With these trucks, farmers can bypass the local elevator, and the shortline railroad serving it, and deliver grain directly to more distant markets.

According to Babcock et al. (1993, p. 80) grain is the principal commodity of most Kansas shortlines, and Babcock, Prater and Russell (1997, p. 12) found that the most important determinant of shortline railroad profitability is carloads per mile of track. Thus increased grain trucking threatens the economic viability of shortlines, possibly resulting in the abandonment of these railroads.

The increasing size of grain railcars has important implications for the economic viability of Kansas shortline railroads. The 286,000 pound railcar is replacing the 263,000 pound car for moving grain. Thus shortlines in Kansas will need to upgrade their tracks and bridges to handle the larger railcar. These railroads face higher costs to maintain their tracks and bridges as more heavy axle load (HAL) cars move on their lines. If shortlines are unable to handle the HAL cars, the share of grain moved by truck would continue to rise, threatening the long term viability of Kansas shortline railroads.

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The negative impacts on Kansas shortlines of increased grain trucking have been serious. Babcock and Bunch (2002) found that based on estimates of executives of four shortlines serving the western two-thirds of Kansas, the combined 1998 and 1999 grain carloadings of these railroads would have been 22% higher if increased grain trucking had not occurred. The four executives estimated that increased grain trucking reduced their profits by 11 to 20%. Thus as grain trucking increased, Kansas shortline railroads have lost market share in their most important commodity market, eroding their profits and threatening their long term viability.

Loss of shortline railroad service would have several negative impacts on rural Kansas communities. Abandonment of these railroads would cause a large diversion of grain traffic to county roads and state highways with a concomitant increase in road damage costs. This could be a significant financial burden for counties where the roads are not engineered to withstand constant, heavy truck traffic.

Abandonment of shortlines would have additional negative effects on Kansas 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 the market is $3.00 per bushel and the transport cost to the market is 30 cents per bushel, the net price paid to the farmer is $2.70 per bushel ($3.00-$0.30). If the transport cost to the market rises to 40 cents per bushel, the farmer receives only $2.60. Of course, the loss of rail service may increase transport cost and reduce profits of other rural shippers as well.

In addition to higher transport costs, abandonment of shortline railroads would result in a reduction of market options for Kansas rural shippers. Markets that are best served by rail (i.e., large volume shipments over long distances) are no longer available to the rural shipper after abandonment. Instead, shippers are limited to local truck-served markets. 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 local 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.

Abandonment of shortline railroads 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 cost, 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 motor carrier user fees will cover the increase in road damage cost.

1.2 Research Objectives

Given the potential negative effects of shortline railroad abandonment on rural Kansas communities it is important that Kansas policymakers know the effects of railroad abandonment in order to develop a state rural transportation plan that effectively deals with the potential impacts. Rural Kansas counties need to know the impacts related to the loss of shortline rail service. Since some of the incremental truck traffic will occur on county roads, county road officials need to be able to determine the direct costs of increased road maintenance and the cost of increased safety risks from additional heavy truck traffic on county roads. Given the increased trend of shortline railroad abandonment in Kansas, the objectives of this research are to measure several quantifiable impacts of shortline railroad abandonment. Accordingly the objectives of this research are:

Objective 1 - Conduct an assessment of Kansas county road conditions and financing to determine the ability of counties to absorb incremental heavy truck traffic resulting from shortline railroad abandonment.

Objective 2 - Compute the changes in wheat handling and transportation costs due to abandonment of Kansas shortline railroads.

Objective 3 - Compute the increase in truck attributable road damage costs to Kansas county and state roads as a result of abandonment of Kansas shortline railroads.

Objective 4 - Calculate additional highway accident benefits and costs attributable to incremental truck traffic resulting from abandonment of Kansas shortlines.

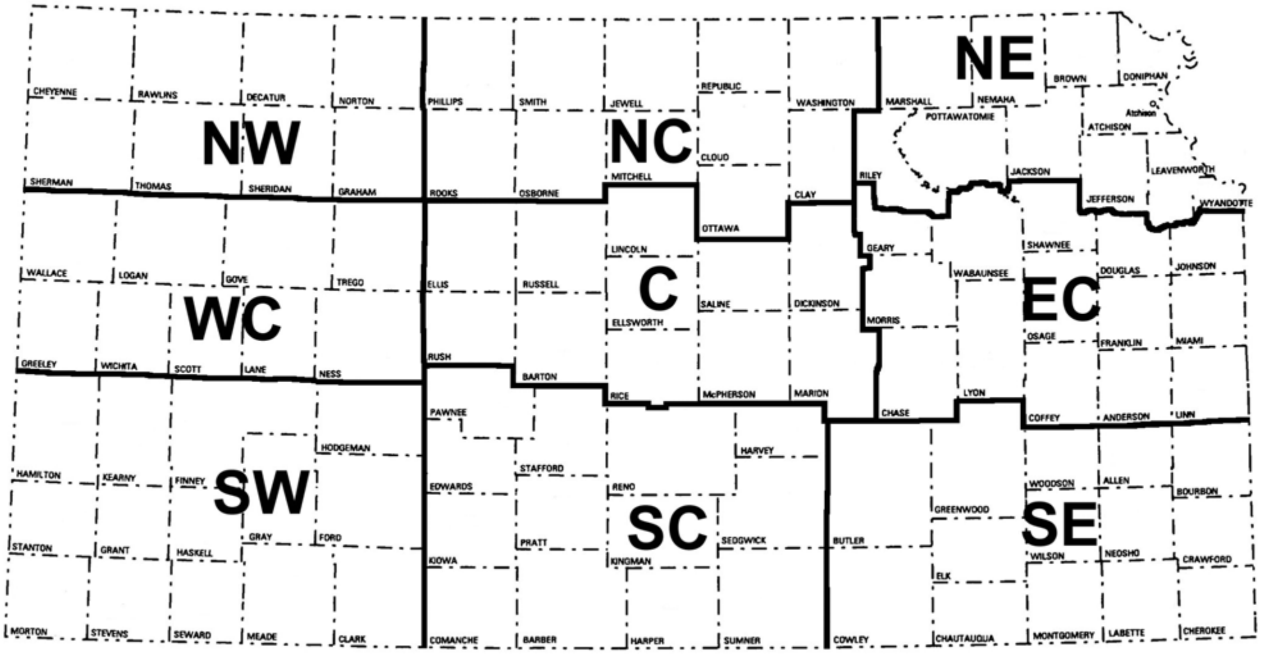
1.3 The Study Area

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 shortline railroads serve the study area. 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 operates over 971 route miles in Kansas and has 108 employees.

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	1,462,561	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*.

The Kyle Railroad serves the northern part of the study area and operates over 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 1072 miles of main line track in Kansas, 188 branchline miles, and 449 miles of trackage rights.. The UP has 1378 main line miles, 127 branchline miles, and 835 miles of trackage rights.

1.4 Description of the Kansas Grain Logistics System

According to Babcock and Bunch (2002, p. 13), a total of 70% of the Class I railroad grain carloadings in the study area originate at terminal elevators in Salina, Hutchinson and Wichita, Kansas and at the unit train loading stations located outside the traditional transhipment locations (i.e., Salina, Hutchinson and Wichita). With regard to the unit train shipping stations located outside the traditional transhipment locations, the BNSF serves the facilities at Wright, Garden City, Concordia, Wellington, Abilene and Dodge City, Kansas. The unit train loading facilities in the study area located on the UP are at Haviland, Wakeeney, Ogallah, Sharon Springs, Colby, Abilene and Plains, Kansas. These locations are also referred to as shuttle train stations.

The majority of the grain received by the terminals in Salina, Hutchinson and Wichita is delivered by motor carrier, and all of the grain received by the shuttle train shipping locations on Class I railroads arrives by truck. It is estimated that each of the dozen study area shuttle train shipping locations receives 15,375 truckloads annually (Babcock and Bunch 2002, p. 15). These are semi-tractor trailer and tandem axle trucks with about one-third of the receipts delivered by farmers and two-thirds from commercial elevators.

The principal destinations for the wheat shipments from shuttle train locations on Class I railroads are the Texas Gulf (export), U.S. flour mills, and Mexico (Babcock and Bunch 2002, p. 16). The two primary destinations for sorghum shipments by shuttle train facilities on Class I railroads are the Texas Gulf (export) and Mexico.

In the 1997-1999 period, nearly 860 million bushels of grain were received by elevators located on the shortline railroads serving the study area. According to Babcock and Bunch (2002, p. 17), nearly 80% of this volume was delivered by farmers in semi-tractor trailer and tandem axle trucks. The remaining 20% of the grain receipts were delivered in smaller farm trucks. During the same time period, about 45% of the wheat shipments of these elevators were transported by shortline railroads and 55% percent by truck (Babcock and Bunch 2002, p. 20). Motor carriers dominated the shipments of corn, sorghum and soybeans from these elevators, accounting for 83% of the sorghum shipments and nearly 98% of the combined corn and soybean shipments. In total, shortlines accounted for only 28% of the grain shipments from the elevators located on their systems (Babcock and Bunch 2002, p. 20).

U.S. flour mills (including those in Kansas), Hutchinson and Wichita were major destinations for both truck and shortline wheat shipments from the elevators located on the shortline railroads serving the study area. Shuttle train locations (excluding Salina, Hutchinson and Wichita) on Class I railroads were major destinations for truck wheat shipments from these elevators. The major destinations for truck shipments of sorghum from these facilities are livestock feedlots in Kansas, Oklahoma and Texas, shuttle train loading locations, and alcohol manufacturing plants. The principal destination for sorghum shipped by shortlines from these elevators was Wichita. Motor carriers dominate the corn and soybean shipments from elevators located on shortlines. The major destinations for the corn shipments are Kansas, Oklahoma and

Texas feedlots, with Wichita as the dominant destination for truck soybean shipments (Babcock and Bunch 2002, p. 20 and 22).

1.5 Methodology

Objective 1 (an assessment of study area county road conditions and finances) was accomplished through personal interviews of County Engineers and County Road Supervisors in the 66 county study area. A questionnaire was also distributed to these individuals, and 55 of them returned completed questionnaires, for a return rate of 83%.

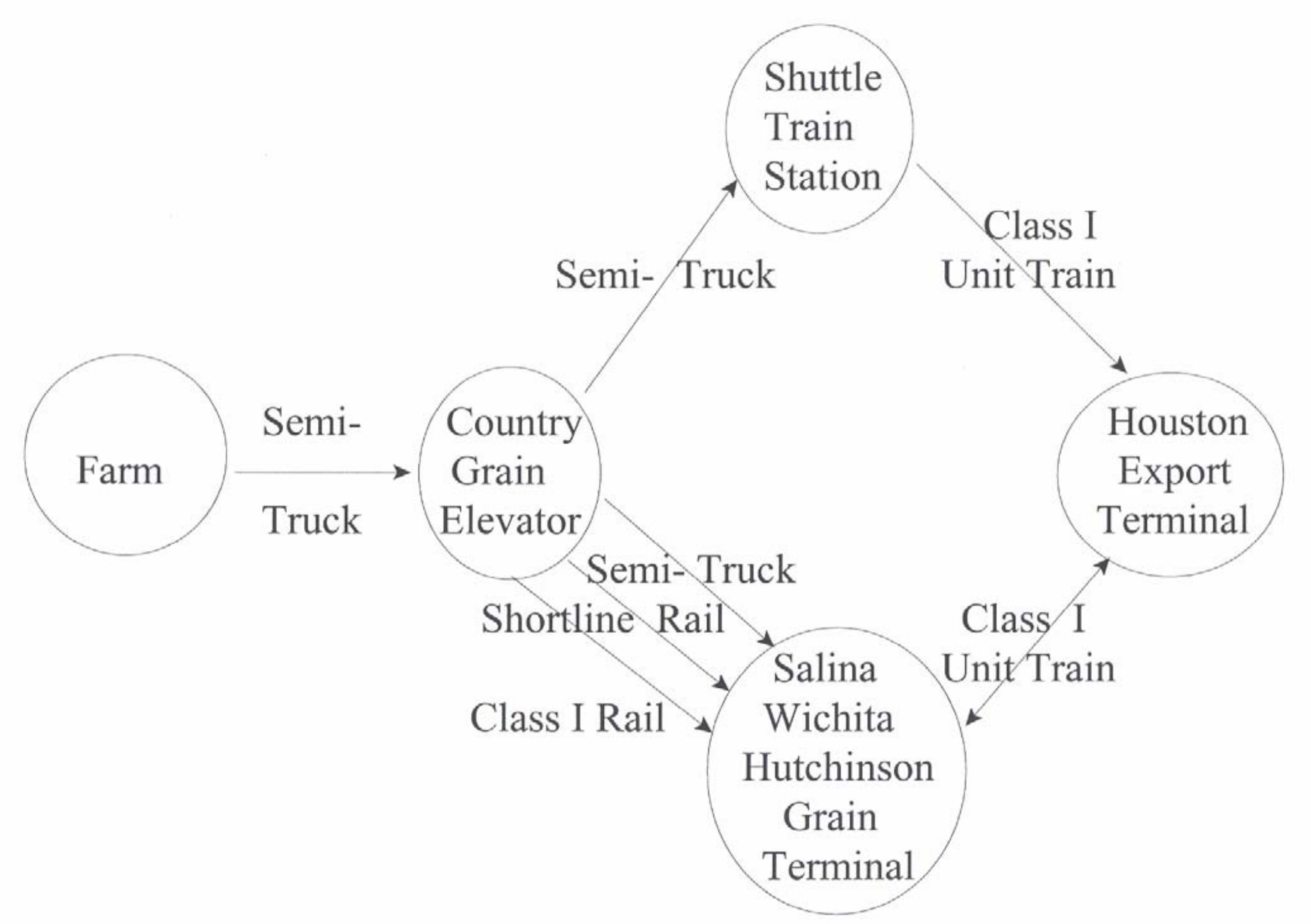
A detailed discussion of the methodology for accomplishing Objective 2 will follow in a later chapter of this report. In general, Objective 2 is achieved by computing the minimum transportation and handling costs for moving Kansas wheat from farms, through Kansas country grain elevators, and then through Kansas unit train loading locations to the export terminals at Houston, Texas (see Figure 2). Using Arc View Geographic Information System (GIS) software, wheat is routed through the logistics system so as to achieve minimum total transportation and handling costs. This analysis is performed with and without study area shortline railroads in the wheat logistics system. The difference in the two scenarios is the impact of shortline abandonment on Kansas wheat transportation and handling costs.

Objective 3 is achieved using the following three step general approach:

1. The transportation cost model developed to achieve Objective 2 reveals how many wheat carloadings occur at each station on each of the four shortline railroads in the study area.
2. Abandonment of the four shortline railroads is assumed, and the shortline railroad carloadings at each station are converted to truckloads at a ratio of one carload equals four truck loads.
3. 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 county and state roads attributable to the increased grain trucking following shortline abandonment. A detailed discussion of the pavement damage model will follow in a later chapter of this report.

FIGURE 2

Wheat Logistics System



Objective 4 is accomplished through the use of a safety cost-benefit model. When shortline railroad abandonment is assumed, wheat that would have moved by rail is trucked to market. Since accidents are proportional to the number of vehicles on the road and vehicle miles, the additional trucks on the county and state highway system will result in safety costs as measured in the following equation:

Safety Cost = (Increased Truck Miles) (Accidents Per Mile Traveled) (Cost Per Accident)

There is also a safety benefit since shortline abandonment will result in fewer highway-rail crossing (HRC) accidents. Thus the safety benefit of shortline railroad abandonment is measured by the following equation:

Safety Benefit = (HRCs Eliminated) (Accidents Per HRC) (Cost Per Accident)

The net annual safety impact of shortline abandonment equals annual safety costs minus annual safety benefits.

CHAPTER 2

LITERATURE REVIEW

2.1 Spatial Transportation Cost Studies

One of the objectives of this study is to measure the minimum wheat transportation and handling costs prior to and after assumed shortline railroad abandonment. This is accomplished by using the Arc View GIS 3.2 computer software to route Kansas wheat through the wheat logistics system to the export terminals at Houston at minimum transportation and handling cost. This analysis is similar to previous studies that have employed spatial models to analyze a variety of grain transportation problems and issues. Since there are a large number of these studies, the following discussion includes only a sample of them.

The first of these studies was "A Working Model for Plant Numbers and Location," authored by John F. Stollsteimer in 1963. The Stollsteimer model is a linear programming technique used to determine the number, size, and location of plants that minimize the combined transportation and processing costs involved in the assembling and processing of raw materials produced in varying quantities at spatially scattered production points. In Stollsteimer's 1963 study, 12 potential plant sites were examined to determine the number, size, and location of pear packing facilities that would minimize the combined cost of assembling and packing the pear crop in the Lake County region of California. The distinguishing features of the model are the inclusion of plant numbers and locations as variables.

Tyrchniewicz and Tosterud (1973) modified the Stollsteimer model by adding a transportation distribution activity to the objective function of the linear programming model. Thus their study minimized the total cost of collecting, handling, and distributing grain. The model was used in a study of the wheat logistics system of the Boissevain Region of Canada. The purpose of the study was to analyze the economic impact on farmers, grain elevators and railroads of abandonment of rail lines, delivery points, and/or individual elevators at a delivery point.

The procedure used by Tyrchniewicz and Tosterud involved eight simulations within two categories which were the farmers preferred delivery point criterion and the minimum delivery distance criterion. The first simulation determined the cost minimizing pattern of delivery points and elevators for the existing system of rail lines. The second through the seventh simulations assumed the abandonment of six rail branchlines, one at a time, in the order in which they were likely to be abandoned. An eighth simulation excluded from the logistics system all remaining elevators that were less than 100,000 bushel storage capacity. The authors concluded that total grain collection, handling and distribution cost would be reduced by about 12% if all six rail branchlines in the analysis were abandoned.

A slightly different model from that of Tyrchniewicz and Tosterud was employed by Ladd and Lifferth (1975) to examine alternative rail-based grain transportation systems related to upgrading or abandoning rail lines within a multicounty region surrounding Fort Dodge, Iowa. The objective of the study was to maximize farmer income from their commercial sales of corn and soybeans. Ladd and Lifferth heuristically maximized the joint net revenue of corn and soybean producers for different rail networks. Joint net revenue was defined as income received at final destinations minus storage, transportation, receiving, load-out, and drying costs. The authors concluded that a grain transportation system having fewer light density rail lines would increase joint net revenue of grain producers.

Baumel, Miller and Drinka (1977) used the Stollsteimer model to study the benefits and costs of upgrading 71 branchlines in Iowa. The lines to be abandoned and the order in which they were abandoned were determined in the study. To determine the order of abandonment, each branchline was assigned a rank based on a ratio defined as the number of cars originating and terminating on the line in the 1972-74 period divided by the annualized cost of upgrading and fixed maintenance cost of the line. The lower this ratio the higher the priority for abandonment.

To determine the benefits of upgrading a branchline, a Stollsteimer model was used to identify the least cost grain logistics system with the branchline upgraded. Then the model was used to reoptimize the grain logistics system with the branchline deleted from the rail network. The difference between the two scenarios was the economic benefit of upgrading, rather than abandoning, the line. If the benefits exceeded the cost of upgrading, the branchline was retained in the network. If the benefits were less than the upgrading costs, the line was deleted from the rail network. The procedure was repeated until all 71 rail lines had been evaluated.

Larson and Kane (1979) employed a network flow model to evaluate the impact of abandoning 17 light density rail branchlines in central and southwest Ohio. They found that rail abandonment had little impact upon aggregate total costs of grain transfer. However, considerable changes occurred in grain movement, storage, and transport throughout the region.

The first step in the study was to simulate the existing grain logistics system to analyze the impact of rail abandonment. Data from crop year 1975-76 was used to estimate the data inputs for the network model including grain production, grain movements, farm storage capacity and costs, commercial grain elevator handling and storage costs, and railroad and truck grain prices. The least cost solution of the model for the existing grain logistics system provided a baseline solution for evaluation of rail lines for abandonment. Next, the 17 branchlines were deleted from the network, and the network model was resolved to yield the abandonment solution. The difference between the two solutions represented the increase in grain logistics costs due to the abandonments. Larson and Kane estimated the increase in total logistics costs (the benefit of the branchlines) resulting from abandonment to be less than $250,000, much less than the $4 million required to upgrade the 17 branchlines. Thus, based on the fact that the benefits are much less than the cost, the authors concluded that the lines should be abandoned to raise economic efficiency.

Fuller and Shanmugham (1981) used a network flow model to determine the effectiveness of competitive forces in limiting rail rate increases in the Southern Great Plains hard red winter wheat producing region. This was an important issue since deregulation of railroads in 1980 allowed them much more flexibility with regard to their prices. They examined three scenarios including (1) the effectiveness of intramodal competition in limiting rail grain price increases in the short run, (2) the effectiveness of intermodal competition in limiting rail grain price increases in the short run, and (3) the effectiveness of intermodal competition in limiting rail grain price increases in the long run.

A network flow model was used to identify the grain flows (movements) that minimized the total annual handling, storage, and transportation costs of the export wheat logistics system. The model required identification of the region's dominant railroad. The Santa Fe was selected because it operated about 54% of the region's track and handled about one-half of the region's rail wheat shipments. In the short run scenario, historic levels of wheat supplied from the region to Gulf of Mexico ports, and existing transport and storage capacity constraints were included in the network model. The procedure employed to measure the effectiveness of intramodal competition required two steps. First the least cost solution of the model for the existing wheat logistics system was used to identify the grain elevators served by the dominant railroad and to estimate the railroad's revenues from each elevator. Second, the export wheat rail prices for elevators served by the dominant railroad were adjusted upward. Then the network model was solved for the new least cost solution. If the dominant railroad's revenues at an elevator increased, the rail wheat prices were adjusted upward again. This procedure was continued until the dominant railroad's revenue began to decline.

The procedure used to determine the effectiveness of intermodal competition to limit short run increases in rail export wheat prices was similar to that used to evaluate intramodal competition. The only difference was that all railroad wheat prices were raised, not just those of the dominant railroad.

To measure the long run effectiveness of intermodal competition, a slight modification was made to the network model. New capital investment was allowed for river elevators and Mississippi River port terminals. This increased the costs at these water carrier served elevators.

Fuller and Shanmugham found that the dominant railroad could profitably increase its export wheat prices by an average of 5%, indicating that intramodal competition was very effective in limiting rail export wheat prices. The short run intermodal analysis indicated that railroads could more easily increase revenue if they collaborated in adjusting their export wheat rates upward. The long run intermodal analysis indicated that the truck-barge combination would be the most effective type of competition in limiting rail export wheat rates following railroad deregulation in 1980.

Fuller et. al. (1983) used a network model to determine the likelihood of rail rate increases on export grain movements in response to rail deregulation in 1980. A multicommodity, multiperiod, cost minimizing network model was used to conduct the analysis. The model included all grain handling, storage, and transportation costs related to the movement of corn, wheat and soybeans. The network model included 165 grain and soybean producing regions, 85 grain deficit regions, 16 U.S. port areas, and 43 barge loading locations.

To identify the maximum rail rates, defined in terms of the ratio of revenue to variable cost, Fuller et. al. employed an interactive procedure that determined the rates that a monopoly rail system could charge. In the base case, the revenue to variable cost ratio was set equal to 1.0. Next, rail costs from the base case were multiplied by 1.1 to yield a rail rate reflecting a revenue to variable cost ratio of 1.1. Then the network model was resolved. If a region that shipped grain when the revenue to variable cost ratio equaled 1.0 failed to ship any grain when the ratio equaled 1.1, then the highest rail revenue to variable cost ratio that could be levied in that region was 1.1. The process of adjusting rail rates upward, in increments of 0.10 and observing the region's least cost transportation modes was continued in order to determine the highest railroad revenue to variable cost ratio that could be levied by railroads before diverting grain traffic to a competing mode.

The maximum rail revenue to variable cost ratio estimated in the study was compared to the results of a 1977 study that calculated the actual revenue to variable cost ratios for wheat, corn and soybean movements in the U.S. Fuller et. al. found that historic rail revenue to variable cost ratios for corn, soybeans, hard wheat and durum wheat were nearly equal to the maximum attainable ratios for a monopoly rail system. They concluded that it was unlikely that railroads would raise rates on export grain shipments as a result of railroad deregulation.

Ming Hong Chow, Michael W. Babcock and L. Orlo Sorenson (1985) used a capacitated network flow model to evaluate structural changes in the grain logistics system of a 12 county area in northwest Kansas. The capacitated network model contained 330 production origins, 50 country elevator locations, eight inland terminal locations, three river elevator locations, five U.S. export areas, and 14 potential subterminal sites.

The Chow, Babcock and Sorenson study measured the impact of abandoning the former Rock Island Railroad, and the economic feasibility of constructing subterminals in northwest Kansas. The first step in simulating abandonment of the Rock Island was to find the least cost solution for the wheat logistics system including the Rock Island. Then the Rock Island was deleted from the network model, and the least cost wheat flow was re-calculated. The authors found that total wheat logistics costs rose only 1.35% as a result of the simulated abandonment of the Rock Island. However the increases in trucking and storage costs were additional burdens for farmers who delivered wheat to country elevators on the former Rock Island line. These country elevators lost most of their export wheat receipts as a result of the abandonment.

The authors estimated total logistics system costs with and without subterminals in northwest Kansas, and total costs were 12 percent less in the scenario that included subterminals.

Reyff and Muten (1986) used the DNS traffic diversion model to estimate the economic impact of the proposed merger of the Southern Pacific and Santa Fe railroads. The model employed a set of rules for diversion of transportation movements and a least cost network algorithm to estimate changes in traffic flows, total revenues, and total costs attributable to the merger. One-tenth of the Santa Fe and Southern Pacific 1982 waybills and the ICC waybill sample for traffic of other railroads were used to simulate the existing rail system.

In the first step of the analysis, rail traffic that would not be attracted by the merged railroads was eliminated from consideration. Next, candidate routes for traffic diversion were selected. These routes favored the merging carriers and were selected with the aid of a minimum path algorithm. In the network model, each link was multiplied by a factor that reflected differences in line type (main line or branch line and class A or B). Each interchange between railroads was also assigned a weighted mileage. The minimum path algorithm was then used to identify routes with the minimum weighted mileage, and to identify those routes that belonged to the potential merged system. Cases were excluded where there was no cost advantage to the diverted route over the pre-diversion route, or where there was no benefit to the diverted route that was caused by the merger. All rail movements not excluded were considered to be possible diversions.

Next a matrix was developed to predict the share of traffic on each route that would be diverted to the merging railroads. The ICC waybill data was used to identify the characteristics of the traffic. Multipliers that indicated the probability of diversion for the given traffic characteristics were estimated. These multipliers were applied to the ICC waybill data to predict the share of the traffic diverted to the merging railroads.

Finally, pre and post-diversion variable costs were calculated using ICC Rail Form A techniques. Cost saving from the rerouting of traffic movements internal to the Santa Fe-Southern Pacific system were also estimated.

The DNS study estimated net public benefits from the proposed merger by estimating the reduction in the physical units of output that the merger would enable. Reyff and Muten estimated that the proposed merger would save 6.4 million loaded car-miles and 413,400 carload interchanges annually. It would also allow the railroads to avoid 19.4 million tons of interline rail traffic.

Lemke and Babcock (1987) used a network flow model employing an out-of-kilter algorithm to analyze the impact of railroad mergers on export grain railroad prices (rates) in western Kansas. The objective function of the model minimized total transportation and handling costs for the movement of wheat from western Kansas production origins to Gulf of Mexico export terminals. The model included 70 production origins, 57 country elevator locations, seven inland terminal locations, and all the major export areas of the Gulf of Mexico including Houston, Galveston and New Orleans. The modes of transportation linking production origins to Gulf of Mexico terminals were rail, motor carrier, and barge. The study measured the impact on western Kansas rail export wheat rates of the Union Pacific - Missouri Pacific merger and the proposed, but never completed, merger of Santa Fe and Southern Pacific railroads. The study assumed that railroads pursue a profit maximizing pricing strategy. However the study measured the maximum constraint on railroad ability to raise rates. This was accomplished by assuming that all rival carriers employ variable cost pricing. Using the network model, profit maximizing railroad rates are initially measured for each railroad in each county assuming no mergers. Then the network model was employed to estimate the railroad rates and costs that result from the railroad mergers.

Lemke and Babcock found that a Santa Fe - Southern Pacific merger would result in a significant increase in the ability of the merged system to raise export wheat rates in southwest Kansas. The Union Pacific - Missouri Pacific merger produced no increase in market power. Both mergers reduced railroad costs due to more direct routing of wheat shipments to Gulf of Mexico terminals. The study indicated that competitive railroad wheat rates will occur if shippers have access to at least two railroads.

Won Koo (1990) used a quadratic programming model to measure the impacts of changing transportation prices (rates) on the hard red spring (HRS) wheat trade and distribution system. The model had 19 U.S. producing regions, 13 U.S. consuming regions, three export port locations and seven importing regions. The modes of transportation analyzed by the model are rail, truck, Great Lakes carriers, and ocean vessels. The model incorporated an export supply equation for each U.S. export port. Domestic producing regions were linked to export ports through transportation activities in shipping wheat from producing regions to export ports. The model also incorporated import demand equations in each importing country which were linked to U.S. export ports through ocean transportation. The objective function of the model is to maximize net social payoff which is the sum of the benefits for U.S. farmers and foreign importers less transportation costs.

Koo used the quadratic programming model to conduct five types of simulations. Model 1 is the base model which is a simulation of the HRS wheat industry for the 1987-88 crop year. All other models were compared to the base model. Models 2 through 5 were based on 10 and 20% increases and decreases in rail rates. Models 6 through 9 assumed 10 and 20% increases and decreases in barge costs. Models 10 through 13 analyzed similar changes in truck costs. Models 14 to 19 measured the effects of changes in ocean rates on spring wheat marketing for 10, 30 and 50% increases and decreases in ocean freight rates. Models 20 to 25 represented 10, 20 and 30% increases and decreases in ocean freight rates with Duluth, Minnesota as origin. Models 26 to 37 were simulations of 10 and 30% increases and decreases of HRS wheat prices for the two export areas of the Gulf of Mexico and the Pacific Northwest.

Thus Koo used sensitivity analysis to evaluate the impacts of changes in domestic freight rates (costs) on modal shares and spring wheat movements from U.S. ports to importing countries. He also employed sensitivity analysis to observe the impacts of ocean freight rates on import and export prices of HRS wheat.

Koo found that the modal shares for transporting HRS wheat are 45% for railroads, 40% for barge, and 15% for truck. Modal shares were more sensitive to change in rail rates than to changes in other transportation rates for both domestic and export port shipments. Changes in ocean freight rates did not alter modal shares and HRS wheat flows in shipping the product to domestic consuming regions and export ports. However, changes in ocean freight rates influenced HRS wheat prices and quantities traded at U.S. ports as well as prices in importing regions.

Fellin and Fuller (1997) employed quadratic programming models of the international corn and soybean sectors to measure the impact of an increase in the U.S. waterway tax from 20¢/gallon to $1.20/gallon on corn and soybean shipment patterns, farmer prices and revenues, and U.S. exports of soybeans and corn. The international corn model included 48 U.S. excess corn demand regions, 58 excess corn supply regions, 17 U.S. ports, 25 foreign excess demand regions, five foreign excess supply regions, 37 U.S. barge loading sites, and 17 U.S. export port areas. The U.S. excess supply and excess demand regions were linked by truck, railroad and barge transportation costs, while U.S. ports and foreign excess supply regions were linked to foreign excess demand regions by ocean shipping costs. The objective function of the quadratic programming models maximized consumer surplus plus farmer producer surplus minus grain handling, storage and transportation costs.

To evaluate the effect of higher waterway user fees, the fuel cost component of the barge costing model was adjusted to reflect user charges of $0.70 per gallon and $1.20 per gallon. The new, higher costs were entered into the corn and soybean models and their solutions compared with a base model solution (assumed the current user fee of $0.20 per gallon) for purposes of measuring the effect of increased waterway user fees.

Fellin and Fuller found that the user fee increase would divert 10.6 million metric tons of corn and soybeans from the inland waterways. Soybean/corn producers in Minnesota, Illinois and Iowa would incur annual revenue losses of $151 million, about 75% of the expected decline in all U.S. farmer revenues. Exports of U.S. soybeans were nearly unchanged, and corn exports fell only 2.2%. Thus the impact of the higher waterway user fees would not be large.

Fellin and Fuller (1998) used a similar quadratic programming model to that discussed above to examine whether privatization of Mexico's state-owned railroad would have unfavorable implications for U.S. overland grain/soybean exports to Mexico. Spatial, intertemporal equilibrium models were developed for the international corn, soybean and sorghum sectors. The objective function of each of the models was to maximize consumer plus producer surplus minus grain handling, storage, and transportation costs. The international corn model had 48 U.S. excess demand regions, 19 Mexico excess demand regions, 58 U.S. excess supply regions, 19 Mexico excess supply regions, 17 U.S. ports, eight Mexico ports, 25 foreign excess demand regions and five foreign excess supply regions. Thirty-seven barge loading sites on the Mississippi and Ohio River Systems were included in the model. The U.S. excess supply and demand regions were linked by railroad, truck and barge transportation costs while U.S. ports and foreign excess supply regions were linked to foreign excess demand regions and Mexico ports by ocean transportation costs. Mexico excess supply and demand regions were linked by railroad and truck costs/rates as were Mexican ports and Mexico excess demand regions.

Fellin and Fuller used a heuristic procedure to accomplish study objectives. They replaced the Mexican railroad's rate structure in the corn, soybean and sorghum models with estimated variable costs and then solved the models to determine the selected transportation modes serving Mexico's 19 excess demand regions and the associated shadow prices. These dual/shadow prices measured the extent to which the selected mode (railroad) on a particular route could increase its prices (rates) above variable cost without diverting traffic to a competitor. The shadow prices served as a guide to the minimum markup over variable cost that could be charged by a privatized railroad. To determine the profitability of increasing the markup above the shadow price, model solutions were obtained involving a series of elevated rates on the Mexico railroad system. The railroad rate that generated the greatest net cash flow (total revenue minus total variable cost) was identified as the profit maximizing rate for each route. To evaluate the effect of privatizing Mexico's railroad industry on U.S./Mexico overland grain/soybean trade, base solutions of the model were compared with solutions that reflect profit maximizing railroad rates under privatization.

Fellin and Fuller found that combined U.S. overland exports to Mexico of corn, soybeans and sorghum would increase from 3.5 to 6.4 million metric tons as a result of privatization. This was a result of lower costs/rates for a privatized rail system and competitive transportation markets. Thus the authors concluded that privatization of Mexico's rail system will not hinder the ability of the U.S. to compete in Mexican grain/soybean markets.

Fuller, Fellin and Grant (1999) used the quadratic programming model discussed above to measure the effects on barge costs and grain prices and revenues that result from a projected doubling of traffic on the upper Mississippi and Illinois Rivers by the year 2050. The authors estimated a lock delay equation as a function of utilized lock capacity. The estimated lock delays associated with the increased traffic levels were entered into a barge costing model to estimate the increased barge costs associated with various routings. The increased barged costs were entered into the spatial quadratic programming models of the international corn and soybean sectors. Then the models were solved to determine the effect of the increased traffic on grain movement patterns and farmer prices and revenue. The impact of the increased traffic levels and heightened barge costs were measured by contrasting solutions representative of the current lock delay patterns (base model) with solutions that reflect the increased lock delay and barge costs associated with the projected elevated traffic levels.

Fuller, Fellin and Grant found that 58% of the corn movement on the Upper Mississippi River would be diverted if congestion and delay associated with a doubling of traffic were experienced. Corn supply regions at comparatively distant locations from the river would initially divert at increasing traffic levels whereas sites near the river would not be diverted at any traffic level. The diverted river traffic was typically rerouted to an alternative domestic market or port area via railroad. Regional corn/soybean prices and revenues declined as traffic levels and barge costs increased. Farmers in Minnesota and Iowa would incur about 75% of the decline in revenues. U.S. exports of corn and soybeans would decline modestly at higher traffic levels.

Joon Park, Michael Babcock and Kenneth Lemke (1999) used a network model combined with a profit improvement algorithm to examine the impact of the Burlington Northern (BN) - Santa Fe (SF) and Union Pacific (UP) - Southern Pacific (SP) railroad mergers on the ability of the merged railroads to increase prices on movements of Kansas wheat to Houston, Texas. The study also analyzed changes in Kansas wheat logistics system costs as a result of the BN-SF and UP-SP mergers.

The network model included 342 production origins, 280 country elevators, 6 subterminals, 3 inland terminals, and 1 destination (Houston). The model identified the least cost transportation routes from the production origins, located in the western two-thirds of Kansas, to Houston. The objective function of the network model was to minimize total wheat logistics system costs, which include grain transportation and handling costs, subject to the following constraints.

(1) The flow of wheat into each transhipment point exactly equals the flow out of the transhipment point.

(2) The total amount of wheat supplied exactly equals the total amount of wheat demanded.

(3) All grain transportation and handling cost coefficients are greater than or equal to zero; all endogenous variables are greater than or equal to zero.

A transportation cost minimizing algorithm was used to solve the network model for the least cost movements of wheat. This algorithm required that the following capacity constraints be added to the model.

(4) Storage at each facility must be equal to the storage capacity (total storage capacity of all elevators at the location was used).

(5) The quantity of wheat shipped by each mode (rail or truck) between each location must be less than or equal to the total storage capacity at the origin location.

(6) No grain stocks remain at the farm or at transhipment points at the end of the crop year.

The profit improvement algorithm was used to evaluate each railroad's ability to raise prices above variable costs. The algorithm simulated a range of prices from variable cost to a level that diverts all traffic to rival railroads or other transportation modes. The algorithm identified a set of prices that maximized the railroad's net revenues subject to the constraint that the prices of all rival railroads are set equal to their respective variable costs.

Park, Babcock and Lemke found that the BNSF and UPSP achieved only minor increases in market power (measured by the ratio of revenue to variable cost) because the merged railroads have only slight advantages in cost relative to other railroads that serve the same areas as the merged railroads. Wheat shippers benefitted from merger induced reductions in transportation and handling costs. Transportation cost reductions accompanied the mergers due to more direct routing of wheat shipments and the assumption that the merged railroads operated at the cost of the lower cost partner.

Joon Je Park, Michael W. Babcock, Kenneth Lemke and Dennis L. Weisman (2001) used the network model and profit improvement algorithm described above to examine the effect of railroad mergers on railroad market power. This was done by measuring railroad profits and revenue/variable cost ratios corresponding to different degrees of intrarailroad competition for movements of Kansas export wheat to Houston. The network model of the Kansas wheat logistics system was used to identify the least cost transportation routes from the Kansas study area (western two-thirds of the state) to the market at Houston. The profit improvement algorithm (utilizing results of the network model) identified Nash equilibrium prices and measured the amount by which railroads could profitably raise their prices above variable cost.

The rail market power and profit (revenue minus variable cost) effects of two intrarailroad competition scenarios were simulated. In the “No Mergers” scenario the four Class I railroads in the network; the Union Pacific (UP), Southern Pacific (SP), Burlington Northern (BN), and Santa Fe (SF), and the five shortline railroads competed with each other for shipment of study area wheat. In the “Mergers” scenario the BN and SF merge to form BNSF and the UP and SP merge to form Union Pacific System. These two Class I railroads and the five shortlines competed with each other for shares of the study area wheat transportation market.

Park, Babcock, Lemke and Weisman found that the ability of railroads to raise prices is restricted if the shippers in the area have access to at least two railroads. They also concluded that railroad mergers do not necessarily increase railroad market power or make railroad shippers worse off. Instead, the study demonstrated that the impact of railroad mergers on shippers and railroad depends on factors that vary geographically, such as the degree of competition between railroads and intermodal competition.

Jean-Philippe Gervais et. al. (2001) used a linear programming model to evaluate the benefits and costs of extending five 600-foot locks on the Upper Mississippi River (UMR) to 1200 feet. The authors modeled 1994-1995 corn movements in three counties of eastern, central and western Iowa. The purpose of the study was to examine the impacts of lock extensions on barge costs and to evaluate the payoffs generated by the investment in lock extensions and captured by grain industry groups. The barge industry could achieve substantial savings resulting from reduced time delay. These cost savings could be passed on to grain elevators and farmers in the form of higher bid prices for grain. The authors employed the linear programming model to simulate the changes in corn movements and profits assuming extension of the five locks to 1200 feet. The model was solved using the Cplex algorithm in the GAMS software.

The model maximized farmer and grain elevators net profits. Farmers' profits were obtained by subtracting transportation costs from the price paid at the market. Elevator profits were calculated by finding the difference between the price they obtained from an end user market (minus the transportation and handling costs) and the price elevators pay farmers for their grain.

The authors conducted three simulations. The first simulation was the base solution that replicates the actual corn flows in the three Iowa counties during the 1994-95 crop year. No lock improvements were made in the base solution. In the second scenario the barge industry was assumed to keep 50% of the barge cost savings due to assumed lock extensions on the UMR. The other 50% was assumed to be passed back to the river terminals. Then the river terminals were assumed to pass their entire 50% decrease in barge rates to country grain elevators through increased bid prices for corn. In the third scenario the barge industry was assumed to pass the full amount of its cost savings back to river terminals. In turn, the river terminals were assumed to pass all the increases in its profits to country grain elevators through higher grain bid prices. The first scenario was used as a yardstick to measure the impacts of lock extensions assumed in the second and third scenarios.

Gervais et. al. found that total annual benefits accruing to grain producers and elevators as a result of lock extensions were 0.21 cents to 0.43 cents per bushel compared to an annual cost of 4 cents per bushel. Thus the authors concluded that the costs of lock extensions on the UMR substantially exceeded the benefits.

Luis Fellin, Stephen Fuller, Warren Grant and Connie Smotek (2001) used their quadratic programming model described above to evaluate the impact of extensions in lock chambers and guidewalls on the Upper Mississippi and Illinois Rivers. Quadratic programming models of the international corn, soybean and hard red spring wheat sectors were employed in combination with a barge costing model to estimate changes in grain producer prices and revenues that would result from extension of lock chambers and guidewalls at selected locks on the Upper Mississippi River and Illinois Waterway. Lock delays were projected before and after assumed extension of lock chambers and guidewalls for 2020 and 2040 grain traffic levels as forecasted by the U.S. Army Corps of Engineers. The lock delay information was entered into a barge costing model to estimate barge transportation costs from selected barge loading sites on the Upper Mississippi River (UMR) and Illinois Waterway to lower Mississippi River ports. The barge transportation costs were entered into the quadratic programming models which were solved to determine the impact of the heightened barge costs in 2020 and 2040 on regional grain prices and revenues.

The authors evaluated three scenarios concerning extension of selected lock chambers and guidewalls. They include:

(1) extension of lock chambers at locks 20 through 25 on the UMR and the LaGrange and Peoria locks on the Illinois River.

(2) extension of lock chambers at locks 20 through 25 and extension of guidewalls at locks 14

through 18, all on the UMR, and extension of lock chambers at the LaGrange and Peoria locks on the Illinois River.

(3) extension of lock chambers at locks 20 through 25 and extension of guidewalls at locks 14 through 18 on the UMR, but with no extension of lock chambers on the Illinois River.

Model solutions that reflected producer prices and revenues before expansion of lock capacity were compared with solutions that reflected producer prices and revenues after expansion of lock capacity. The authors found that the first scenario would annually raise grain producer revenues by $93.6 million in 2020. The corresponding figures for the second and third scenarios were $169.6 million and $159.9 million respectively.

Nancy Lee and Ken Casavant (2002) used a transportation cost minimizing model in combination with modal energy intensity and emissions coefficients to identify potential effects on energy consumption and emissions output, attributed to wheat and barley transportation in eastern Washington, if breaching of the lower Snake River dams occurs. Breaching of four dams on the Snake River could occur to restore the environment for salmon.

The transportation cost minimizing model was based on a Geographical Information System (GIS) database and Generalized Algebraic Modeling System (GAMS) model. This model utilized a Washington State Department of Transportation (WSDOT) database of eastern Washington roads with supplemental information from U.S. Bureau of Census, Topological Integrated Geographic Encoding and Referencing (TIGER) databases to construct the network of road and transportation coverage within GIS. The GIS database contained information on the location of Interstate, state, and county roads, wheat and barley farms, grain elevators, feedlots, and river ports.

Using the GIS database and taking into consideration the appropriate truck, rail, and barge rates and constraints, least cost wheat and barley transportation routes and modal choices were determined for “with barge” transport and “no barge” transport (dams are breached) scenarios. The solution to the no barge scenario was compared to the base case (i.e., with barge transport) which represented current grain transportation conditions in eastern Washington.

The ton-miles of each mode obtained from the transport cost minimizing model were translated into energy consumption by applying the appropriate energy consumption coefficient (British Thermal Units (Btu) per ton-mile). These results were translated into emissions output by mode by applying mobile source emissions coefficients (pounds per gallon of diesel fuel) to modal energy consumption.

Lee and Casavant found that breaching the Snake River dams would cause a small 0.61% increase in energy consumption for wheat transportation and a significant increase (37.16%) for barley transport. Emissions output for wheat and barley transportation increased 1.29% and 20.86%, but only 2.77% in total. This was due to the fact that wheat transportation is much greater than barley transport, and the impacts on wheat transport were minor.

Eric L. Jessup, Kenneth L. Casavant, and Terrence C. Farrell (2001) used an integrated Geographic Information System (GIS) and Generalized Algebraic Modeling System (GAMS) optimization model to identify the impacts to grain transportation costs, which would arise from breaching four Snake River dams. The breaching would eliminate barge transport above the Tri-Cities in eastern Washington. The objective function of the transportation cost minimization model was to maximize shipper profit over each of the available transport modes. The model was optimized with the GAMS system. The objective function does not include long term costs to taxpayers of road damage. The road damage was estimated ex post to determine the gross social costs associated with increased trucking of grain resulting from breaching of the four Snake River dams.

The GIS data and the GAMS models were used to derive transportation costs for three scenarios. In the first scenario, no restrictions were imposed on the model so it reflected current modal use. In the second scenario, it was assumed that barge transportation above the Tri-Cities was eliminated, that railroad capacity was limited to 110% of historical volume, and that rail rates were increased by 10%. In the third scenario, barge transport is eliminated, both rail and barge rates were increased by 10% and rail capacity was constrained as in the second scenario.

Jessup, Casavant and Farrell found that shipper costs would increase from 49.61 cents per bushel in the base scenario to 54.45 cents in the second scenario (about a 10% increase) and to 55.89 cents in the third scenario (about a 13% increase).

The next section of the literature review summarizes some studies of road damage costs associated with structural changes in the grain logistics system. Jessup, Casavant and Farrell addressed this problem as well as changes in transportation cost. They measured the social cost of road damage associated with each of the three scenarios by multiplying the number of ton-miles estimated for each scenario by a damage coefficient for the three types of roads in the network, which were interstate and state highways and county roads. The damage coefficients were obtained from previous studies. They found that the road damage costs were about $2.1 million for each of the three scenarios.

2.2 Road Damage Cost Studies

Kenneth L. Casavant and J.C. Lenzi (1990) developed a model-procedure to measure road damage impacts related to railroad abandonment in Washington. They applied the model-procedure to four railroad abandonments in Washington that occurred over an eight year period. Their methodology involved five stages, and at each stage they identified the information needed, as well as the characteristics and sources of the information. The five stages include the following:

1. Stage I involved the identification and evaluation of rail lines facing the potential for imminent abandonment. This information could be obtained from Carrier System Diagram maps which identify lines that the railroad intends to abandon in the future. Also light density lines and those that have deferred maintenance should be monitored at this stage.
2. Stage II - Information should be collected concerning the shippers located on the rail lines identified in Stage I. This information could be obtained from the railroads as well as state

Departments of Transportation and Agriculture.

3. Stage III - Traffic volumes and routes before and after abandonment need to be determined by road segment. This information could be obtained from the shippers located on the rail line since they know their before rail abandonment traffic volumes and markets, and could estimate their traffic volumes, routes, modes used, and markets after abandonment. The shippers could also provide other useful information such as truck vehicle types, characteristics and configurations.

The physical condition of specific road segments could be obtained from the state Department of Transportation Pavement Management System or from county engineers.

4. Stage IV - The above collected information was utilized with road damage functions to calculate the physical deterioration of each road segment caused by the increased truck traffic resulting from railroad abandonment. The measured road deterioration was translated into road damage costs based on road reconstruction and maintenance cost estimates provided by the state Department of Transportation and county engineers.

5. Stage V - Road damage costs for all affected road segments were aggregated.

Casavant and Lenzi found that the amount of road damage due to abandonments is heavily dependent on the volume of abandonment-related truck traffic relative to the type of roads used. Rigid, well structured pavements with high structural design were hardly affected by increased truck traffic. However, county roads built to lesser design standards were greatly impacted from increased truck use.

Kenneth Ericksen and Kenneth L. Casavant (1998) conducted a study of road damage costs to Washington highways related to increased truck traffic generated by the North American Free Trade Agreement (NAFTA). Part I of the study estimated the increased truck traffic expected from NAFTA. The resulting road investment requirements to maintain the use life of the highways was calculated based on road damage functions, and assigned to specific Washington highway corridors.

The study utilized a procedure developed by the South Dakota Department of Transportation to quantify pavement impacts by corridor generated by NAFTA-related truck traffic. The procedure calculated the amount of truck traffic in ton-miles and multiplied that figure by a road damage function expressed as pavement cost per ton-mile.

The authors determined that truck traffic on Washington highways would increase 30% between 1994 and 2005, partly due to NAFTA. They estimated truck ton-miles for major Washington highways (Interstate 5, U.S. 97 and U.S. 395) and then used the procedure described above to estimate the costs required to maintain the road in a condition that would support the estimated truck traffic. Ericksen and Casavant identified highway corridors with low serviceability ratings as those most in need of immediate maintenance since these roads are expected to have the greatest deterioration as a result of increased NAFTA-related truck traffic.

Victor E. Eusebio and S.J. Rindom (1991) developed a procedure for estimating the highway damage costs associated with railroad branchline abandonment, and applied the procedure to a six county area in south central Kansas. Most of the rail service in this area was supplied by Missouri Pacific Railroad which is now part of Union Pacific System. Wheat is the dominant agricultural product in the region. Rail is the dominant mode for transporting wheat, but trucks are readily substitutable for rail.

The authors employed a network model developed by Chow to simulate wheat movements in the region. The objective function of the Chow model is to minimize the transport cost of wheat from production origins in the study area to Kansas transhipment points and to export terminals at Houston, Texas. The network model contained 114 simulated farms, 27 country elevators, three Kansas inland terminals, one out-of-state wheat processing center, and one final market (Houston). The model assumed two types of trucks. Single unit, two axle farm trucks were assumed to transport wheat from the simulated farms to local grain elevators. Five axle semi-tractor trailer trucks were assumed to transport wheat from country grain elevators to Kansas inland terminals. Transportation competition in the model was between railroads (intramodal competition) and between railroads and trucks (intermodal competition). The model simulated wheat movements with all railroad branchlines in the model (base case) and then was re-estimated assuming all branchlines were abandoned. In the post-abandonment scenario, wheat formerly moved by rail was shipped by truck.

Eusebio and Rindom estimated highway damage for the pre-abandonment and post abandonment scenarios using the Highway Performance Monitoring System (HPMS) road damage functions. They estimated highway damage for farm to country elevator shipments and for country elevator to inland terminal movements. The authors used the HPMS pavement damage functions to estimate the useful life of a pavement section. Highway damage costs resulting from abandonment-related truck traffic represented the increased maintenance and rehabilitation costs to maintain the useful life of the pavement.

Eusebio and Rindom found that the average haul from production origins (simulated farms) to country elevators increased from 4.7 (pre-abandonment) to 7.0 (post-abandonment) miles. Abandonment resulted in 740 thousand bushels of wheat being diverted from rail to truck shipment for movements from country elevators to inland terminals. The authors found that abandonment-related road damage for farm to country elevator wheat movements was $138,000. The corresponding figure for country elevator to inland terminal movements was about $56,000. Thus the total abandonment-related road damage was $194,000.

J.C. Lenzi, Eric Jessup, and Kenneth Casavant (1996) estimated state and country road damage costs in the state of Washington resulting from a potential drawdown of the lower Snake River. The authors assumed two potential drawdown scenarios which were:

Scenario 1. The duration of the drawdown is from April 15 to June 15. From previous studies the authors estimated that about 5.5% (362,630 tons) of eastern Washington grain moves by barge during this period.

Scenario 2. The duration of the drawdown is from April 15 to August 15. From previous studies the authors estimated that about 15% (967,020 tons) of eastern Washington grain moves by barge during this period.

In both scenarios there is no barge transport of grain in eastern Washington during the drawdown period. In both scenarios it was assumed that grain formerly moved by barge would be shipped by truck to the nearest elevator with rail service. The average truck length of haul was 15 miles compared to 45 miles for truck-barge movements. From previous studies, the authors assumed that in the before drawdown case, 17% of the truck to barge grain shipments would move on county roads and 83% on state roads. The road damage costs obtained from other studies were assumed to be \$0.071 per ton-mile for state highways and \$0.1065 per ton-mile for county roads. Thus road damage costs before the lower Snake River drawdown were estimated as follows:

1. 362,630 tons (45 miles) = 16.3 million ton-miles
2. 16.3 million ton-miles (17% county roads) = 2.7 million ton-miles
3. 16.3 million ton-miles (83% state highways) = 13.5 million ton-miles
4. 2.7 million ton-miles (\$0.1065) = \$295,440 county road damage cost
5. 13.5 million ton-miles (\$0.071) = \$961,640 state road damage cost
6. Total road damage cost is \$1,257,080

The road damage cost for the two month drawdown scenario was calculated in a similar manner only the shipping distance in step 1 was only 15 miles and the mix of road use was 38% for county roads and 62% for state highways. The total highway damage cost for Scenario 1 was only \$459,770, 63% less than the pre-drawdown cost.

The road damage costs for the four month drawdown utilized the 967,020 tons of grain moved by barge in eastern Washington during the four month period. Employing the same procedure as for Scenario 1, the authors estimated the pre-drawdown road damage costs to be \$3,352,240. The post-drawdown road damage costs were estimated to be only \$1,225,540, or 63% less than the pre-drawdown costs.

Lenzi, Jessup and Casavant concluded that both drawdown scenarios resulted in decreased road damage costs in the absence of a railcar shortage.

Stephen J. Rindom, John J. Rosacker, and Michael Wulfkuhle (1997) measured road damage costs related to subterminal (unit train) locations at Dodge City and Colby, Kansas. The research included two study areas that included all Kansas farms within a 50 mile radius of Dodge City and Colby. The authors estimated that 50 miles would be the maximum distance that the higher grain prices paid at subterminals would influence grain transportation flows. Higher bid prices for grain at subterminals induce farmers to bypass the local country elevator and truck grain a longer distance to the subterminal to obtain the higher grain price. Increased pavement deterioration results from the increased truck traffic.

The authors employed the Chow model described above to simulate grain flows in the two study areas for a base case that assumed no subterminals in the logistics system and several scenarios for which subterminals were included in the system. According to 1994 data used by the authors, nearly 38 million bushels of wheat were produced within 50 miles of Dodge City and 43 million bushels in the Colby study area. The Chow network model minimized the transportation cost of shipping these pre-determined amounts of wheat from simulated (8 mile by 8 mile) farms to Kansas transhipment locations, and from Kansas transhipment points to export terminals in the Pacific Northwest (PNW) or the Gulf of Mexico.

Rindom, Rosacker and Wulfkuhle estimated a base scenario for each study area that assumed no subterminal elevators. Two additional scenarios were assumed for the Dodge City study area which were (a) a fully operational subterminal at Dodge City, and (b) a subterminal at Dodge City and a supplemental, competing subterminal at Bucklin, Kansas. Three additional simulations were conducted for the Colby study area which were (a) limited subterminal operations at Colby, (b) expanded subterminal operations at Colby, and (c) expanded subterminal operations at Colby with an additional subterminal at Wakeeney, Kansas.

They used a three step procedure to measure road damage costs. The steps are:

1. Estimate the pavement life (in equivalent single axle loads or ESALs) of each road segment in the rural road network.
2. Estimate the ESALs resulting from farm truck traffic on the road network.

3. Calculate the truck attributable road damage cost for each road segment by multiplying pavement rehabilitation cost per ESAL-mile by truck loadings (in ESALs), and by the number of miles in the road segment.

Rindom, Rosacker and Wulfkuhle found that average haul distances increased substantially for the subterminal scenarios relative to the base case. For example the haul distance in the Dodge City study area increased from about 12 miles in the base case to 33 miles with a fully operational subterminal at Dodge City. In the Colby study area the average haul distance rose from about 16 miles in the base case to 48 miles with subterminals at Colby and Wakeeney. Thus subterminals generated substantial increases in truck-miles and road damage costs. For the Dodge City study area the maximum additional road damage cost relative to the base case was $3.3 million per year. The corresponding figure for the Colby study area was $7.6 million per year.

Eugene R. Russell, Michael W. Babcock and Curtis A. Mauler (1996) estimated potential road damage costs resulting from hypothetical abandonment of 800 miles of railroad branchline in south central and western Kansas. The Chow model referred to above was employed to measure changes in grain transportation resulting from railroad abandonment. The model contained 400 (5 kilometer by 5 kilometer) simulated farms. The objective function minimized the total transport cost of moving Kansas wheat from the simulated farms to country elevators, and from country elevators to Kansas terminals, and from Kansas terminals to export terminals at Houston, Texas. The authors employed the model to estimate base case truck and railroad wheat movements assuming no abandonment of branchlines. The model was re-estimated assuming abandonment of 800 miles of Kansas branchline. The authors estimated the road damage costs of the additional abandonment-related truck traffic.

The authors used the same methodology as in the study discussed immediately above. They employed Highway Performance Monitoring System (HPMS) pavement functions to measure the pavement life of each pavement segment in ESALs. The American Association of

State Highway Transportation Officials (AASHTO) traffic equivalency functions were used to measure road damage in ESALs for each type of truck.

Russell, Babcock and Mauler estimated that farm-to-elevator road damage costs before abandonment totaled $638,613. These costs increase by $273,359 in the abandonment scenario. Elevator-to-terminal road damage costs in the before abandonment case were $1,451,494. Abandonment resulted in an increase in these road damage costs of $731,231. Thus the total abandonment related road damage costs were $1,004,590.

Denver Tolliver, K. Andres, and B. Lindamood (1994) measured road damage cost associated with the decline or loss of rail service in Washington. The authors identified three potential situations which would result in traffic being diverted from rail to truck which were:

1. The loss or temporary closure of railroad mainline service.
2. The loss of branchline service as a result of continued railroad abandonment.
3. All growth in port traffic is diverted to trucks due to potential railroad mainline capacity constraints.

The study used American Association of State Highway Transportation Officials (AASHTO) procedures to estimate pavement deterioration rates. The Highway Performance Monitoring System (HPMS) damage functions were used to measure the pavement life of each highway segment in ESALs. The HPMS procedure measured highway impacts as the decline in pavement serviceability rating (PSR). The pavement deterioration estimation used by the authors consists of the following six steps.

1. The maximum life of an impacted pavement was defined in terms of allowable decline in PSR.
2. The maximum feasible life of a pavement was defined in years.
3. The life of a pavement was determined in terms of traffic by using a standardized measure of axle passes (ESALs).
4. The loss of PSR that would occur in the absence of truck traffic was computed from a time

decay function for a typical design performance period. The remaining road damage costs were considered to be a function of truck traffic.

5. An average cost per ESAL was computed by multiplying the average resurfacing or reconstruction cost per mile by the percent of PSR loss due to traffic and dividing by the ESAL life of the pavement.

6. The avoidable road damage cost was computed by multiplying the avoidable ESALs by the average cost per ESAL. This is the annual road damage costs that was avoided if traffic continues to move by rail.

The first scenario assumed a system wide loss of mainline rail service in Washington. The authors estimated that incremental annual pavement resurfacing cost would be $65 million and annual pavement reconstruction cost would be $219.6 million.

The second scenario assumed the loss of all branchline rail service in Washington. The loss of mainline rail service (Scenario 1) would result in the loss of branchline rail service as well (Scenario 2). Thus the total road damage related to loss of all rail service was obtained by summing the road damage costs of Scenarios 1 and 2. In Scenario 2 the authors estimated road damage due to abandonment-related truck traffic for several different truck configurations. The annual resurfacing costs ranged from $17.4 to $28.5 million, and the annual reconstruction cost varied from $63.3 million to $104 million.

In Scenario 3 all port traffic growth was diverted to trucks due to railroad capacity constraints. The authors concluded that incremental annual pavement resurfacing costs would be $63.3 million, and the corresponding figure for annual reconstruction cost was $227.5 million.

Michael W. Babcock and James L. Bunch (2002) measured the road damage costs related to the hypothetical abandonment of four shortline railroads serving western and central Kansas. The four shortlines that were assumed to be abandoned were the Central Kansas Railroad (CKR), the Kyle Railroad, the Cimarron Valley Railroad (CV), and the Nebraska, Kansas and Colorado Railnet (NKC). The CKR system was purchased by Kansas and Oklahoma Railroad in June

2001, which was after the study was initiated.

Road damage cost estimates were obtained using the following 12 step process:

1. The incremental increase in truck traffic was determined given the simulated removal of shortline rail service.
2. The least cost route (origin-destination) was determined for the incremental truck traffic.
3. Pavement characteristics along the new truck routes were ascertained.
4. Axle load equivalency factors for a standard grain truck were calculated given truck and road characteristics.
5. The maximum tolerable decline in pavement serviceability (PSR) was quantified given Kansas Department of Transportation (KDOT) design and pavement management policies.
6. The maximum feasible life of the pavement in the study area in the absence of truck traffic was estimated.
7. The total number of standardized truck passes until pavement failure (ESAL life) for each impacted pavement segment was calculated.
8. The expected percentage of loss in pavement serviceability (PSR) as a result of temporal-environmental decay was estimated.
9. The adjusted unit cost per mile per truck pass (ESAL) was calculated for each impacted pavement segment by separating estimated non-traffic costs.
10. The total cost of the incremental increase in truck traffic was determined for each shortline's grain traffic.
11. The pavement characteristics for county paved roads were estimated using the pavement characteristics of nearby state highways with similar traffic patterns and steps 3 through 9 were used to estimate damage using the approximated road characteristics.
12. Damage to county roads was estimated by determining an average cost to apply aggregate (gravel) and multiplying that by the amount of aggregate expected to be lost to incremental grain truck traffic.

Babcock and Bunch found that the four shortline railroads annually save the state of Kansas $49.5 million in pavement damage cost. Of the total pavement damage savings of the four railroads, 37% each was provided by the CKR and the Kyle, 21% by the CV, and 5% by the NKC. The CKR and the Kyle railroads each prevented over $18 million in pavement damage cost per year, the CV prevented over $10 million, and the NKC prevented about $2.5 million annually.

2.3 Highway Safety Impacts of Railroad Abandonment

Denver Tolliver and HDR Engineering Inc (2000) described a method by which the safety costs of rail abandonment-related truck traffic can be measured. The study is part of a more general analysis that estimated the total value of rail service in the state of Washington.

The author compared property damage, injury, and fatality costs of a non-abandonment (base case) and abandonment scenarios. In the abandonment scenario, truck traffic includes all traffic in the non-abandonment scenario plus additional trucks hypothesized to transport the freight that was being transported by assumed abandoned railroads. The analytical procedure employed by Tolliver includes the following four steps.

1. Existing annual rail freight is converted into equivalent truck trips.
2. The incremental abandonment-related truck traffic is associated with a statistically probable quantity of accidents, injuries, and fatalities.
3. The increased annual quantity of accidents are multiplied by their respective cost estimates.
4. The costs are aggregated into a dollar figure that represents the safety impact of rail abandonment.

By this straightforward method, the safety costs of the base case can be directly compared to the safety costs of the abandonment scenario.

Tolliver used accident rates for rail movements on the Burlington Northern Santa Fe and Union Pacific Railroads. He found the rail accident rates of fatality, injury, and property damage to be 1.42, 11.32 and 3.56 per million ton-miles respectively. For highway accident rates, Tolliver indicated that he considered specific design and traffic characteristics of Washington roads but didn't publish the rates employed in the study.

For cost estimates of fatality and injury accidents , the author utilized estimates of the National Safety Council. These estimates are "comprehensive costs," including wage and productivity losses, medical expenses, benefit and travel costs, and an estimate of the value of "lost quality of life."

Tolliver's conclusions concerning the safety impact of abandonment-related truck traffic in Washington were unreported.

CHAPTER 3

STUDY AREA COUNTY ROAD CONDITIONS AND FINANCES

3.1 Rail Service and County Road Conditions

If the four shortline railroads in the study area are abandoned there will be a large diversion of wheat shipments from railroads to trucks. According to Babcock and Bunch (2002) the incremental truck traffic could be as high as 140,000 truckloads or 290 million truck-miles. Much of this additional truck traffic will move over county roads that are not engineered to withstand a large increment in 80,000 pound semi-tractor-trailer trucks. To assess the potential magnitude of this problem it is important to measure the current condition of study area county roads.

County officials need to know how many additional trucks will be using their roads and bridges if abandonment of shortline railroads occurs. To document the potential challenge facing counties, a survey of study area county road conditions and finances was conducted in the summer of 2001. The survey consisted of personal interviews of county engineers and road supervisors, who were also given questionnaires to complete and return after the interview (see Appendix A). Completed questionnaires were received from 55 of the 66 counties in the study area, a return rate of 83.3% which will enable an accurate assessment of current county road conditions and finances.

3.2 Description of the Study Area County Road System

There are 43,128 miles of roads in the 55 counties that returned questionnaires, an average of 784 miles per county. County road mileage varies widely over the 55 county sample ranging from a low of 214 miles to a high of 1608 miles. One of the reasons for the large variation is that some counties maintain township roads while others do not, and of course some counties are larger than others and thus have more county road mileage.

Of the 43,128 miles in the 55 sample counties, 0.3% are cement roads, 14.7% are asphalt, and 85% are unpaved gravel roads. Within the 55 county sample, asphalt roads range from a low of one mile to a high of 560 miles. The corresponding figures for the unpaved roads are zero and 1500 miles.

The distribution of mileage between paved and unpaved county roads has not changed in recent years. About 30% of the counties reduced the number of paved miles, about 27% increased the paved mileage in the county, and the remaining 43% reported no change in paved mileage.

3.3 Condition of Study Area County Roads and Bridges

The respondents were asked to assess the condition of the paved roads in the county using a five category scale that ranged from very poor to very good. For the counties with cement roads, 22% of the miles were rated in the poor or very poor categories, 38% were classified in the good or very good categories, and the remaining 40% were rated fair. For the counties with asphalt roads, 18% of the miles were rated very poor or poor, 55% were classified as good or very good, and 27% were rated fair.

The county engineers and road supervisors were asked to describe the overall condition of the county's roads compared to five years ago using a five category scale that ranged from much worse to much better. A total of 29% of the respondents rated the condition of their roads as worse than five years ago, 44% classified their roads as better or much better, and the remaining 27% rated the condition of their roads as unchanged.

To further assess the condition of county roads and bridges, the respondents were asked if any of the county's roads and bridges were closed to heavy trucks. A total of 42% of them reported closure of roads and bridges to heavy trucks, with the collective total amounting to 959 miles of road (only 2.2% of total sample county mileage) and 1526 bridges.

If the overall condition of the county's roads and bridges had declined, the respondents were asked to rank the reasons for the deterioration. The county engineers and road supervisors were asked to rank the reasons in order of importance with the number 1 being the most important and the number 5, the least important. Thus the lower the average rank number, the more significant the reason for explaining the decline of the condition of county roads and bridges. The respondents were asked to rank the following reasons.

(a) Decline in county population (tax base)
(b) Decline in state aid for county roads
(c) Increase in the cost of road maintenance
(d) Increases in the number of heavy trucks on the county's roads
(e) Other

The average rank numbers for the reasons in the same order as listed above were 3.31, 3.60, 1.89, 1.64, and 3.88. Thus the respondents ranked increases in the number of heavy trucks on the county's roads as the most important reason for the decline in the condition of the roads. The second most important reason was the increase in the cost of road maintenance. The other reasons listed were of much less importance.

The county engineers and road supervisors listed a wide variety of reasons in the "Other" category. These included the following:

1. Weather conditions
2. Increasing age of bridges
3. Increased size of trucks and farm tractors
4. Farming practices
5. Decline in the number of county road personnel and the amount of road maintenance equipment.
6. Not enough money for road improvements
7. Growth in the agribusiness industry and the accompanying increase in truck traffic.

3.4 County Road Finances

There is wide variation in sample county annual expenditure for road and bridge maintenance. However, the average expenditures cluster around $1.5 million per year. The average expenditures for the sample counties during the 1996-2000 period are as follows:

Year	Average Expenditure	Percent Change from Previous Year
1996	$ 1,439,978	
1997	1,429,138	-0.8
1998	1,459,701	2.1
1999	1,518,571	4.0
2000	1,608,428	5.9
1996-2000 Period		11.7

Thus the average county road and bridge maintenance expenditure began increasing in 1998, and the year 2000 average was nearly 12% greater than the 1996 average expenditures.

The respondents were asked to list their principal sources of revenue for the county's road and bridge maintenance budget. The principal source of revenue was the property tax as 89% of the sample counties used the property tax to finance road and bridge maintenance. A local fuel tax was used by 51% of the sample counties, and 26% received grants from the state of Kansas. A variety of other taxes and fees such as a vehicle tax were utilized by 47% of the sample counties. Counties also receive demand transfers which are monies the state collects through various taxes and fees and then redistributes to counties. These are the Local Ad Valorem Tax Reduction (LAVTR), city-county revenue sharing, and special city-county highway funds.

The county engineers and road supervisors were asked if the current budget for road and bridge maintenance was sufficient to maintain an adequate level of service on the county's roads, and if not, what was the budget shortfall. In terms of measuring the latter, if the budget is 90% of what is needed to provide adequate service, the budget shortfall is 10%. A total of 74% of the respondents said the current budget is inadequate, and the distribution of percentage shortfalls was as follows:

Percent Shortfall	Percent of Counties
10% or less	7.5%
11 to 20%	45.0%
21 to 30%	22.5%
31 to 40%	15.0%
41% or more	10.0%

Thus a substantial majority of the county representatives (74%) said that the current road and bridge maintenance budget is inadequate. Nearly 68% of them that said the budget was inadequate indicated a budget shortfall between 11 and 30%. Another 25% of the respondents said the budget shortfall was greater than 30%.

3.5 Abandonment of County Roads

One possible solution to inadequate road and bridge budgets is to abandon some county roads, resulting in more funds for the remaining roads. The respondents were asked if their county had abandoned any roads in recent years. One-third of the counties had abandoned some roads which collectively amounted to 234 miles. The county engineers and road supervisors were asked to provide the reasons for road and bridge abandonment. The reasons fell into two broad categories which were (a) lack of road use, and (b) funding problems. Lack of use was related to the increasing size of farms and declining rural population. With regard to funding, the respondents said that some roads had too much deferred maintenance and would be too expensive to reconstruct, and the county lacked the funds to maintain all its roads and bridges.

The respondents were also asked if their county had recently considered abandoning any of its roads. A total of 26% of them indicated they had recently considered abandoning a collective total of 421 miles.

The county engineers and road supervisors who indicated that they had considered abandoning some county roads were asked to provide the reasons for such an action. Some said they considered abandoning roads that have bridges out of service since repairing the bridges would be expensive. Other respondents indicated they considered abandonment because of lack of road use and lack of money to properly maintain all the county's roads. Some respondents cited the increasing cost of road maintenance and substantial deferred maintenance on some county roads.

3.6 Suggestions for Improving County Road and Bridge Conditions

For counties that recently experienced a decline in the condition of the county's roads and bridges, the respondents were asked what changes would help restore the condition of the county's roads and bridges. The most frequently mentioned suggestion was an increase in state and federal aid for county roads. However, the respondents had several other suggestions related to funding of county roads and bridges including the following:

1. More state aid should be provided to low population counties so they could complete larger projects. Also more state aid should be given to low population counties since they have a relatively small tax base to finance many miles of county roads.
2. The matching formula for county bridge projects should be changed from 80% state, 20% local to 90% state, 10% local.
3. Remove the cap on state transfers of federal aid to county roads and bridges.
4. Tax revenue should go directly to a county road and bridge program rather than to the state general fund.
5. Taxes on heavy trucks and diesel fuel should be increased.

However, the suggestions of the respondents were not limited solely to financing. For example, some county engineers and road supervisors suggested better enforcement of the weight limits on county roads and bridges. Others said that the state of Kansas should develop a policy for low volume roads that is less restrictive in its design standards than the policy for state highways. Other respondents recognized the relationship between county road and bridge damage costs and rail service by suggesting that the state of Kansas should develop a policy to stop the decline of rail service.

3.7 Summary

If the four shortlines serving the study area are abandoned there will be a large diversion of wheat shipments from railroads to trucks. Much of this additional traffic would move over county roads that are not built to handle a large increment in five axle 80,000 pound trucks. County officials need to know how many additional trucks will be using their roads and bridges if abandonment of shortline railroads occurs. To document the potential challenge facing counties, a survey of study area county road conditions and finances was conducted in the summer of 2001.

For counties with cement roads, 22% of the miles were rated in the poor or very poor categories, 38% were characterized as good or very good, and 40% were rated as fair. For the counties with asphalt roads, 18% of the miles were rated poor or very poor, 55% were classified as good or very good, and 27% were rated as fair. A total of 29% of the respondents rated the condition of their roads as worse than five years ago, 44% said their roads were better or much better, and 27% rated the condition of their roads as unchanged.

If the overall condition of the county's roads had declined in the previous five years, the respondents were asked to specify the reasons for the deterioration. Increases in the number of heavy trucks on the county's roads was ranked as the most important reason for the decline in road conditions. The second most important factor was increase in the cost of road maintenance.

The average expenditure of the sample counties for road and bridge maintenance in year 2000 was $1.6 million and the principal revenue source was the property tax. A total of 74% of the county engineers or road supervisors said that the current budget for road and bridge maintenance is insufficient to maintain an adequate level of service on the county's roads. Nearly 68% of the county representatives that indicated that the budget was inadequate said the budget shortfall was between 11 and 30%. Another 25% of the respondents in this group said the budget shortfall was greater than 30%.

To deal with the budget shortfall, one-third of the sample counties had abandoned some roads which collectively amounted to 234 miles. About one-fourth of the respondents indicated that they had recently considered abandoning a collective total of 421 miles.

For counties that recently experienced a decline in the condition of the county's roads and bridges, the respondents were asked what changes would help restore the condition of the county's roads and bridges. The most frequently mentioned suggestion was an increase in state and federal aid for county roads. Most of the other suggestions related to the financing of state and federal aid programs for county roads and bridges.

In general, a substantial number of county road miles in the study area are not in good condition. Current road and bridge maintenance budgets are inadequate in the majority of counties even to maintain the current level of service. The counties are not equipped to deal with a large increment in heavy truck traffic triggered by abandonment of shortline railroads.

CHAPTER 4

TRANSPORTATION COST ANALYSIS

4.1 Transportation Cost Analysis Overview

This chapter will focus on computing the changes in wheat handling and transportation costs resulting from abandonment of study area shortline railroads. The impact of shortline abandonment will be estimated by comparing two scenarios. The no-abandonment scenario is a simulation of the current logistics system by which wheat moves from a study area farm to its final destination. The abandonment scenario is a simulation of the same wheat movement without study area shortline railroads in the logistics system. The difference in these two scenarios is the impact of shortline abandonment on Kansas wheat transportation and handling costs.

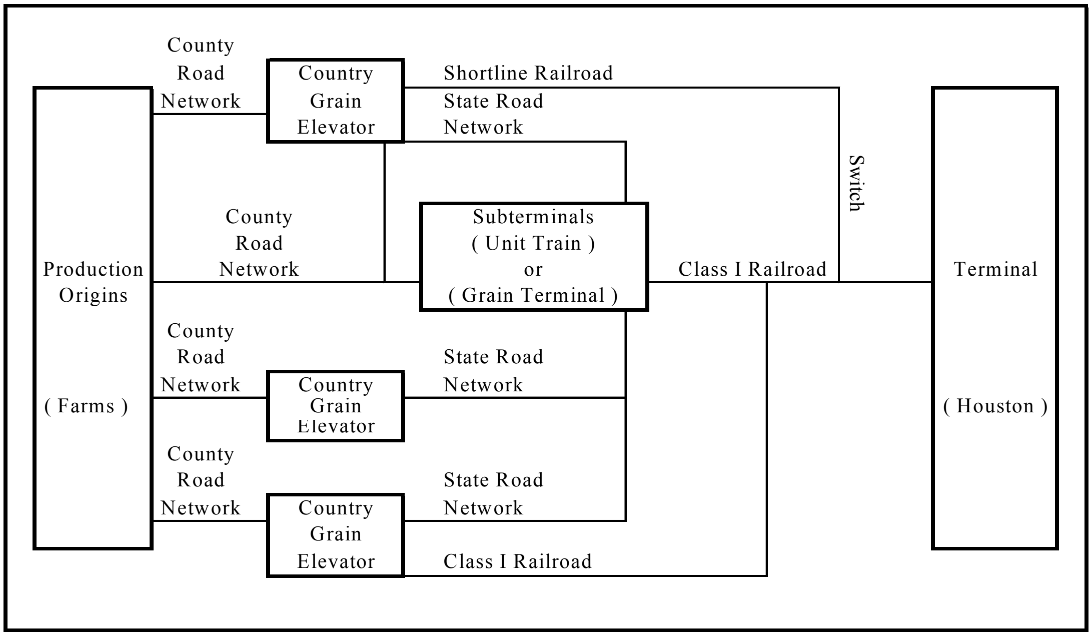
4.2 Model and Assumptions

In general, Kansas wheat originates at farms and then moves by truck over county and state roads to a country grain elevator, a shuttle train station, or a terminal grain elevator. Country grain elevators send wheat to either shuttle train stations or terminal grain elevators. Most country elevators have the option of shipping wheat by either railroad or truck. Some country elevators must use trucks because they do not have rail service. Shuttle train stations and terminal grain elevators ship wheat to Houston, Texas by unit trains on Class I rail lines. Babcock and Bunch (2002, pp. 62-65) provide the baseline model for analysis of the wheat logistics system in Kansas. In particular, they propose that when modeling the system in its entirety, it is best to consider the movement of wheat 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, shortline railroads, and Class I railroads constitute the arcs which connect these nodes. Figure 3 portrays the current Kansas wheat logistics system.

FIGURE 3

Wheat Transportation Network Model With Shortlines



Given the magnitude and complexity of the wheat logistics system, the movement of Kansas wheat through the various possible network paths 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 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 intermediate storage facility 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 shortline 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 system, costs serve as the most consistent influence on agents' behavior. Profits ultimately decide individual behavior; however, cost minimization is the constant and consistent strategy for maximizing profits, regardless of market conditions. Thus, it is assumed that all agents in the system seek to minimize the costs involved in shipping wheat to market. Costs, therefore, are the most influential factors in the wheat logistics system. Farmers seek 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 so as to minimize the cost of handling wheat and shipping it to various market destinations. Thus, the methodological goal is to determine the least cost transport path for Kansas wheat from production origin to final destination utilizing the transportation network. Kansas wheat is shipped to both domestic and international export markets. 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. Thus, it is assumed that all agents seek to minimize the costs involved in shipping wheat to market. This relationship is succinctly summarized in mathematical form by the following objective function:

$$\text{(1)} \qquad \text{Minimize } TSC = \sum_{i} (H_i + T_i + R_i)\, X_i$$

Subject to the following constraints:

$H_i , T_i , R_i \geq 0$

Total Wheat Demanded = Total Wheat Supplied

Actual Wheat Stored at Facility i ≤ Maximum Storage Capacity of Facility 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 Storage Facility i = Flow of Wheat out of Storage Facility i

Where:

TSC is total system transportation and handling costs

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

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

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

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

Several assumptions were necessary in order to implement the least cost model. With respect to Step I, although other methods are available, the optimal methodology for determining wheat movements is individual routing choice analysis. By this method, the initial movement of wheat is determined independently by each farmer. A farmer may choose to truck wheat to a country grain elevator, a shuttle train station, or a terminal grain elevator. This choice is based on the wheat price offered by each available destination market and the costs of transporting wheat to that destination. Based on the spatial distribution of farms and potential destinations, the principal determinant in this choice of destination is usually the transportation cost. That is, the difference in wheat prices between destinations tends to be negligible due to low cost information and high levels of competition, while each farm is usually much closer to one destination than any other potential destination. In short, the farmer has neither the time nor the expertise needed to market his product any further than the local country elevator. Thus, farmers are assumed to always choose the least-distant, least transport cost destination.

It is also assumed that movement from the farm to the closest storage facility occurs entirely upon the county road system. Although this assumption is not entirely accurate, it is based upon two reasons. First, empirical evidence suggests that the majority of the trip miles from the farm to the elevator are necessarily traveled on county roads. Second, the majority of farms are positioned adjacent to the county road network and the shortest, least transport cost path to the nearest storage facility lies along that road network.

Three key assumptions were made governing system behavior for the Step II handling aspect of wheat transport. First, vehicle and storage capacities are available in equilibrium quantities such that a capacity constraint never influences wheat movements. This is reasonable to assume for wheat storage facilities, as the Kansas wheat storage industry is over 100 years old and most of the profits to be gained by expanding storage capacity have already been undertaken. Thus, storage capacity is "right-sized" for Kansas wheat production. Vehicle capacity constraints are known to influence individual transport firm behavior within the system as a whole; however, the modeling of truck and rail industry supply and demand involves both national and global factors that are well outside the scope of this study and will not be considered. The second key assumption for Step II is that a country grain elevator does not ship wheat to another country grain elevator. Instead, country grain elevators ship to unit train facilities because of the large volumes of wheat that must be handled, stored, and shipped to Houston. And finally, input costs and technologies across the study area are assumed to be uniform, thereby making it possible to characterize economic entities by type. Thus, all country elevators have the same characteristics, as do all grain trucks and shortline railroads.

Three additional assumptions were made for Steps III and IV of Kansas wheat movement. Houston is the destination for a large portion of Kansas wheat shipments and will be used as a proxy for all markets, both domestic and export. A second key assumption is that Kansas wheat must use rail to reach Houston. Although physically possible, the high motor carrier variable (with distance) costs of shipping wheat makes trucking wheat to Houston economically unfeasible. A profit maximizing wheat shipper would never ship wheat from Kansas to Houston by truck. And since wheat must reach the Port of Houston by rail, the large economies of scale associated with unit train transport makes rail the least cost mode of transport for every wheat long distance movement. Thus, if rail service is available from an elevator, it will be utilized, and wheat shipments will never change modes of transport once loaded on a rail car.

4.3 Methodology

4.3.1 Structural Elements of the Model

Before analyzing the movement of Kansas wheat, some structural elements had to be quantified and geo-spatially referenced. First, the farms where wheat is produced were determined. Second, the transshipment nodes (i.e. country grain elevators, shuttle train facilities, and Salina, Wichita and Hutchinson grain terminals) and the terminal node (Houston) were defined. Next, the road and rail systems available for transporting the wheat had to be specified. And finally, system behaviors as defined by the cost functions of activities were approximated using a four-step approach.

Traditional network models determine origin points by assuming a study area is evenly divided into homogenous ‘simulated farms’ that generate equal amounts of the grain produced in the county. In the traditional models a study area of the magnitude used in this study would probably be divided into 10 mile x 10 mile squares. While the simulated farm assumption was the best available approximation in the past, tremendous advances in computer technology have recently enabled a much more detailed approximation of reality. Using GIS software and satellite imagery data on land usage in each county, (see p. 64), a specific land use map was generated for the entire study area. This land use map represents the actual usage, by category, of all land. Or, alternately stated, distinct parcels of urban area, woodland, water, and cropland were defined within the study area, and all cropland was identified for its possible contribution to wheat production. The land usage map of the study area was then divided into legal land sections as defined by the U.S. Public Land Survey System. Thus, a potential wheat farm for the model was defined as the typical 1 mile x 1 mile area (640 acres) of a legally defined section. Farm sections, though generally 640 acres in area, sometimes consisted of odd acreages when affected by geographic features (such as waterways) and legal factors (such as county borders). Thus, the entire study area was subdivided into rough 640 acre plots which contained various parcels of cropland and other land uses that were further analyzed to estimate simulated wheat farms in the model.

After the actual amount of cropland in a section was identified, the amount of wheat that it would be estimated to produce for the simulation had to be determined. One way to generically determine this would be to divide the total wheat produced in the study area in a particular year by the total amount of land used for wheat production in that year to obtain a per-area multiplier and then multiply the land used for wheat in each section by this multiplier. That is:

(2) $$\text{SectionWheat}_i = \text{SectionCropLand}_{i,t} \cdot [\text{Wheat}_t \div \text{StudyAreaCropLand}_t]$$

Where:

SectionWheat_i represents the wheat originating in section i

$\text{SectionCropLand}_{i,t}$ represents land producing wheat in section i in year t

Wheat_t represents the total wheat produced in the entire study area in year t

$\text{StudyAreaCropLand}_t$ represents land in the study area producing wheat in year t

This generic approach has three primary shortcomings. First, the amount of wheat produced in a particular year will vary with changes in exogenous factors such as weather. To avoid this problem, the average wheat production over a four year period was used. Next, good farming practices involve periodically rotating the crop planted on a particular section of land, primarily for restoring nitrogen to the soil. The result of crop rotation practices is that different fields will be used to cultivate wheat each year and, therefore, different roads will be used to transport wheat in a particular year. Since this study is aimed at a multi-year simulation of study area road usage, all land used for growing crops will be included instead of just the land used for growing wheat in a particular year. Finally, the generic approach assumes land in every county is equally suited for producing wheat. However, factors such as area soil type and average annual rainfall cause variations in fertility. This variation can be reasonably approximated without attempting to measure the fertility of every parcel of land in the area by using the four-year average production of wheat that occurred in each county. Thus, the wheat production of origin points for study area wheat is determined by dividing the average wheat produced in a particular county by the total cropland in that county and multiplying this result by the exact amount of cropland in each section in that county. That is:

$$\text{SectionWheat}_i = \text{SectionCropLand}_{i,t} \cdot [\text{Wheat}_{j,avg} \div \text{CountyCropLand}_{j,t}] \quad (3)$$

Where:

SectionWheat_i is the amount of wheat originating in section i

$\text{SectionCropLand}_{i,t}$ is the land used to produce crops in section i in year t

$\text{Wheat}_{j,avg}$ is the average wheat produced in county j over a four year period

$\text{CountyCropLand}_{j,t}$ is the total land in county j used to produce crops in year t

By applying the resulting estimated wheat production for a particular section to the centroid, or center point of the simulated farm, the result was a geo-referenced set of origin points which served to spatially distribute the average county wheat production according to the actual distribution of study area cropland. This approach, therefore, allowed the model to account for geographical variances in both land usage patterns and historic wheat yields, thereby offering a vastly more accurate estimate of origin point locations and wheat production than postulating homogenous 10 mile by 10 mile simulated farms.

Having established the origin nodes for the model, attention was turned to the transshipment and terminal nodes. The numbers of country grain elevators, shuttle train stations, Salina, Wichita and Hutchinson grain terminals, and terminal nodes (Houston) were small enough that actual data concerning these entities could be used. Street addresses for facilities licensed to handle and store grain in the state of Kansas were used to identify and geo-reference the transshipment nodes in the model. The model was, however, simplified slightly by limiting each town to one transshipment facility, except in the instances where more than one railroad provided service to the town. In the case of multiple rail service in a town, a node was allowed for each rail service to simulate use of both railroads. The reasons for streamlining the transshipment facilities was two-fold: (1) to remove from consideration the redundant regional storage capabilities of local milling and feed firms, and (2) to avoid modeling anomalies created by marginal trip distance variances (i.e. the elevator located on a curved street losing all of its business to the elevator in the same part of town on a straight street because the overall trip distance is shorter.). The Salina, Wichita and Hutchinson grain terminals and shuttle train facilities were those identified by Babcock and Bunch (2000). The geographic center of the Port of Houston served as the terminal node for the model.

Having defined all of the nodes in the system, the next step in formulating a model of the wheat logistics system was to define the arcs that serve to connect the different origin, transshipment, and terminal nodes of the network. The actual road system maintained by state and county governments was utilized to define network arcs. Likewise, those railroads identified and monitored by various agencies in the state of Kansas were utilized for the study. The only arc segment that was considered outside of the study area involved connecting rail service to the two small segments of the NKC Railroad that ships wheat in the Northwest Kansas crop reporting district. All rail segments, both shortline and Class I, used to move Kansas wheat through Nebraska to Class I railroad switches were used in the study to estimate the distances and costs of utilizing the NKC to transport Kansas wheat.

Having established all of the structural elements of the model, logistics system behavior was approximated by tracing the flow of wheat through the system from origin nodes, through transshipment nodes, and then on to the terminal node utilizing various network arcs. The flow of wheat is believed to move in three distinct phases. Step I (Collection) involves the collection of wheat from production origins, or farms, to an intermediate Kansas storage facility that can ship the wheat via rail from the intermediate storage location to the Port of Houston. Step II (Handling) involves the handling of wheat necessary to unload and store the commodity and then load it out from the transshipment nodes. Step III (Distribution) involves the shipment of wheat from Kansas to Houston by rail. For simulation purposes, Step IV involves the analysis of differences in Steps II and III without shortlines in the wheat logistics system.

4.3.2 Step I Component of the Model

Step I (Collection) involves the transport of wheat from the farm to the nearest storage facility, whether that facility is a country grain elevator, a shuttle train station, or a Salina, Wichita or Hutchinson grain terminal, utilizing the county road network. Thus, modeling the farmer's routing decision begins with the wheat produced at a particular origin point. The quantity of wheat produced at the origin point is first converted into truckloads. Berwick (2002) finds that a standard grain truckload transports a payload of 56,600 pounds, equivalent to 943 bushels of wheat. So, the total number of bushels of wheat estimated to be produced at each origin point was divided by 943. The result was rounded to the nearest hundredth of a truckload. Next, the closest storage facility from each origin point was determined. The nearest facility having been identified, the next step in the analysis was to determine the minimum transport cost routing from each farm to the elevator (see Appendix B). This was assumed to be the route each respective farmer would utilize to deliver his wheat to the nearest intermediate storage facility, and the corresponding mileage generated was the simulated trip miles from each farm. The trip-miles generated from each farm were multiplied by the total number of truckloads needed to transport the wheat from each origin point. This calculation, in turn, yielded the total truck-miles traveled. Having identified the total truck-miles traveled, an average custom-cutter transport rate of \$0.01 per bushel, or \$9.43 per truck-mile, was applied to the trip miles to estimate the costs associated with transport from the farm to the nearest storage facility.

Not all transshipment facilities in the model are elevators capable of shipping wheat to Houston. Rail access is required to reach Houston. Thus, wheat collected by elevators without rail service had to be shipped to a storage facility with rail service. The wheat collected by elevators with no rail service was moved by commercial truck over the state highway system to the nearest unit train loading facility. Berwick estimated the cost of commercial truck travel to be \$1.134 per truck-mile. Thus, once routing and trip distances were identified, the truck-miles were multiplied by \$1.134 to yield the estimate of the cost of this additional transport of wheat from the country elevators without rail service.

4.3.3 Step II Component of the Model

Step II (Handling) involves the unloading of wheat from trucks into an intermediate storage facility (nearly always a country grain elevator) and the subsequent loading out of the wheat into trucks or rail cars. In Step I, all transportation to intermediate storage facilities was by truck. For facilities with rail service, wheat was loaded out into rail cars. For elevators without rail service, an additional unload and loadout cost was incurred when transporting the wheat to a storage facility with rail service. Handling costs were estimated to be $0.09 a bushel for both unload and loadout of wheat by country elevators; these handling costs were estimated to be $0.07 a bushel for unit train shipping facilities. Newer technology and economies of scale are believed to account for the difference in handling costs among intermediate storage facilities. Thus, in order to measure total wheat logistics system handling costs, the number of bushels of wheat estimated to be stored at each elevator in the model was multiplied by the corresponding per bushel unload and loadout cost for that type of facility.

4.3.4 Step III Component of the Model

In Step III (Distribution), wheat from storage locations is loaded out into railcars for shipment to Houston. Once wheat is loaded onto a rail car it remains on rail lines until it reaches Houston. This is due to two factors. First, railroads are the least cost mode for transporting wheat over long distances. Also, once wheat is loaded on a rail car it would incur additional handling costs to unload the rail car, load a truck, and then unload the truck and load another rail car. The remaining step in the logistics system analysis is the routing of wheat from a Kansas intermediate storage facility to Houston via the rail network. Step III was modeled in two sub-phases in an attempt to simulate the intermediate handling necessary to assemble large volumes of wheat for long-haul shipment.

Obviously, wheat is not shipped to Houston in single rail cars. Instead, Class I railroads make maximum use of economies of scale by assembling 100-car unit trains of a single commodity in order to reduce the labor costs associated with assembling trains with multiple commodities shipped to multiple destinations. It is assumed that unit trains are shipped only from shuttle train locations and the terminal elevators in Salina, Wichita and Hutchinson.

The average cost per mile for intra-Kansas rail shipments was estimated for shortline railroads, the BNSF, and the UP by calculating the cost per hundredweight (cwt.) to ship wheat 200 miles utilizing URCS cost functions, and then dividing the total by 200 to obtain the estimated cost per mile. Costs for the Illinois Central (the least cost Class I railroad) were used to estimate shortline costs. A distance of 200 miles was chosen to represent the trip distance within the study area since it is about the upper limit of distance for which truck is competitive with rail. Shortlines were estimated to generate costs of \$0.0010 per cwt, the BNSF \$0.0012 per cwt, and the UP \$0.0013 per cwt. Thus, to estimate the transport costs associated with intra-Kansas rail movement, wheat was routed from rail-served elevators to the nearest unit train shipping location using the same routing algorithm utilized in Step I. The corresponding car-miles, transport costs, and wheat amounts were the model outputs for the intra-Kansas rail movement sub-phase of Step III.

At this point in the analysis, all of the wheat produced in the study area has been routed to a shuttle train facility or a Salina, Wichita or Hutchinson terminal elevator. URCS costs contained in Table 7 were used to determine the rail costs for the transport of wheat from Kansas to Houston, as well as the car-miles and ton-miles of this sub-part of Step III. Total wheat logistics system transport and handling costs were then summed by mode for Steps I to III to determine total system costs for the no-abandonment scenario.

Step IV analyzes the Kansas wheat logistics system adaptation to the simulated abandonment of shortlines, and the corresponding handling and transportation cost changes. Step I of the model remains unchanged, except for the number of country elevators that require intermediate wheat shipments in order to connect with a rail-served elevator. These include not only the country elevators that had no rail service in the no abandonment scenario, but also all the elevators located on study area shortlines. Utilizing the same closest facility algorithm, wheat from shortline elevators was shipped by truck to the nearest unit train shipping location. The corresponding truck-miles and transport costs, estimated at $1.134 per truck-mile, were calculated. The handling costs for the shortline elevators increased because an additional unload and loadout of their wheat occurred in order to reach a rail-served elevator, each handling incurring a cost of $0.09 a bushel. These additional costs were added to the Step I and II costs calculated for the no-abandonment scenario. Since shortlines were assumed to be abandoned, their costs were subtracted from the no-abandonment scenario total transport and handling costs. Class I rail costs for shipment of wheat from Kansas to Houston are unaffected by shortline abandonment so these costs remain unchanged. Thus, the impact of shortline abandonment is the change in handling and transport costs associated with shipping wheat from shortline elevators to Kansas unit train shipping locations. These cost changes reflect a change from shortline to truck shipments and the additional handling costs associated with this shift. Total wheat logistics system costs after simulated shortline abandonment were summed and compared with pre-abandonment costs. The difference in the two wheat logistics systems' costs represents the impact of shortline railroad abandonment.

4.4 Data

The model in this study requires much more data than traditional network models. Identifying wheat origin points requires two sets of data. Data describing the location and amount of all cropland in the study area is required. This data is available through the State of Kansas Data Access and Support Center (DASC), an initiative of the state's GIS policy board. The data of interest to this study is collected by DASC for each county, so the data for the 66 counties in the study area were obtained from DASC and used to form a single land use map of the entire study area. This provides the spatial location of all origin points. The amount of wheat produced at each origin point is the subject of the second set of data. The amount of wheat produced per Kansas county in 1998, 1999, 2000, and 2001 is found in *Kansas Farm Facts*, published by the Kansas Agricultural Statistics Service, Kansas Department of Agriculture, 2000, 2001, and 2002 issues (see Table 2). The wheat production for each county is averaged over this four-year period and the county average production is distributed across all origin points in the county. The distribution of production is based on a rate of production per square mile so that a 1-mile by 1-mile section that is 100% cropland will produce twice as much wheat as a 1 mile by 1 mile section in the same county that is only 50% cropland. Land sections that contained less than 25% cropland were not considered as farms, as their corresponding outputs would produce less than a single truckload of wheat per year. Thus, the total cropland available for a county was calculated by summing the total area of cropland represented by those land sections which contained at least 25%, or approximately 160 acres, of crop land.

The system of county and state roads in the study area was provided in digitized form by KDOT. The locations and storage capacities of country grain elevators and terminal grain elevators were obtained from the *2002 Kansas Official Directory*, published by the Kansas Grain and Feed Association. Shuttle train facility locations in Table 3 were from Babcock and Bunch (2002). Rail systems for Class I (UP and BNSF) and shortline railroads were obtained through Kansas rail maps provided by KDOT and the Kansas Corporation Commission.

The key data for generating wheat movements are the various transport costs involved in the wheat logistics system. Truck costs incurred by farmers when transporting wheat from origin points to the nearest destination (Step I) are from the Kansas Department of Agriculture's annual

TABLE 2
Study Area Wheat Production by County
1998-2001
(Thousands of Bushels)

Northwest Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Cheyenne	6050	7012	3353	4473	5222
Decatur	6600	4513	3746	4512	4843
Graham	4806	3099	3291	3245	3610
Norton	6374	3782	3633	3909	4425
Rawlins	7359	7235	4439	6195	6307
Sheridan	6902	5942	3948	3552	5086
Sherman	8074	8464	5526	5984	7012
Thomas	9826	8522	6174	7400	7981
Total	55,991	48,569	34,110	39,270	44,486

West Central Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Gove	6271	6284	4107	2739	4850
Greeley	9013	7230	5006	3294	6136
Lane	7036	4891	3887	2187	4500
Logan	5084	6500	3875	2706	4541
Ness	7097	3690	5348	3765	4975
Scott	8553	7119	5398	3456	6132
Trego	5450	4229	3848	3159	4172
Wallace	3150	4243	2401	2419	3053
Wichita	8607	5587	4550	3890	5659
Total	60,261	49,773	38,420	27,615	44,018

Southwest Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Clark	2724	2688	1986	1686	2271
Finney	9792	8786	6106	5936	7655
Ford	9589	9432	5873	4362	7314
Grant	4503	4830	3168	3222	3931
Gray	8415	8236	5052	3689	6348
Hamilton	8178	5434	3876	4235	5431
Haskell	6902	6165	4060	3438	5141
Hodgeman	6032	5123	3653	2899	4427
Kearney	6014	4680	3506	3350	4388
Meade	4708	4769	2807	2186	3618
Morton	4158	4484	2849	3233	3681
Seward	3036	3774	2048	1828	2672
Stanton	6088	5862	3936	5756	5411
Stevens	4092	5177	3510	3590	4077
Total	84,231	79,380	52,430	49,410	66,365

North Central Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Clay	5400	3963	3404	3703	4118
Cloud	5731	5567	4610	4201	5027
Jewell	7008	6734	4489	4457	5672
Mitchell	9414	9031	6709	6412	7892
Osborne	7671	6069	4866	3682	5572
Ottawa	7074	5855	4921	4618	5617
Phillips	6612	3688	3570	3754	4406
Republic	4951	4821	2779	3878	4107
Rooks	6372	4284	3835	3120	4403
Smith	7259	6519	5144	4517	5885
Washington	5346	4429	3018	3433	4057
Total	72,838	60,960	47,345	45,775	56,756

Central Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Barton	9384	6888	7465	5788	7381
Dickinson	8228	6610	5841	6380	6765
Ellis	4598	5513	4015	3155	4320
Ellsworth	4717	4890	4096	3587	4323
Lincoln	5830	4675	4670	3499	4669
M^{c}Pherson	11,184	10,570	8659	7942	9589
Marion	6626	6375	4697	5056	5689
Rice	8250	7487	6312	6371	7105
Rush	5170	2943	5218	3868	4300
Russell	4769	4438	3897	2871	3994
Saline	8316	5975	5610	5938	6460
Total	77,072	66,364	60,480	54,455	64,595

South Central Crop Reporting District

County	1998 Production	1999 Production	2000 Production	2001 Production	Average Production
Barber	6356	5652	4330	4421	5190
Comanche	2690	3082	2044	1963	2445
Edwards	5130	4558	3705	3551	4236
Harper	10,889	10,635	8320	7424	9317
Harvey	5535	5634	4123	4598	4973
Kingman	9243	11,745	7438	6619	8761
Kiowa	3612	4544	2336	2069	3140
Pawnee	7181	4778	5220	4221	5350
Pratt	6768	7098	5821	6920	6652
Reno	11,722	12,484	9284	7736	10,307
Sedgwick	10,397	9601	7373	6906	8569
Stafford	6728	7465	5567	4781	6135
Sumner	15,744	15,056	13,439	12,726	14,241
Total	101,995	102,332	79,000	73,935	89,316

Source: Kansas Department of Agriculture, Kansas Agricultural Statistics Service, *Kansas Farm Facts*, 2000 and 2001 issues.

TABLE 3

Unit Train Loading Stations on Class I Railroads in the Study Area Excluding Wichita, Hutchinson, and Salina

BNSF Facilities

Company Name	**Location**
Right Coop Association	Wright, Kansas
Wind River Grain LLC	Garden City, Kansas
Ag Mark LLC	Concordia, Kansas
Farmland Grain Division	Wellington, Kansas
DeBruce Grain Inc.	Abilene, Kansas
Collingwood Grain Inc.	Dodge City, Kansas

UP Facilities

Company Name	**Location**
Farmers Coop Co.	Haviland, Kansas
Cargill North America Grain	Wakeeney, Kansas
Farmland Industries	Ogallah, Kansas
Wallace County Coop Equity Exchange	Sharon Springs, Kansas
Cornerston Ag LLC	Colby, Kansas
DeBruce Grain Inc	Abilene, Kansas
Collingwood Grain Inc.	Plains, Kansas

Source: Michael W. Babcock and James L. Bunch. *Impact of Kansas Grain Transportation on Kansas Highway Damage Cost*. Topeka, Kansas, Kansas Department of Transportation, 2002, p. 9.

survey of custom cutters published in *2000 Kansas Custom Rates* (see Table 4). Statewide, movements from origin points tend to be 12 miles or less and are 12.6 cents per bushel for 12 mile trips. In the study area the costs vary from a low of 0.89 cents to a high of 1.17 cents. Thus, truck movements from origin points are assumed to cost 1.0 cent per bushel per mile. Truck shipments of wheat by grain elevators typically involve commercial trucking companies. To estimate the commercial truck costs (per hundred pounds) for various distances, the study by Mark Berwick (2002) was used. Commercial truck costs for wheat are in Table 5 assuming a 100 mile trip by a five axle semi-tractor trailer operating at a GVW of 80,000 pounds and hauling 943 bushels of wheat. About 65% of the total cost per mile is variable cost and 35% fixed costs. Table 6 contains Berwick's wheat commercial truck costs for different distances.

Elevator charges for loading and unloading wheat by truck and rail are required under Kansas statute to be publicly posted. Based on the reported averages of 345 country grain elevators, truck unload and loadout costs were found to average 9 cents per bushel. The rail loadout cost at country elevators, based on 238 reports, was also found to average 9 cents per bushel. Rail and truck unloading and loadout costs at 16 shuttle train facilities and Salina, Wichita and Hutchinson terminal elevators were all found to average 7 cents per bushel.

The rail costs of shipping wheat per hundred pounds were obtained through the Uniform Rail Costing System (URCS) Phase III Movement Costing Program which is maintained by the Surface Transportation Board. Phase I of URCS involves three distinct operations. A database of relevant railroad expenses and operating statistics is constructed. Next, theoretical relationships between measures of output and expense categories are developed. Regression analysis is utilized to develop variability ratios or specific relationships between expenses and operating statistics. Phase II involves classifying expenses into variable and fixed components. Variable expenses are assigned to units of service. This is accomplished with the variability ratios calculated in Phase I and with the use of default procedures where regression analysis could not provide appropriate results. Variable costs of railroad services can be calculated once

TABLE 4

Custom Cutter Rates for Hauling Wheat From Field to Farm Storage or Elevator, 2000

Crop Reporting District	Transport Cost (Cents)	Miles Limit	Cents per Mile	Cents Per Bushel Per Mile Over Mileage Limit
Northwest	12.5¢	11	1.14¢	0.9¢
West Central	12.5¢	14	0.89¢	1.0¢
Southwest	12.4¢	13	0.95¢	0.8¢
North Central	12.7¢	13	0.98¢	1.1¢
Central	12.5¢	12	1.04¢	0.9¢
South Central	12.9¢	11	1.17¢	1.2¢
State	12.6¢	12	1.05¢	1.1¢

Source: Kansas Agricultural Statistics Service, Kansas Department of Agriculture. *2000 Kansas Custom Rates*. Topeka, Kansas January 2001, p. 10.

TABLE 5

Commercial Truck Costs for Kansas Wheat*

Variable Costs	**Cost Per Mile**	**Cost Per Trip**	**Cost Per Bushel**
Fuel	$0.227	$22.71	$0.024
Labor	$0.350	$35.00	$0.037
Tires	$0.048	$ 4.82	$0.005
Maintenance	$0.111	$11.13	$0.012
Total Variable Costs	$0.736	$73.66	$0.078
Fixed Costs	**Cost Per Mile**	**Cost Per Trip**	**Cost Per Bushel**
Equipment Cost	$0.196	$19.58	$0.021
License Fees and Taxes	$0.031	$ 3.08	$0.003
Insurance	$0.064	$ 6.40	$0.007
Management and Overhead	$0.107	$10.72	$0.011
Total Fixed Costs	$0.398	$39.78	$0.042
Total Cost	$1.134	$113.44	$0.120

* Costs are estimated for a five axle semi tractor-trailer truck operating at a gross vehicle weight (GVW) of 80,000 pounds and hauling 943 bushels of wheat. Costs are based on a 100 mile trip with no backhaul or deadhead miles.

Source: Mark Berwick, *Motor Carrier Cost Estimates for Kansas Grain*, Fargo, North Dakota, 2002

TABLE 6

Kansas Wheat Commercial Truck Costs for Various Distances*

Distance (Miles)	**Cost Per Mile**	**Cost Per Trip**	**Cost Per Bushel**
25	$1.134	$ 28.362	$0.030
50	$1.134	$ 56.725	$0.060
75	$1.134	$ 85.067	$0.090
100	$1.134	$113.450	$0.120
125	$1.134	$141.812	$0.150
150	$1.134	$170.175	$0.180
175	$1.134	$198.537	$0.210
200	$1.134	$226.900	$0.241
225	$1.134	$255.262	$0.271
250	$1.134	$283.624	$0.301
275	$1.134	$311.987	$0.331
300	$1.134	$340.349	$0.361
325	$1.134	$368.712	$0.391
350	$1.134	$397.074	$0.421
375	$1.134	$425.437	$0.451
400	$1.134	$453.799	$0.481
425	$1.134	$482.162	$0.511
450	$1.134	$510.524	$0.541
475	$1.134	$538.886	$0.571
500	$1.134	$567.249	$0.601

* Costs are estimated for a five axle semi tractor-trailer truck operating at a gross vehicle weight (GVW) of 80,000 pounds and hauling 943 bushels of wheat. Costs are based on a 100 mile trip with no backhaul or deadhead miles.

Source: Mark Berwick, *Motor Carrier Cost Estimates for Kansas Grain*, Fargo, North Dakota, 2002 the rail data files and statistical outputs from Phase I have been transformed into cost parameters. Phase III involves the processing of Phase II unit cost data. Unit train (100 cars) costs for movements from Kansas' terminals to Houston, as cited previously, are listed in Table 7.

4.5 Results and Analysis

The trip miles and associated transportation costs for Step I (Collection) by county are provided in Table 8. A total of 2.2 million truck-miles, or 62.1 million ton-miles, were generated during Step I by moving wheat from the farm to the closest storage facility. The total cost for this portion of the system was \$20.7 million. Shipments from elevators without rail service to the nearest unit train shipping facility resulted in an additional 4.8 million truck-miles, or 132 million ton-miles, costing an additional \$6.1 million. In total, Step I (Collection) costs include 7.8 million truck-miles, or 216.8 million ton-miles, which generate a total truck transportation cost of \$34.3 million.

The Step II (Handling) costs are depicted in Table 9. In total, 365.5 million bushels of wheat were handled in the no-abandonment scenario. A total handling cost of \$32.3 million was generated from the receipt of wheat from the farm; \$11.5 million in additional handling costs were created from the handling of wheat that was received by elevators with no rail service and shipped to a unit train facility by truck. A total of \$30.9 million in load-out costs were generated from loading wheat into rail cars at unit train shipping facilities. Total handling costs for the no-abandonment scenario amount to \$74.8 million.

The Step III (Distribution) costs are depicted in Tables 10 and 11. Table 10 provides the traffic and corresponding transportation costs associated with intra-Kansas rail movement in the no-abandonment scenario. Shortline railroads handled 159.7 million bushels of wheat generating 3.7 million car-miles, or 414.8 million ton-miles of rail wheat traffic that cost a total of \$10.9 million. Class I railroads handled 106.3 million bushels of wheat generating 787,947 car-miles,

TABLE 7

Unit Train (100 Cars) Costs of Movements from Kansas Terminals to Houston*
Cost Per Car and Total Cost

BNSF Origins

Origin	**Miles to Houston**	**Cost Per Car**	**Total Cost**
Wellington	631	$655.62	$65,552
Wichita	646	$666.40	$66,640
Hutchinson	702	$715.36	$71,536
Abilene	769	$772.48	$77,248
Salina	792	$791.52	$79,152
Wright	814	$807.84	$80,784
Dodge City	822	$816.00	$81,600
Concordia	824	$818.72	$81,872
Garden City	872	$856.80	$85,680

UP Origins

Origin	**Miles to Houston**	**Cost Per Car**	**Total Cost**
Wichita	642	$710.22	$71,022
Hutchinson	692	$752.78	$75,278
Salina	737	$787.36	$78,736
Abilene	738	$790.02	$79,002
Haviland	770	$816.62	$81,662
Plains	799	$840.56	$84,056
Ogallah	864	$893.76	$89,376
Wakeeney	873	$901.74	$90,174
Colby	940	$957.60	$95,760
Sharon Springs	981	$989.52	$98,952

* URCS Inputs: Shipment type was originated and terminated, car type was covered hopper, number of cars was 100, car ownership was rail owned, commodity was grain, tons per car was 100, movement type was unit train, and empty/loaded ratio was 1.0.

Source: Office of Economics, Environmental Analysis, and Administration, Surface Transportation Board, *Uniform Railroad Costing System Phase III Movement Costing Program*, 1996.

TABLE 8

Summary of Step I Wheat Truck Traffic and Costs, By County

Northwest District

County		**Total Step I Ton Miles**	**Total Step I Truck Miles**	**Total Step I Truck Costs**
Cheyenne		1,607,483	56,822	$ 535,827
Decatur		1,570,696	55,519	$ 388,231
Graham		8,807,167	311,317	$ 603,831
Norton		4,080,355	144,233	$ 442,560
Rawlins		1,792,080	63,347	$ 597,360
Sheridan		993,967	35,135	$ 331,322
Sherman		3,416,903	120,779	$ 786,935
Thomas		4,022,935	142,201	$ 786,671
	District Subtotal	26,291,586	929,353	$4,472,737

West Central District

County		**Total Step I Ton Miles**	**Total Step I Truck Miles**	**Total Step I Truck Costs**
Gove		2,038,720	72,065	$1,167,169
Greeley		2,309,510	81,637	$ 769,836
Lane		1,577,733	55,770	$ 525,910
Logan		1,501,287	53,068	$ 500,429
Ness		1,222,763	43,222	$ 407,587
Scott		2,154,254	76,149	$ 718,084
Trego		4,748,015	167,833	$ 511,861
Wallace		1,272,034	44,964	$ 424,011
Wichita		2,550,786	90,166	$ 850,261
	District Subtotal	19,375,102	684,874	$5,875,148

Southwest District

County	Total Step I Ton Miles	Total Step I Truck Miles	Total Step I Truck Costs
Clark	824,153	29,132	$ 156,994
Finney	2,509,695	88,713	$ 836,346
Ford	4,357,819	154,041	$ 621,050
Grant	1,234,139	43,625	$ 411,379
Gray	1,498,288	52,962	$ 498,774
Hamilton	1,851,072	65,432	$ 617,023
Haskell	1,282,761	45,343	$ 427,587
Hodgeman	1,029,563	36,393	$ 343,187
Kearney	1,271,279	44,937	$ 423,759
Meade	1,468,218	51,898	$ 346,329
Morton	945,750	33,430	$ 315,250
Seward	679,556	24,021	$ 226,518
Stanton	1,759,428	62,193	$ 586,475
Stevens	926,650	32,755	$ 308,883
District Subtotal	21,638,371	764,875	$6,119,554

North Central District

County	Total Step I Ton Miles	Total Step I Truck Miles	Total Step I Truck Costs
Clay	2,322,985	82,113	$ 324,810
Cloud	10,356,282	366,075	$ 709,674
Jewell	6,057,621	214,126	$ 535,282
Mitchell	4,515,511	159,615	$ 711,496
Osborne	1,257,719	44,458	$ 353,821
Ottawa	12,719,507	449,611	$ 830,437
Phillips	2,942,953	104,028	$ 327,852
Republic	3,017,131	106,650	$ 405,797
Rooks	1,490,720	52,694	$ 399,650
Smith	2,325,610	82,206	$ 440,387
Washington	4,581,244	161,938	$ 394,964
District Subtotal	51,587,283	1,823,514	$5,434,170

Central District

County	Total Step I Ton Miles	Total Step I Truck Miles	Total Step I Truck Costs
Barton	2,112,266	74,665	$ 462,981
Dickinson	2,305,378	81,491	$ 433,666
Ellis	5,003,398	176,859	$ 526,611
Ellsworth	3,305,951	116,859	$ 351,249
Lincoln	13,360,647	472,275	$ 811,821
M^{c}Pherson	5,812,148	205,449	$ 671,181
Marion	1,334,633	47,176	$ 309,250
Rice	3,208,128	113,401	$ 440,995
Rush	1,107,716	39,156	$ 369,238
Russell	5,189,564	183,440	$ 437,778
Saline	15,205,487	537,485	$ 856,716
District Subtotal	57,945,318	2,048,256	$5,671,486

South Central Crop Reporting District

County	Total Step I Ton Miles	Total Step I Truck Miles	Total Step I Truck Costs
Barber	3,121,553	110,341	$ 488,069
Comanche	837,745	29,613	$ 279,248
Edwards	3,508,070	124,004	$ 368,168
Harper	1,997,718	70,616	$ 546,504
Harvey	2,580,188	91,205	$ 525,002
Kingman	2,368,800	83,733	$ 564,846
Kiowa	1,180,129	41,716	$ 288,865
Pawnee	1,463,400	158,646	$ 465,968
Pratt	4,772,522	118,860	$ 504,255
Reno	3,599,079	324,485	$ 806,799
Sedgwick	9,168,671	78,759	$ 524,912
Stafford	1,770,128	69,675	$ 380,310
Sumner	3,577,741	219,030	$1,020,825
District Subtotal	39,945,744	1,520,681	$6,763,771
Study Area Totals	216,783,402	7,771,555	$34,336,866

TABLE 9

Step II Wheat Handling Costs by Railroad

No-Abandonment Scenario

Access Method To Class I Railroad	**% of Wheat Collected**	**Total Bushels**	**Collection Cost Truck Unload**	**Intermediate Handling Cost**	**Final Rail Loadout Cost**
BNSF	15%	53,481,292	$ 4,813,316	$0	$ 4,813,316
UP	14%	52,781,014	$ 4,750,291	$0	$ 4,750,291
NKC	4%	14,561,975	$ 1,310,578	$0	$ 1,310,578
KYLE	11%	41,930,054	$ 3,773,705	$0	$ 3,773,705
K & O	21%	77,982,504	$ 7,018,425	$0	$ 7,018,425
CV	7%	25,265,486	$ 2,273,894	$0	$ 2,273,894
No-Rail Elevators	20%	71,969,326	$ 6,477,239	$11,515,092	$ 5,037,853
Farm to Terminals	8%	27,561,350	$ 1,929,295	$0	$ 1,929,295
Study Area Total	100%	365,533,001	$32,346,743	$11,515,092	$30,907,357

TABLE 10
Intra-Kansas Step III Rail Wheat Traffic and Costs by Railroad

No-Abandonment Scenario

Shortline Railroads

Railroad	Bushels	Car Miles	Ton Miles	Cost
NKC	14,561,975	210,724	23,845,784	$ 856,119
KYLE	41,930,054	1,153,350	130,514,563	$ 2,747,968
K & O	77,982,504	1,909,839	216,117,945	$ 6,111,292
CV	25,265,486	392,075	44,369,109	$ 1,148,154
Total	159,740,019	3,665,988	414,847,401	$10,863,532

Class I Railroads

Railroad	Bushels	Car Miles	Ton Miles	Cost
BNSF	53,481,292	346,511	39,211,255	$1,339,196
UP	52,781,014	441,436	49,953,424	$2,187,453
Total	106,262,306	787,947	89,164,679	$3,526,649

Shortline and Class I Railroads

Railroad	Bushels	Car Miles	Ton Miles	Cost
Total	266,002,324	4,453,935	504,012,080	$14,390,181

TABLE 11
Kansas to Houston Step III Rail Wheat Traffic and Costs by Railroad

No-Abandonment Scenario

Railroad	Bushels	Tons	Ton-Miles	Cars	Car-Miles	Total Cost
BNSF	181,193,981	5,435,825	4,410,478,231	48,037	38,590,584	$38,426,174
UP	184,339,019	5,530,176	4,193,743,857	48,870	37,060,266	$39,437,405
Total	365,533,000	10,966,001	8,604,222,088	96,907	75,650,850	$77,863,579

or 89.2 million ton-miles of rail wheat traffic that cost a total of $3.5 million. Total system intra-Kansas railroad movements were 266 million bushels of wheat generating 4.5 million car-miles, or 504 million ton-miles of rail wheat traffic that cost a total of $14.4 million.

Table 11 provides the traffic and corresponding transportation costs associated with wheat shipments from Kansas unit train facilities to the Port of Houston. The BNSF handled 181.2 million bushels of wheat generating 38.6 million car-miles, or 4.4 billion ton-miles of rail traffic that cost a total of $38.4 million. The UP handled 184.3 million bushels of wheat generating 37.1 million car-miles, or 4.2 billion ton-miles of rail wheat traffic that cost a total of $39.4 million. Total Kansas to Houston Class I rail movements were 365.5 million bushels of wheat generating 75.7 million car-miles, or 8.6 billion ton-miles of rail wheat traffic that cost a total of $77.9 million.

Step IV (Shortline Abandonment) incremental wheat traffic and transportation costs are depicted in Tables 12 and 13. The Step IV (Handling) costs are depicted in Table 12. The same 365.5 million bushels of wheat were handled in the wheat logistics system without shortlines. As in the no-abandonment scenario, total handling costs of $32.3 million were generated from the initial elevator receipt of wheat from the farm. However, $37.1 million in handling costs were created due to the handling of wheat that was collected by elevators that had no rail service prior to shortline abandonment as well as the elevators on abandoned shortlines. This wheat required shipment from country elevators to a unit train facility by truck. A total of $27.7 million in load-out costs were generated from loading wheat into rail cars at unit train facilities. Total handling costs for the entire wheat logistics system without shortlines amounted to $97.1 million.

Table 13 provides the results of incremental truck wheat shipments from elevators on abandoned shortlines to the nearest unit train shipping location utilizing the state highway system. Incremental traffic from “abandoned” shortline elevators resulted in an additional 8.1 million truck-miles, or 228.6 million ton-miles of wheat traffic costing $9.2 million.

TABLE 12
Step IV Wheat Handling Costs by Railroad

Abandonment Scenario

Access Method To Class I Railroad	**% of Wheat Collected**	**Total Bushels**	**Collection Cost Truck Unload**	**Intermediate Handling Cost**	**Final Rail Loadout Cost**
BNSF	15%	53,481,292	$ 4,813,316	$0	$ 4,813,316
UP	14%	52,781,014	$ 4,750,291	$0	$ 4,750,291
Abandoned - NKC	4%	14,561,975	$ 1,310,578	$ 2,329,916	$ 1,019,338
Abandoned - KYLE	11%	41,930,054	$ 3,773,705	$ 6,708,809	$ 2,935,104
Abandoned - K & O	21%	77,982,504	$ 7,018,425	$12,477,201	$ 5,458,775
Abandoned - CV	7%	25,265,486	$ 2,273,894	$ 4,042,478	$ 1,768,584
No-Rail Elevators	20%	71,969,326	$ 6,477,239	$11,515,092	$ 5,037,853
Farm to Terminals	8%	27,561,350	$ 1,929,295	$0	$ 1,929,295
Study Area Total	100%	365,533,001	$32,346,743	$37,073,496	$27,712,556

TABLE 13

Step IV Incremental Truck Wheat Shipments and Costs by County Abandonment Scenario

Northwest District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Cheyenne	1,149,707	40,640	$ 46,086
Decatur	11,608,275	410,331	$ 465,315
Graham	10,555,644	373,122	$ 423,121
Norton	3,991,472	141,091	$ 159,997
Rawlins	4,726,019	167,056	$ 189,442
Sheridan	490,191	17,327	$ 19,649
Sherman	4,539,010	160,446	$ 181,945
Thomas	4,560,157	161,193	$ 182,793
District Subtotal	41,620,475	1,471,206	$1,668,348

West Central District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Gove	0	0	$ 0
Greeley	8,749,672	309,285	$ 350,729
Lane	3,114,379	110,088	$ 124,839
Logan	0	0	$ 0
Ness	7,487,141	264,657	$ 300,121
Scott	2,617,443	92,522	$ 104,920
Trego	8,989,105	317,748	$ 360,326
Wallace	0	0	$ 0
Wichita	1,386,627	49,015	$ 55,583
District Subtotal	32,344,367	1,143,313	$1,296,517

Southwest District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Clark	0	0	$ 0
Finney	16,227,307	573,605	$ 650,468
Ford	3,704,098	130,933	$ 148,478
Grant	9,531,703	336,928	$ 382,076
Gray	2,369,799	83,768	$ 94,993
Hamilton	0	0	$ 0
Haskell	2,341,509	82,768	$ 93,859
Hodgeman	294,289	10,403	$ 11,797
Kearney	0	0	$ 0
Meade	0	0	$ 0
Morton	328,164	11,600	$ 13,154
Seward	10,126,020	357,936	$ 405,899
Stanton	2,287,645	80,864	$ 91,700
Stevens	7,002,800	247,536	$ 280,706
District Subtotal	54,213,334	1,916,341	$2,173,130

North Central District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Clay	0	0	$ 0
Cloud	5,485,039	193,886	$ 219,867
Jewell	1,030,779	36,436	$ 41,319
Mitchell	9,370,982	331,247	$ 375,634
Osborne	2,673,059	94,488	$ 107,149
Ottawa	362,661	12,819	$ 14,537
Phillips	2,720,370	96,160	$ 109,045
Republic	4,045,092	142,986	$ 162,147
Rooks	9,909,563	350,285	$ 397,223
Smith	1,256,429	44,412	$ 50,364
Washington	1,017,248	35,958	$ 40,776
District Subtotal	37,871,222	1,338,677	$1,518,061

Central District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Barton	1,174,115	41,503	$ 47,064
Dickinson	0	0	$ 0
Ellis	0	0	$ 0
Ellsworth	0	0	$ 0
Lincoln	4,540,374	160,494	$182,000
M^{c}Pherson	266,078	9,405	$ 10,666
Marion	0	0	$ 0
Rice	6,439,149	227,612	$258,112
Rush	1,772,928	62,670	$ 71,067
Russell	0	0	$ 0
Saline	7,646,343	270,284	$306,502
District Subtotal	21,838,987	771,968	$875,411

South Central Crop Reporting District

County	Total Step IV Ton Miles	Total Step IV Truck Miles	Total Step IV Truck Costs
Barber	911,080	32,205	$ 36,520
Comanche	423,733	14,978	$ 16,985
Edwards	1,486,936	52,560	$ 59,604
Harper	720,235	25,459	$ 28,870
Harvey	0	0	$ 0
Kingman	8,128,271	287,319	$ 325,820
Kiowa	3,278,304	115,882	$ 131,410
Pawnee	1,335,551	47,209	$ 53,535
Pratt	2,114,883	74,757	$ 84,775
Reno	7,297,033	257,937	$ 292,500
Sedgwick	14,801,598	523,209	$ 593,319
Stafford	0	0	$ 0
Sumner	165,400	5,847	$ 6,630
District Subtotal	40,663,024	1,437,362	$1,629,968
Study Area Totals	228,551,409	8,078,867	$9,161,436

Finally, Table 14 provides a summary of total wheat logistics system traffic and costs both before and after abandonment. The logistics system with shortline railroads handles 365.5 million bushels of wheat generating 9.28 billion total ton-miles of traffic at a total handling and transport cost of $201.4 million. The system without shortline railroads handles the same 365.5 million bushels of wheat, but only generates 9.09 billion total ton-miles of wheat traffic with total handling and transport cost of $222 million.

In summary, the wheat logistics system with shortlines results in total handling and transport costs that are about $20.7 million less than the system without shortlines. This cost reduction provides a savings of approximately $0.06 a bushel and lowers overall wheat logistics system costs by around 10%. The aggregate amount of ton-miles decreases for the no-abandonment scenario. However, the total amount of truck miles doubles (from 7.8 million to 15.9 million) if the shortlines are abandoned. The increase in truck transport costs caused by shortline abandonment is roughly equal to the amount formerly paid for shortline transport. Thus, the major impact of shortline abandonment is the additional $22.4 million in handling costs.

Most of the additional costs of a system without shortlines will be borne by the Kansas wheat farmer. At an increased cost of $0.056 a bushel, Kansas farm income would fall by $20.5 million (365.5 million bushels multiplied by $0.056 per bushel).

TABLE 14

Comparison of Wheat Traffic, Transport Costs, and Handling Cost

No-Abandonment and Abandonment Scenarios

Variable	**No Abandonment**	**Abandonment**	**Difference**	**% Change**
Bushels	365,533,000	365,533,000	0	0.0%
Total Ton-Miles	9,284,523,972	9,098,231,759	-186,292,213	-2.0%
Total Truck-Miles	7,771,552	15,850,420	8,078,868	104.0%
Shortline Car-Miles	3,665,988	0	-3,665,988	-100.0%
Class I Car-Miles	76,438,797	76,438,797	0	0.0%
Total Truck Transport Costs	$ 34,336,869	$ 43,498,306	$ 9,161,437	26.7%
Total Shortline Transport Costs	$ 10,863,532	$ 0	-$10,863,532	-100.0%
Total Class I Transport Costs	$ 81,390,227	$ 81,390,227	$ 0	0.0%
Total Handling Costs	$ 74,769,192	$ 97,132,794	$22,363,602	29.9%
Total Transport & Handling Costs	$201,359,820	$222,021,327	$20,661,507	10.3%
Cost Per Bushel	$0.551	$0.607	$0.056	10.2%
Cost Per Ton-Mile	$0.022	$0.024	$0.002	9.1%

CHAPTER 5

ROAD DAMAGE COST ANALYSIS

5.1 Pavement Cost Analysis

This chapter explains the pavement damage cost analysis methodology employed in this study. Pavement damage costs are determined as the costs associated with reduced life expectancy of pavement segments attributed to increased abandonment-related truck traffic. Accelerated pavement deterioration speeds up the resurfacing or reconstruction schedule for highways. This type of impact is called build-sooner cost, and it can mean postponing other highway projects or attempting to secure additional road maintenance funding (Tolliver, 1994, p. 11). These costs will continue to build over each life-cycle of the impacted pavements. For example, if resurfacing is done earlier than scheduled, and a light asphalt treatment is applied, the life expectancy of the resurfaced pavement will again be reduced by the increased truck traffic. Until the highway is upgraded with the addition of several inches of asphaltic concrete, it will not perform to the standards for which it was designed. If resurfacing is deferred, the serviceability of pavement may decline to a point where the highway must be entirely reconstructed.

This chapter will discuss the truck and pavement characteristics which relate to pavement deterioration. The methodology used for estimating costs associated with pavement deterioration will be presented, and the data input requirements will be identified. Finally, the road damage impacts resulting from study area shortline abandonment will be discussed.

5.2 Truck Characteristics

Estimation of pavement deterioration resulting from grain transportation by trucks involves application of certain truck characteristics to an estimation methodology. Pavement deterioration results from the weight of vehicles being applied to a pavement surface. Truck characteristics determine how the weight is actually applied. Axles and axle group configurations distribute truck weight across pavement and are the most important truck characteristics to consider when estimating pavement damage costs. Weight applied to a pavement is referred to as traffic loading. Another important factor is the manner in which trucks are designed to be loaded with their cargo. This concept is known as loading configuration.

Vehicle weights result in pavement damage as vehicles travel along paved surfaces. Vehicle weight may be thought of in terms of gross vehicle weight (GVW) or the total weight of the vehicle (U.S. Department of Transportation, 2000, p. VI-2). However, GVW is not directly related to pavement deterioration. GVW is considered a factor in the life of long-span bridges but not for the performance of pavement (U.S. Department of Transportation, 2000, p. VI-3). Axles distribute the weight of a vehicle to a road surface, so pavement stress results from the loads applied by axles or axle groups (U.S. Department of Transportation, 2000, p.VI-2). In general, more axles result in less pavement stress. Axle spacing also affects pavement loading. Axles placed close together cease to function as separate axles and apply a load with less pavement stress (U.S. Department of Transportation, 2000, p. VI-17). It is possible for a vehicle with a greater GVW to result in less pavement damage than a lighter vehicle due to numbers and spacing of axles and axle groups (Battelle Team, 1995, p. 3).

Empirical studies have been conducted in order to quantify relationships between traffic loadings and road damage. The American Association of State Highway and Transportation Officials (AASHTO) conducted road tests in the 1950s and 1960s for this purpose, and the tests resulted in commonly used load equivalence factors. Road tests were conducted using varying load weights applied to single and dual axle configurations (AASHTO, 1993, p. I-10). The resulting factors indicate a non-linear relationship between pavement damage and traffic load. Damage increases sharply with weight. In fact, roughly a fourth-power relationship is indicated by the AASHTO load equivalence factors (Battelle Team, 1995, p. 2). Other more recent studies have questioned the AASHTO results and have found the relationship to be closer to that of a third-power, but the general findings of a non-linear relationship appear to hold (Battelle Team, 1995, p. 3). AASHTO load equivalence factors provide the basis for the pavement deterioration estimation methodology employed in this study. Despite the fact that AASHTO road tests were conducted decades ago under limited conditions, load equivalence factors based on AASHTO empirical studies are still considered to be some of the best available (AASHTO, 1993, p. I-10).

In addition to axle configuration, pavement loadings are related to how weight is distributed on a truck. Weight distribution involves how the cargo is actually loaded onto the vehicle and how the vehicle is designed to carry its own components such as the engine, the cab, and the trailer. The loading configuration expresses the amount of weight which is applied to each axle or axle group on a fully loaded vehicle (Tolliver, 1994, p. 50). Trucks are designed for specific loading configurations. Typically, loading configurations are expressed in the following manner. Numbers are given which represent the weight applied to each axle group in thousands of pounds. Numbers for specific axle groups are separated with forward slash (/) symbols. For instance, a five-axle semi-tractor trailer classified as a 3-S2 vehicle is designed with a single axle under the front tractor and two separate tandem axle groups supporting the trailer and cargo (U.S. Department of Transportation, 2000, p. III-5). A loading configuration of 10/35/35 for grain hauling trucks was utilized in Babcock and Bunch (2002). This configuration assumes that the tractor unit applies a 10,000 pound load to the front axle, and each of two tandem axle groups under the trailer supports 35,000 pounds of weight. This configuration assumes a truck is at its maximum legal gross vehicle weight of 80,000 pounds. This configuration was suggested by the KDOT Bureau of Materials Research and the KDOT Planning Traffic and Field Operations Division. This configuration was also utilized for this study.

There are numerous configurations of grain hauling vehicles. However, the five-axle semi-tractor trailer configuration is becoming the most common grain hauling vehicle on the road. For purposes of simplification, it is assumed in this analysis that all grain hauling trucks are of the 3-S2 type.

5.3 Pavement Characteristics

In addition to vehicle characteristics, pavement characteristics affect estimates of pavement deterioration resulting from abandonment-related truck traffic. There are two broad categories of pavement types: flexible and rigid. Each pavement type has a single most important characteristic which determines performance under traffic loading conditions. The methodology used for this study will rely on measures of these important characteristics.

Flexible pavements generally consist of at least four distinct layers. A prepared roadbed underlies a flexible pavement. On top of the roadbed are the subbase, base, and surface courses (AASHTO, 1993, p. I-16). Each layer is made up of different materials. As the term flexible implies, flexible pavements respond to traffic loadings by flexing in an elastic manner. Each layer of a flexible pavement structure will have unique characteristics which affect how that layer responds to a load. Flexible pavement design procedures use a measure of resilient modulus to define how elastically each layer responds to a loading (AASHTO, 1993, p. I-16). Based on resilient modulus, each layer in a flexible pavement structure may be given what is known as a layer coefficient. This coefficient multiplied by the thickness of the layer defines the contribution of a single layer to the response of the flexible pavement as an entire structure. Layer contributions are additive, so the response of a flexible pavement is the sum of the layer contributions which is also known as the structural number (SN) (AASHTO, 1993, p. II-35). The structural number for flexible pavement segments is key to the estimation procedure utilized in this study.

Pavements categorized as rigid are constructed with a prepared roadbed, a subbase, and a pavement slab (AASHTO, 1993, p. I-21). As the term rigid implies, this type of pavement does not flex as does flexible pavement. Rather, the entire rigid concrete slab supports the weight of traffic loadings. The pavement slab is typically constructed using portland cement concrete over reinforcing steel. The most significant characteristic of a rigid pavement which relates to structural strength is the thickness of the concrete slab. The slab thickness in inches is used in a similar manner to the flexible pavement structural number in the pavement deterioration estimation procedure.

5.4 Application of Truck and Pavement Characteristics to Pavement Deterioration Models

Empirical road test data and resulting load equivalence factors have been applied to practical uses in at least two ways. They have been used to formulate design procedures such as the AASHTO pavement design procedures (AASHTO, 1993, p. I-7). They have also been used to develop pavement deterioration models such as the Highway Economic Requirements System (HERS) pavement deterioration model (Weinblatt, 2000, p. 6-12) and the pavement deterioration model developed by Denver Tolliver in *Benefits of Rail Freight Transportation in Washington: A Multimodal Analysis* (Tolliver, 2000). Tolliver's method was chosen for use in this study. Important aspects of developing both the pavement design procedures and the pavement deterioration models involve the modeling of traffic loadings and serviceability of pavement segments.

Traffic loadings on pavement relate directly to weight transferred to a road surface by vehicle axles. Axle load equivalency factors are used in procedures and models to define the effects of different truck configurations. The equivalent single axle load (ESAL) refers to the equivalent effects of a single 18,000 pound axle load applied to a pavement segment. The ESAL value is a standard reference load factor. The effects of an axle pass of any weight may be expressed in terms of ESALs (AASHTO, 1993, p. I-10). An axle pass which applies a load greater than a single 18,000 pound (18-KIP) axle has a load equivalency value greater than one. An axle pass applying a load which is less than the reference axle has a value in ESALs of less than one. Equivalent 18-KIP load factors are a function of pavement type, functional class, and truck configuration (Weinblatt, 2000, p. 6-12).

In addition to modeling the effects of axle passes, it is necessary to measure the serviceability of pavement segments for the estimation of pavement damage. The serviceability of pavement refers to structural and functional performance (AASHTO, 1993, p. I-7). Pavement performance involves its physical condition and how well it performs for the road user. The method of pavement deterioration estimation utilized in this study relies on the present serviceability index (PSI). The PSI is a composite index measuring the condition of pavement based on four major types of distress in flexible pavements: cracking, patching, slope variance or longitudinal roughness, and rut depth (Tolliver, 2000, p. 87). A PSI is also defined for rigid pavements. The PSI index is scaled from 0 to 5 with a value of 5 being considered very good or like-new serviceability. A terminal PSI is the rating at which a pavement segment must be resurfaced or reconstructed.

5.5 Road Damage Cost Methodology

The methodology employed in this study to estimate abandonment-related pavement damage costs resulting from increased trucking of grain was developed in a study by Denver Tolliver and HDR Engineering, Inc (Tolliver, 2000). The methodology may be found in Appendix D of that study. What follows is a description of the Tolliver methodology.

The methodology used in this study relates the physical life of pavements to axle loads. This approach involves the question: how will increased truck traffic affect pavement service life? Two types of deterioration models are used: a time decay model, and an ESAL model reflecting the fact that pavement deterioration results from traffic and environmental factors.

A damage function relates pavement deterioration to axle passes. Damage functions based on AASHTO road test data provide a basis for expressing the life of a pavement structure in terms of axle passes. The general form of a damage function may be illustrated as follows:

$$g = \left(\frac{N}{\tau}\right)^{\beta} \tag{4}$$

where:

g = An index of damage or deterioration

N = Number of axle passes of specified weight and configuration

τ = The number of axle passes at which the pavement section reaches failure; i.e., the theoretical life of the pavement

β = A deterioration rate that describes a deterioration curve

When N = 0 for a new pavement section, then g = 0. Also, when N = (life of pavement), then g = 1.0.

Road test data are used to statistically relate axle passes to changes in PSI. The parameters β and τ in the damage function above were estimated for AASHTO pavement design procedures to develop a damage index. The theoretical life of the pavement is estimated as follows:

(5) $$\log_{10}(\tau) = 5.93 + 9.36\log_{10}(SN + 1) - 4.79\log_{10}\left(L_1 + L_2\right) + \log_{10}\left(L_2\right)$$

where:

SN = A structural number

L_1 = Axle load in thousand-pounds or kips

L_2 = Axle type (1 = single, 2 = tandem, 3 = triple or tridem)

τ = The number of axle passes at which the pavement section reaches failure; i.e.,the theoretical life of the pavement

The deterioration rate is determined by:

(6) $$\beta = 0.4 + \frac{0.081(L_1 + L_2)^{3.2}}{(SN + 1)^{5.19}{L_2}^{3.23}}$$

where:

β = Deterioration rate

L_1 = A structural number

L_2 = Axle load in thousand-pounds or kips

τ = Axle type (1 = single, 2 = tandem, 3 = triple or tridem)

The resulting damage function is:

(7) $$\log_{10}(\tau) = 9.36\log_{10}(SN + 1) - 0.2$$

This function expresses the theoretical life of the pavement in 18,000 pound axle loads.

As mentioned above, traffic loadings are expressed as axle load equivalency factors. The steps required to compute equivalent single axle loads are: 1. compute the pavement deterioration for the reference axle, 2. compute pavement deterioration for the axle load of interest, and 3. use deterioration rates to compute the load equivalency factor. Equations for deterioration rates expressed in terms of ESALs are derived in this manner for both flexible and rigid pavements.

5.5.1 Flexible Pavements

Using the AASHTO damage function, deterioration rates for flexible pavements may be calculated as follows. First, the deterioration rate for the reference axle is calculated.

(8) $$\beta_{18} = 0.4 + \frac{1{,}094}{(SN + 1)^{5.19}}$$

where:

β_{18} = Rate of deterioration for the reference 18,000 pound axle

SN = Structural number

Next, the equivalent rate of deterioration of flexible pavement caused by a single axle load in comparison to the reference axle is computed.

(9) $$\log_{10}(ESAL) = 4.79\log_{10}\left(\frac{L_1 + 1}{18 + 1}\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

The equivalent rate of deterioration of flexible pavement for a tandem axle group is computed with the following formula.

(10) $$\log_{10}(ESAL) = 4.79\log_{10}\left(\frac{L_1 + 2}{18 + 1}\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta}$$

where:

(11) $$G = \log 10\left(\frac{P_I - P_T}{P_I - 1.5}\right)$$

where:

P_I = Initial PSR

P_T = Terminal PSR

Since these equations are expressed in logarithms, the actual ESALs are obtained by taking inverse logarithms.

5.5.2 Rigid Pavements

The deterioration rate of rigid pavement is also derived from AASHTO road test data. The equation for the deterioration rate of a single reference axle is:

(12) $$\beta_{18} = 1 + \frac{3.63(19)^{5.2}}{(d + 1)^{8.46}}$$

where:

β_{18} = Rate of deterioration for the reference 18,000 pound axle

d = Pavement thickness in inches

For all other axle configurations the equation used is:

$$\beta = 1 + \frac{3.63(L_1 + L_2)^{5.2}}{(d + 1)^{8.46} L_2^{3.52}} \tag{13}$$

The equivalent pavement deterioration of rigid pavement for single axles is computed with the following equation.

$$\log_{10}(ESAL) = 4.62\log_{10}\left(\frac{L_1 + 1}{18 + 1}\right) + \frac{G}{\beta_{18}} - \frac{G}{\beta} \tag{14}$$

For tandem axle groups, equivalent pavement deterioration is calculated as follows:

$$\log_{10}(ESAL) = 4.62\log_{10}\left(\frac{L_1 + 2}{18 + 1}\right) - 3.28\log_{10}(2) + \frac{G}{\beta_{18}} - \frac{G}{\beta} \tag{15}$$

where:

$$G = \log_{10}\left(\frac{P_I - P_T}{P_I - 1.5}\right) \tag{16}$$

The equations for equivalent damage are expressed in logarithms, so inverse logarithms will yield the appropriate ESALs.

The ESAL life of pavement is the cumulative number of equivalent single axle loads which will result in the need for rehabilitation. For flexible pavements, this life may be calculated as follows:

$$LGE = XA + \frac{XG}{XB} \tag{17}$$

where:

LGE = Cumulative ESALs a pavement section can accommodate before reaching terminal serviceability rating (in logarithmic form)

XB = Rate at which a pavement deteriorates with accumulation of ESALs

(18) $$XB = 0.4 + \left(\frac{1{,}094}{SNA}\right)^{5.19}$$

XG = Maximum tolerable pavement PSR loss (from P_I to P_T)

(19) $$XG = \log_{10}\left(\frac{P_I - P_T}{3.5}\right)$$

XA = Theoretical life of newly constructed pavement in ESALs

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

SNA = Pavement structrual number

(21) $$SNA = \sqrt{\frac{6}{SN}}$$

As indicated by equation (20), the theoretical life of flexible pavements is directly related to the structural number.

Rigid pavement life is a function of concrete slab thickness. The equation for rigid pavement life is as follows:

(22) $$LGE = XA + \frac{XG}{XB}$$

where:

LGE = The logarithm of expected ESAL life of rigid pavement

XA = Theoretical life of newly constructed pavement

(23) $$XA = 7.35\log_{10}(d+1)0.06$$

XB = Traffic-related pavement deterioration

(24) $$XB = 1 + \frac{16{,}240{,}000}{(d+1)^{8.46}}$$

XG = Maximum tolerable pavement PSR loss (from P_I to P_T)

(25) $$XG = \log_{10} \frac{\left(P_I - P_T\right)}{3.5}$$

The life cycle of flexible or rigid pavement is obtained by taking the inverse logarithm of the appropriate LGE.

(26) $$ESALLifecycle = 10^{LGE}$$

Over time, environmental factors in addition to traffic loadings contribute to the deterioration of pavement serviceability. Thermal cracking, heaving, disintegration of surface materials, and other effects occur in the absence of traffic due to environmental factors. Environmental deterioration is modeled in the following manner.

(27) $$\delta = \frac{-\log\left(\frac{P_T}{P_I}\right)}{L}$$

where:

δ = Decay rate due to environmental factors

P_T = Terminal PSR

P_I = Initial PSR

L = Maximum feasible life of the pavement section measured in years

PSR loss due to environmental factors may be computed as follows:

(28) $$P_E = P_I \times e^{(-\tau\delta)}$$

where:

P_E = PSR loss due to environment

τ = Typical pavement performance in years

5.5.3 Structural Numbers for Flexible Pavements

Pavements are constructed and resurfaced in layers. Each layer will contribute to the performance of the pavement. The structural contributions of the layers for flexible pavements are additive. Each layer has a particular thickness (d). Each layer has a structural contribution modeled here with a coefficient (a). The resulting model of a multilayer pavement segment is:

(29) $$SN = a_1d_1 + a_1^*d_1^* + a_2d_2 + a_3d_3$$

where:

SN = Structural number of the pavement
a_1 = Surface layer coefficient
d_1 = Thickness of surface
a_1^* = Layer coefficient of old surface
d_1^* = Thickness of old surface layer
a_2 = Base layer coefficient
d_2 = Base layer thickness
a_3 = Subbase layer coefficient
d_3 = Subbase layer thickness

As indicated by equation (20), ESAL life is directly affected by the structural number of the pavement.

5.5.4 Pavement Damage Cost Analysis Process

The Tolliver study lists all of the steps involved in the pavement damage cost analysis process (Tolliver, 2000, p.104).

1. The maximum life of an impacted pavement is defined in terms of tolerable decline in PSR.

2. The maximum feasible life of a pavement in the absence of truck traffic is defined in

terms of years.

3. The life of a pavement is determined in terms of traffic. (ESALs)

4. The loss in PSR that would occur in the absence of truck traffic is computed from a time decay function for a typical design performance period. The remaining pavement rehabilitation costs are considered to be a function of traffic.

5. Unit costs per ESAL are computed by multiplying the average resurfacing or reconstruction cost per mile by the percent of PSR loss due to traffic and dividing by the ESAL life of the highway sections.

6. The avoidable cost for a highway section is computed by multiplying the incremental ESALs by the average cost per ESAL. This is the annual road damage cost that is avoided if the traffic continues to move by rail rather than by truck.

Incremental truck trips are converted to ESALs before pavement costs are estimated. The following steps are used for the conversion.

1. The origins and destinations are identified for each commodity and the traffic is distributed among markets.
2. The most likely highway route connecting each station and market is determined and the total loaded trip distance is computed.
3. Each route is broken into highway segments with beginning and ending milepost references.
4. Key highway attributes are compiled for each segment including the functional class, terrain, pavement type and structural number or slab thickness.
5. Based on the routes identified, the total incremental truck vehicle miles of travel (VMT) diverted to each highway segment are computed.
6. An ESAL factor is computed for each truck moving over each highway segment.
7. The truck ESAL factor is multiplied by the incremental truck VMT to compute annual ESALs for each highway segment.

8. Truck diesel fuel taxes and prorated user fees are estimated based on typical fuel efficiency ratings and annual service miles. The user fees are deducted from the estimated road damage costs to arrive at a net road damage cost estimate.

5.6 Data Input Requirements

The model requires certain data inputs related to the configuration of trucks and regarding each pavement segment. As previously discussed, it is assumed that all grain hauling vehicles are five-axle semi-tractor trailer configurations. Loading configurations are assumed to be 10/35/35. This configuration was also used in Babcock and Bunch (2002). It was recommended by the staffs at the KDOT Bureau of Materials and Research, and the KDOT Planning Traffic and Field Operations Division. The loading configuration indicates that the rear tandem axle groups are only slightly overloaded by design specification standards. This loading is consistent with research done at KDOT. The data inputs required for this type of vehicle may be found in The Comprehensive Truck Size and Weight Study prepared for the U.S. Department of Transportation (USDOT, 2000).

There are seven important pavement data inputs required for the methodology used in this study. The following inputs are required for each pavement segment.

Structural number for flexible pavement (SN)
Pavement thickness for rigid pavements (d)
Initial PSR (P_I)
Terminal PSR (P_T)
Maximum feasible life of pavement segment in years (L)
Typical pavement performance (τ)

The Kansas Department of Transportation maintains a database of 11,254 pavement segments which make up the state highway system (the KDOT CANSYS database). All of the required data inputs for the methodology with the exception of typical pavement performance may be found in the KDOT database. The typical performance period refers to the number of years after which a new pavement segment is resurfaced. The Kansas Department of Transportation uses a value of 10 years as the typical performance period for flexible pavements.

This methodology offers the advantage of having data input requirements which are available. In addition, most highway officials are familiar with ESALs as the use of these empirical methods have been in widespread use for a long period of time.

5.7 Empirical Results - Road Damage Cost Analysis

This section of Chapter 5 describes the estimation of road damage cost resulting from abandonment of study area shortline railroads. The computation of pavement impacts generated by truck movements of wheat from farms to country elevators is explained. These impacts are referred to below as Phase I impacts, and are reported in truck miles for both state highways and county roads. Also discussed below are the road damage costs of truck movements of wheat from country elevators to shuttle train stations and terminal elevators. These impacts are referred to below as Phase II impacts, and are measured in dollars for the state highway system and in truck-miles for county roads.

5.7.1 Phase I Pavement Impacts

Phase I involves the collection of wheat from production areas into country elevators. Wheat moves from the production areas or farms by truck to country elevators, and pavement deterioration results. All Phase I wheat movements are determined by the network model discussed in the previous chapter, which routes wheat from farms to the closest country elevator.

Routing of wheat and truck miles for estimation of pavement impacts of Phase I are provided by the network model. The network model computes Phase I truck miles by county for the state highway system, which consists of those highways designated as U.S., Kansas, and Interstate. The road impacts of Phase I wheat movements on county roads are also reported below. The network model computes Phase I truck miles by county for county roads.

Phase I wheat movements on the state highway system result in a total of 4,775,199 truck miles (See Table 15). The table reports the impacts by county and for the entire study area. The mean truck miles by county on state highways is 73,465. The maximum number of state highway truck miles for a county is 507,687 (Saline County). It is interesting to note that some counties have no pavement impacts on the state highway system while others have a considerable amount. This variation is due to the least cost routing of the network model and variations in county wheat production. In certain counties, the state highway system is used more than in others, and in some counties the state highway system is not used at all for Phase I wheat movements.

Table 15 also has truck miles on county roads resulting from Phase I wheat movements. Total truck traffic reported for county roads is almost 3 million or 2,996,355 truck miles. The average county truck miles for county roads is 45,399, and the maximum is 93,111 (Sumner County). Again, there is much variability between counties for truck miles on county roads, but all counties have greater than 14,000 truck miles for Phase I movements.

It is important at this point to note that shortline rail abandonment will not generate incremental Phase I truck miles under the assumptions of the network model used in this study. All Phase I wheat movements are routed based on least distance from the farm to the country elevators. Shortline abandonment does not affect the location of farms or country elevators in this model. Thus the pavement impacts for Phase I are identical under the abandonment and no-abandonment scenarios.

5.7.2 Phase II Pavement Impacts

Phase II involves movement of wheat from country elevators to shuttle train stations and terminal elevators. Elevators which do not have rail service are assumed to truck grain to unit train loading stations based on least distance. It is evident that under the no-abandonment scenario,

TABLE 15

Phase I State Highway and County Road Truck Miles by County

District	County	State Highway System Truck Miles	County Road System Truck Miles
Northwest			
	Cheyenne	0	56,822
	Decatur	16,311	39,208
	Graham	281,086	30,231
	Norton	110,602	33,631
	Rawlins	0	63,347
	Sheridan	0	35,135
	Sherman	42,431	78,348
	Thomas	66,813	75,388
District Total		517,243	412,110
West Central			
	Gove	21,527	50,538
	Greeley	0	81,637
	Lane	0	55,770
	Logan	0	53,068
	Ness	0	43,222
	Scott	0	76,149
	Trego	129,075	38,758
	Wallace	0	44,964
	Wichita	0	90,166
District Total		150,602	534,272

Southwest			
	Clark	14,190	14,942
	Finney	26	88,687
	Ford	100,236	53,805
	Grant	0	43,625
	Gray	79	52,883
	Hamilton	0	65,432
	Haskell	0	45,343
	Hodgeman	0	36,393
	Kearney	0	44,937
	Meade	17,246	34,652
	Morton	0	33,430
	Seward	0	24,021
	Stanton	0	62,193
	Stevens	0	32,755
District Total		131,777	633,098
North Central			
	Clay	54,185	27,928
	Cloud	330,571	35,504
	Jewell	178,872	35,254
	Mitchell	95,669	63,946
	Osborne	7,886	36,572
	Ottawa	410,968	38,643
	Phillips	78,728	25,300
	Republic	72,314	34,336
	Rooks	11,723	40,971
	Smith	40,359	41,847
	Washington	136,465	25,473
District Total		1,417,740	405,774

Central			
	Barton	29,063	45,602
	Dickinson	40,356	41,135
	Ellis	137,557	39,302
	Ellsworth	90,493	26,366
	Lincoln	438,974	33,301
	Marion	16,348	30,828
	McPherson	152,628	52,821
	Rice	75,745	37,656
	Rush	0	39,156
	Russell	155,745	27,695
	Saline	507,687	29,798
District Total		1,644,596	403,660
South Central			
	Barber	66,592	43,749
	Commanche	0	29,613
	Edwards	96,575	27,429
	Harper	14,393	56,223
	Harvey	40,388	50,817
	Kingman	27,092	56,641
	Kiowa	12,598	29,118
	Pawnee	124,164	34,482
	Pratt	74,324	44,536
	Reno	271,588	52,897
	Sedgwick	26,252	52,507
	Stafford	33,356	36,319
	Sumner	125,919	93,111
District Total		913,241	607,442
Study Area Total		4,775,199	2,996,356

pavement damage costs will result from trucking. However, with abandonment of shortline railroads, greater numbers of elevators will truck grain to the unit train loading stations. This represents the incremental truck miles resulting from shortline rail abandonment. The road damage costs reported in this section are the costs associated with the incremental truck traffic resulting from shortline abandonment.

The Tolliver methodology previously described is utilized to estimate pavement damage costs on the state highway system. Pavement impacts are calculated using data provided by the network model for Phase II and pavement characteristics data obtained from KDOT. The network model provides railcar loadings for each station on the shortline railroads. These carloadings are used to determine the incremental truck traffic resulting from shortline abandonment and the resulting pavement impacts. The process is described below.

The estimation of incremental truck miles and pavement impacts is based on a predefined routing system for truck traffic related to each shortline rail network. The routes are constructed in the following manner. For each station along a shortline railroad, an alternative truck route to a unit train loading station is identified. Routes are selected based on least distance giving priority to the state highway system, which is assumed to provide better serviceability. In the post-abandonment scenario, wheat from stations on the abandoned line moves on these alternative truck routes to unit train loading stations. The truck routes were corroborated in the Babcock and Bunch (2002) study with surveys and interviews of managers of elevators located on the shortline railroads.

In order to apply the Tolliver pavement damage methodology to this study, it is necessary to know pavement characteristics on truck routes. As previously mentioned, this information is obtained from the KDOT CANSYS database. This database maintained by KDOT contains information on numerous pavement characteristics for the entire state highway system. For example, some of the information on pavement segments in the database includes the following:

- designation as U.S., Kansas, or Interstate highway
- route number
- beginning and ending points of highway segments by street, mile marker, or other landmarks
- mile posts along pavement segment
- length of pavement segment
- soil support value
- pavement structural number
- annual 18-kip traffic loads
- remaining 18-kip traffic loads until substantial maintenance or reconstruction is required

Calculations for pavement damage on truck routes are based on median pavement segment values of the routes. This eliminates the effects of any outlier characteristics. Urban highway segments are assigned the average pavement characteristic values of neighboring segments due to highly variable urban pavement characteristics.

It is necessary to calculate load equivalency factors for a standard grain truck. The standardized model grain truck is a 3-S2 tractor and trailer with a loading configuration of 10/35/35. The pavement impacts of this truck will vary on different pavement segments due to different pavement characteristics.

There are three basic steps involved in calculating ESALs under the Tolliver methodology. First, the rate of deterioration is computed for the 18,000 pound reference axle. Next, the deterioration rate for the axle load of interest is computed, and last, the two deterioration rates are used to compute the load equivalency factor. To perform these computations it is necessary to know the type of axle group, the load in kips, the initial and terminal PSR, pavement characteristics and pavement type. All pavement segments along truck routes are assumed to be of the flexible type. This is consistent with the observations of the routes in Babcock and Bunch (2002). A description of the computation process follows.

The front axle ESAL calculation involves using equations (6), (8), (9) and (10) of the

Tolliver method described above. The load applied to the axle is 10 kips. The initial and terminal PSR values are 4.2 and 2.5. These are standard values utilized by KDOT for pavement management. The pavement structural number for each truck route is obtained from the CANSYS database, and the ESAL value is computed. A rear tandem axle group ESAL value for a standard grain truck is computed using equations (6), (8), (10), and (11). The ESAL value is computed in the same manner as the single axle ESAL, but the load is 35 kips. The total ESALs for a standard grain truck are the sum of the front single axle and two rear tandem axle groups. The ESALs are computed for the standard grain truck over each truck route.

The maximum life of truck route pavement in terms of tolerable decline in PSR must be specified. In the state of Kansas, new state highways are constructed to an initial PSR of 4.2. KDOT uses a value of 2.5 as terminal PSR. Subtracting the terminal PSR from the initial PSR gives the maximum life of a truck route pavement in terms of tolerable decline in PSR. This value is 1.7 for Kansas state highways.

It is also necessary to calculate the maximum feasible life of truck route pavement in terms of years. The maximum life of a pavement is the time it takes for the pavement to deteriorate from the initial PSR to the terminal PSR in the absence of truck traffic. This may be determined by examination of the pavement management process. The typical performance period of flexible pavements on the state highway system is 10 years. This means that pavements are resurfaced or reconstructed every 10 years. The KDOT pavement management process is as follows. A new pavement segment receives substantial maintenance after 10 years and after 20 years. The pavement is then reconstructed after 30 years. Therefore, the maximum feasible life of the pavement is 30 years.

Next, the life of pavement is defined in terms of traffic. Equations (17), (18), (19), (20) and (21) of the Tolliver methodology are used. To solve these equations the pavement structural number, and the initial and terminal PSR values are required.

The time decay function (equation 27) is used to determine the PSR loss which occurs in the absence of truck traffic due to environmental factors such as weather and time. Equation (28) gives the loss in PSR due to environmental factors. It is necessary to compute this loss so that it is not attributed to abandonment-related truck traffic. The initial and terminal PSR values, the maximum pavement life in years, and the typical pavement performance period in years are the inputs required to determine environmental impacts on pavement condition.

Once the PSR loss due to environmental factors is determined, the unit cost per ESAL due to truck traffic may be calculated for pavement segments. As mentioned, the pavement management process involves two substantial maintenance treatments after 10 and 20 years and one reconstruction after 30 years. The sum of the costs of these three activities is the total pavement life cycle cost. KDOT cost figures for 1999 are used to determine maintenance and reconstruction costs. These figures are found in Babcock and Bunch (2002). In 1999, KDOT reconstructed a total of 200 miles of pavement at a total cost of $250 million, so reconstruction costs are estimated to be $1.25 million per mile. KDOT also performed 1400 miles of substantial maintenance in 1999 at a total cost of about $150 million. Thus substantial maintenance costs are estimated at $107,143 per mile. Pavement cost is the sum of two substantial maintenance treatments and one reconstruction, so pavement cost is estimated to be $1,464,286 per mile. To determine unit ESAL pavement cost, the total pavement life cycle cost is multiplied by [1 - environmental decay], and the result is divided by the ESAL life of the pavement sections. ESAL cost per mile will reflect only the cost which may be attributed to truck traffic.

Pavement damage costs for a pavement segment are obtained by multiplying ESAL cost per mile by the length of the segment and by the incremental ESALs. The pavement impacts related to the abandonment of a shortline network are determined using pavement segment damage costs. The pavement damage costs are determined for each truck route associated with a particular shortline railroad. The pavement damage costs for all such routes are summed, and the result represents the pavement damage cost of abandonment-related truck traffic.

Table 16 displays state road damage costs by county due to shortline railroad abandonment. Note that the road damage costs for some counties amounted to zero. These are counties that have no shortlines, so they do not have shortline abandonment-related road damage costs. Note that there is a great deal of variation in road damage costs by county within each crop reporting district as indicated below.

Crop Reporting District	County With Least Road Damage Cost	County With Most Road Damage Cost
Northwest	Sheridan ($21,563)	Decatur ($2,053,209)
West Central	zero (three counties)	Greeley ($6,185,838)
Southwest	zero (four counties)	Seward ($2,077,117)
North Central	Clay (zero)	Rooks ($4,637,440)
Central	zero (5 counties)	Lincoln ($3,018,086)
South Central	Sumner ($65,251)	Sedgwick ($6,288,384)

Abandonment-related road damage costs by shortline railroad for the state highway system are reported in Table 17. The total pavement damage costs resulting from abandonment of all four shortline rail networks is $57,780,416. Pavement damage costs may also be allocated by specific shortline railroad. Abandonment of the Kansas and Oklahoma Railroad results in $30,564,897 in pavement damage costs. The incremental truck traffic generated by abandonment of the Cimarron Valley Railroad, the Kyle Railroad, and Nebraska, Kansas, and Colorado Railnet results in pavement damage costs of $15,763,173, $8,534,025, and $2,918,321 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 are 27.3%, 14.8%, and 5% respectively.

Other information is presented in Table 17. The truck miles listed are the incremental truck traffic generated by abandonment of each shortline railroad. The miles of rail line comprising each railroad network are listed, as are the miles of highway comprising the truck routes utilized after shortline abandonment. Average pavement damage costs per truck mile are

TABLE 16
State Road Damage Costs by County Due to Shortline Railroad Abandonment

Northwest District

County	Road Damage Costs
Cheyenne	$ 21,819
Decatur	$2,053,209
Graham	$1,253,124
Norton	$ 473,256
Rawlins	$ 675,037
Sheridan	$ 21,563
Sherman	$ 916,807
Thomas	$ 752,167
District Total	$6,166,982

West Central District

County	Road Damage Costs
Gove	$ 0
Greeley	$ 6,185,838
Lane	$ 349,968
Logan	$ 0
Ness	$ 974,230
Scott	$ 540,343
Trego	$ 1,795,618
Wallace	$ 0
Wichita	$ 637,797
District Total	$10,483,794

Southwest District

County	Road Damage Costs
Clark	$ 0
Finney	$1,776,815
Ford	$ 149,131
Grant	$1,347,314
Gray	$ 261,411
Hamilton	$ 0
Haskell	$1,239,858
Hodgeman	$ 12,946
Kearney	$ 0
Meade	$ 0
Morton	$ 123,401
Seward	$2,077,117
Stanton	$ 682,659
Stevens	$1,148,736
District Total	$8,819,388

North Central District

County	Road Damage Costs
Clay	$ 0
Cloud	$ 2,940,597
Jewell	$ 13,874
Mitchell	$ 3,619,645
Osborne	$ 349,559
Ottawa	$ 18,771
Phillips	$ 745,011
Republic	$ 41,382
Rooks	$ 4,637,440

Smith	$ 305,447
Washington	$ 301,728
District Total	$12,973,454

Central District

County	Road Damage Costs
Barton	$ 30,868
Dickinson	$ 0
Ellis	$ 0
Ellsworth	$ 0
Lincoln	$3,018,086
McPherson	$ 25,235
Marion	$ 0
Rice	$ 732,154
Rush	$ 473,532
Russell	$ 0
Saline	$3,002,508
District Total	$7,282,383

South Central District

County	Road Damage Costs
Barber	$ 484,158
Comanche	$ 194,901
Edwards	$ 903,129
Harper	$ 99,649
Kingman	$ 2,642,997
Kiowa	$ 440,512
Pawnee	$ 527,521

Pratt	$ 220,725
Reno	$ 187,188
Sedgwick	$ 6,288,384
Sumner	$ 65,251
District Total	$12,054,415
Study Area Total Road Damage Cost	$57,780,416

TABLE 17

Road Damage Impacts by Railroad – State Highways

Railroad	Truck Miles	Miles of State Highway Impacted	Miles of Rail Abandoned	Pavement Damage Costs		
				Total Cost	Cost Per Truck Mile	Cost Per Rail Mile Abandoned
Kansas & 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 & Colorado	706,908	269	122	$ 2,918,321	$4.13	$23,921
All Shortlines Total	8,078,868	2,399	1,761	$57,780,416	$7.15	$32,811

presented in the sixth column of the table. The average pavement damage cost per truck mile for the shortline railroads have a range of $4.13 to $8.08, and the average pavement damage cost per truck mile for all the truck routes in the study area is $7.15. The final column of the table shows the estimated pavement damage cost per mile of abandoned rail line. The average pavement damage cost for the entire shortline rail system in the study area is $32,811 per mile of abandoned track.

The county road system pavement impacts for Phase II are estimated in the following manner. The truck routing systems corresponding to each shortline railroad are examined, and the county road segments are identified. Any road segment which is not designated as a US highway, a Kansas highway or an Interstate highway is a county road. Twelve total road segments within the truck route systems are county roads. The total length of these segments is 110 miles. The truck route system related to the abandonment of the Kansas and Oklahoma Railroad contains 10 segments of county roads, and the truck routes associated with abandonment of the Kyle Railroad contain two county road segments. The total truckloads traveling over these 12 county road segments is 14,303. The network model provides the truckloads for each country elevator on the truck routes used after shortline abandonment. The truck routing system is used to determine the number of truck miles associated with each pavement segment, and these figures are multiplied by the lengths of each segment to obtain abandonment-related truck miles. The total incremental truck traffic on county roads related to shortline abandonment is 251,640 truck miles. Since there is no available methodology for measuring gravel road damage, we did not estimate any road damage costs for these movements.

5.8 Abandonment-Related Truck User Fees

The increase in truck traffic resulting from shortline abandonment will generate an increase in state revenue through highway user fees. There are several types of state highway user fees paid by truck operators. For example, a yearly state registration fee of $1,725 for a vehicle in the 80,000 pound class is required. In addition, all haulers registered at the state level must pay a trailer fee of $35. It is not possible to determine how much of the incremental trucking demand related to shortline abandonment would be satisfied by new entry into the trucking industry and how much of that demand would be met by increased utilization of existing trucks, so the incremental revenue from registration fees was not estimated. However, the state also places a 25 cent tax per gallon on diesel fuel for trucks. This user fee would apply to all incremental Phase II truck miles.

The incremental fuel tax revenue generated by abandonment is calculated in the following manner. It is known that the Kansas diesel fuel tax is 25 cents per gallon for trucks. This tax is multiplied by the total Phase II incremental truck miles of 8,078,868 which was reported in Table 17. A study by Berwick and Dooley (1997) estimated the fuel consumption rate for fully loaded 80,000 pound tractor trailer trucks to be close to 7 miles per gallon. The previous result is divided by the 7 miles per gallon figure to obtain the total incremental diesel fuel tax revenue to the state of $288,531. This revenue increase offsets a small part of the pavement damage costs generated by abandonment.

5.9 Summary

This chapter described a methodology developed by Denver Tolliver for use in estimating pavement damage costs associated with abandonment-related truck traffic. The abandonment of shortline railroads in the state of Kansas would result in incremental truck traffic, and a major focus of this study was to estimate the road damage costs of abandonment. It was found that the data required to use the Tolliver methodology was available from KDOT. The KDOT CANSYS database contains all of the necessary data on state highway pavement characteristics such as serviceability ratings and structural numbers of pavement segments. In addition, the staff at KDOT was able to provide the necessary information regarding their pavement management process.

The chapter also outlined the application of the Tolliver methodology to this project and the road damage cost results. The network model of the study provided truck traffic inputs for the pavement damage impacts analysis. Phase I of the network model involved the collection of grain from individual farms into country elevator stations. It was determined that shortline abandonment would not generate incremental Phase I truck miles, but the total pavement impacts for Phase I were determined. It was found that collection of wheat results in a total of 4,775,199 truck miles on the state highway system and 2,996,355 truck miles on county roads.

Phase II of the network model involved shipments of wheat from country elevators to unit train loading stations by either truck or rail. Incremental truck traffic would be generated by shortline abandonment for Phase II movements, and the resulting pavement impacts were determined. Pavement impacts on the state highway system were estimated using defined truck route systems which would be used by trucks under the assumption of shortline abandonment. The Tolliver methodology was applied to truck movements on these routes in order to estimate pavement damage costs. A total of $57,780,416 of pavement damage costs were calculated for the state highway system under the assumption that all four shortline railroads were abandoned. The pavement damage costs were also allocated by specific railroad and the results are presented in Table 17. The average pavement damage cost per truck mile was estimated to be $7.15, and the average pavement damage cost per mile of abandoned shortline was $32,811.

State fuel tax revenues would increase due to abandonment-related truck traffic. The total increase was computed to be $288,531. The amount of increased fuel tax revenue is small in comparison to the state highway pavement damage costs.

The pavement impacts on county roads for Phase II were estimated by identifying county road segments on the truck route systems associated with abandoned shortlines. The truck trips and lengths of segments were used to compute truck miles on county roads. The total abandonment-related truck miles for county roads was 251,640.

This chapter presented estimates of the pavement damage costs which would result from shortline rail abandonment in the study area. As expected, the impacts of abandonment would be significant both on the state highways and on the county roads. It was assumed that all shortlines were abandoned for this analysis. While this assumption may be unrealistic, estimates of pavement damage costs per mile of abandoned track for each railroad were presented as was an estimate for the total system. These figures could be applied to smaller scale shortline abandonments.

CHAPTER 6

HIGHWAY SAFETY ANALYSIS

6.1 Variables Affecting Vehicle Accident Rates

This chapter is focused on measuring the highway safety costs and benefits resulting from abandonment of Kansas shortline railroads. Tolliver (2000, chapter 2) has described the only published method for estimating the safety costs of rail line abandonment. Tolliver's method is expanded to include safety benefits and then adapted to the study area.

Traffic accidents can be linked with numerous variables, such as the vehicle's speed, time of day, driver's age, and vehicle type (Cerrelli, 1997). On the most general level, however, there are two primary factors. The first factor is the opportunity for accidents to occur. A non-moving vehicle will never strike a tree, roll in a ditch, or otherwise initiate an accident. As a vehicle increases its amount of travel, the opportunity for that vehicle to be involved in an accident increases (proportionately to variables such as Cerrelli has identified). The influence of this factor on the probability of accidents on a fixed system of roads can be considered the "distance factor" because it is principally determined by the distance traveled by a vehicle. The second fundamental factor is the "interaction factor." The interaction factor involves the probability of accidents resulting from vehicular interplay. If a single vehicle travels on a road, there is no chance of it hitting another car, encountering debris from another vehicle or meeting a drunk driver. As the number of vehicles traveling on the same road increases, opportunities for dangerous interactions increase. For example, vehicles enter and leave a road system via access points such as driveways. As traffic density increases, the probability of accidents at access points increases.

While the distance and interaction factors are related, it is useful to distinguish between them. The distance factor is a relationship between vehicle miles traveled and accidents; it is independent of whether the miles are traveled by a single vehicle or a large fleet of vehicles. The interaction factor is a relationship between traffic density and accidents; it is independent of the distance traveled by individual vehicles. Thus, the distance factor is controlled by the individual driver when deciding his distance of travel; the interaction factor is external to the individual's control.

Events that result in substantial changes in traffic density and/or vehicle miles traveled will have significant safety impacts. One event that can have substantial safety consequences is railroad abandonment.

Railroads are the least cost mode for long distance transport of large volumes of freight. Hoover (1963, p. 20) explains that rail transport generally supplants truck traffic as the lowest cost transport mode for shipments exceeding 35 miles in distance. Hoover's 35-mile rule was based upon trucks hauling 10 ton (20,000 pound) loads. Motor carrier technological advances and sturdier road structures have enabled trucks to haul substantially larger loads. Berwick (2002) finds that five-axle grain semi-trucks ("18-wheelers") are currently hauling payloads of 28.3 tons (56,600 pounds). The increase in truck payloads has expanded the distance over which trucks are the lowest cost mode of transport beyond Hoover's 35 mile range; Park et al. (1999, p. 278) estimated that commercial trucks have a cost advantage relative to railroads for distances up to 50 miles.

The expansion of distance over which trucks have a cost advantage is one of several factors contributing to rail service being increasingly supplanted by trucks. Babcock and Bunch (2002, p.38) find that frequency and dependability of truck service relative to rail service, competitiveness of truck rates, and availability of service are cited by shippers located on shortlines as reasons for increased trucking of grain relative to rail. Reduced rail transportation of grain has been documented in Kansas (Babcock and Bunch, 2002), 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).

When trucks replace railroads for transporting grain there will be increased highway safety costs due to increased traffic density and vehicle miles traveled. Prior to Tolliver (2000), however, no methodology for estimating the highway safety impact of rail abandonment had been developed. Clarifying the appropriate methodology for quantifying these safety effects will promote more accurate impact analysis of shortline railroad abandonment.

6.2 Methodology

The safety impact of rail abandonment is conceptually straightforward. Grain that was formerly transported by rail must instead be transported by another mode. In practice, reduced rail transport will be offset by increased truck shipments. When this shift occurs it is important to notice that rail cars are substantially larger than truck trailers. In general, every rail car must be replaced by about four trucks in order to transport the same amount of grain. Thus, when rail service is terminated the total increase in truck miles traveled can be found by equation (30).

(30) Increased Truck Miles = (Rail Carloads Terminated) x (4 Trucks per 1 Railcar) x (Distance Traveled per Truck)

This increase in truck miles consists entirely of new traffic introduced onto an existing road system resulting in a highway safety impact.

To estimate the safety impact, a rate is needed that specifies the accidents which occur from an increment in traffic. This rate can be determined on a per-mile basis by dividing the total number of accidents that occur in a given time period by the total number of miles traveled in the same time period for a particular road system. That is:

(31) Accidents per Mile Traveled = (Accidents per Time Period) ÷ (Miles Traveled per Time Period)

When making this calculation it is important to use a long time period and a large road system so that a representative average is obtained. A three day period of observation would fail to capture significant weather variations and seasonal driving patterns. A time period should be used that reflects the time frame for which an impact case is being estimated. For rail abandonments a time period of at least one year should be used. Similarly, a road system of two city blocks would not be used to estimate traffic impacts on a statewide level because the drivers and road characteristics of the two block system are unrepresentative. In order to avoid distortions, the road system used to determine an accident rate should be the same system for which an impact case is being determined or a larger system with similar geographic and traffic features.

If time and road system considerations are observed, it is reasonable to make the implicit assumption that the shortline railroad abandonment case will continue to have the same rate of accidents per mile traveled as the no abandonment case. This enables the accidents resulting from rail abandonment to be estimated by equation (32).

(32) Increased Traffic Accidents = (Increased Truck Miles) x (Accidents per Mile Traveled)

This increase in accidents is given economic significance by multiplying the result by a cost for each accident as in equation (33).

(33) Safety Cost of Rail Abandonment = (Increased Truck Miles) x (Accidents per Mile Traveled) x (Cost per Accident)

When making this computation, it is important to capture all of the economic costs involved in accidents. This includes explicit accident costs like medical expenses and property repairs and also other costs such as lost wages and reduced quality of life.

An estimate of the safety cost of rail abandonment has been obtained by determining the increase in traffic, the additional traffic accidents, and the cost of each traffic accident that would result from the rail abandonment. However, this cost does not express the entire safety consequence of rail abandonment. There is also a safety benefit to consider.

Though previously unrecognized, rail abandonment provides a safety benefit for highway users. Highway-rail crossings (HRCs) can no longer produce train-vehicle collisions if there are no trains at the crossings. The highway safety benefit of rail abandonment can be found by determining the total number of active HRCs that will be eliminated, estimating the number of collisions that would occur if the HRCs remain active, and multiplying these collisions by the costs they would generate. That is:

(34) Safety Benefit of Rail Abandonment = (HRCs Eliminated) x (Accidents per HRC) x (Cost per Accident)

The net highway safety effect of rail line abandonment is the difference between the safety costs and the safety benefits generated:

(35) Net Highway Safety Effect of Rail Abandonment = Safety Costs - Safety Benefits

6.3 Data

Estimating the highway safety impact of shortline railroad abandonment in the study area requires four data inputs.

1. Increased Truck Miles: Chapter 4 describes the data and methodology used to determine the origin locations and quantities of grain produced in the study area. A computerized network model predicts the movement of grain to shipment destinations, yielding the truck miles traveled under a scenario where shortline railroads are abandoned and not abandoned. By taking the difference between these scenarioes, a total increase of 8,078,868 truck miles was generated by shortline railroad abandonments in the study area.

2. Rate of Truck Accidents: The National Highway Traffic Safety Administration (NHTSA) annually reports information about all vehicle accidents in the United States. The information is classified by vehicle type and accident severity. The safety impact methodology uses the average number of fatality, injury, and property damage only (PDO) accidents reported for large trucks (vehicles exceeding 20,000 pounds) in the three year period, 1998-2000 (NHTSA, 2001). These accident averages are divided by a three year average (1998-2000) of the estimated vehicle miles traveled (VMT) by trucks (NHTSA, 2001). This VMT estimate is developed annually by the Federal Highway Administration (FHWA) based on 4,000 observation points throughout the United States and collected by the NHTSA. Using these sources, the fatality, injury, and PDO rates were found to be 2.5, 48.3, and 158.2, respectively, per 100 million vehicle miles traveled

by trucks.

3. Highway-Rail Crossing Accidents: The National Inventory of Highway-Rail Grade Crossings is a database of all public HRCs in the United States and is maintained by the Federal Railroad Administration (FRA). This database is used to determine the location of all HRCs on shortlines in the study area. For each HRC the Web Accident Prediction System (WBAPS), developed by the FRA and available for public use (http://safetydata.fra.dot.gov/officeofsafety/), predicts annual collisions. This prediction is based upon data about the crossing's physical and operating characteristics (type of warning device, trains passing through daily, total number of tracks, maximum train speed, number of traffic lanes, paved/unpaved road, and Average Annual Daily Traffic count of vehicles using the crossing) and a five year accident history for the crossing. In total, there are 1,914 public HRCs on 1,761 miles of shortline track in the study area. Each crossing has a uniquely generated probability (from WBAPS) of producing an accident during a 12 month period with an average probability of .006492 accidents per HRC per year for the crossings in the study area. When all 1,914 probabilities are summed, a total of 12.42 accidents are predicted to occur at shortline HRCs in the study area per year. FRA's records of collisions that historically occurred at these same HRCs reveals that 112 collisions involving 117 motorists actually occurred over the 10 year period from 1990-1999. Given an historic average of 11.2 collisions per year, the WBAPS prediction of 12.42 accidents per year is a reasonable estimate. The records of accidents that actually occurred report six fatalities, 37 non-fatal injuries, and 74 property damage only accidents. Assuming this is a representative distribution of shortline rail accidents by category, highway-rail collisions can be estimated to result in fatalities 5.1% of the time, non-fatal injuries 31.6% of the time, and PDOs 63.3% of the time. Therefore the 12.42 predicted accidents are expected to produce .64 fatal, 3.93 non-fatal injury, and 7.86 PDO accidents per year on study area shortlines.

4. Cost per Accident: The National Safety Council annually estimates the costs of unintentional injuries resulting from motor vehicle crashes and reports the findings at http://www.nsc.org/lrs/

statinfo/estcost0.htm. Their estimates include explicit economic costs (lost wages, medical expenses, property repairs, etc.) and a measure of the lost quality of life, obtained through studies of what people actually pay to reduce their safety and health risks. In 2000 the average comprehensive costs per individual fatality, non-fatal injury, and PDO were $3,214,290, $159,499, and $1,861 respectively.

6.4 Empirical Results–Highway Safety Analysis

The highway safety consequence of abandoning shortline rail service in the study area can now be calculated. The total highway safety cost is given by equation (36).

(36) Safety Cost = [(Increased Truck Miles) x (Rate of Truck Fatalities) x (Cost per Fatality)]
+ [(Increased Truck Miles) x (Rate of Truck Injuries) x (Cost per Injury)]
+ [(Increased Truck Miles) x (Rate of Truck PDOs) x (Cost per PDO)]
= 8,078,868 miles x 2.5 fatalities per 100 million miles x $3,214,290 per fatality
+ 8,078,868 miles x 48.3 injuries per 100 million miles x $159,499 per injury
+ 8,078,868 miles x 158.2 PDOs per 100 million miles x $1,861 per PDO
= $1,295,361

Abandoning all shortline railroads in the study area would result in increased annual highway safety costs of $1.3 million resulting from an increase of .20 fatal, 3.90 non-fatal injury, and 12.78 PDO accidents on the study area's road system each year. This cost must be compared to the highway safety benefits conferred from closing the shortline HRCs in the study area:

(37) Safety Benefit = (Reduced HRC Fatalities) x (Cost per Fatality)
+ (Reduced HRC Injuries) x (Cost per Injury)
+ (Reduced HRC PDOs) x (Cost per PDO)
= .64 fatalities x $3,214,290 per fatality
+ 3.93 injuries x $159,499 per injury
+ 7.86 PDOs x $1,861 per PDO

= \$2,698,604

Eliminating all shortline rail crossing accidents in the study area would confer an annual highway safety benefit of \$2.7 million. Thus, the net safety impact of shortline rail abandonment in the study area is:

(38) Net Annual Safety Impact = Annual Safety Benefits - Annual Safety Costs

= \$2.7 million - \$1.3 million

= \$1.4 million

The abandonment of all shortline railroads in the study area is estimated to result in increased net annual highway safety benefits of \$1.4 million.

6.5 Summary of Highway Safety Analysis

Rail line abandonments result in more trucks on study area highways. The increase in truck traffic brings a safety cost for highway travelers due to an increase in truck accidents. At the same time truck accidents are increasing, however, highway-rail accidents are decreasing. The decline in highway-rail accidents is a benefit conferred on highway travelers when study area shortlines are abandoned.

A full analysis of the highway safety impact of rail line abandonment compares the resulting safety costs and safety benefits. The highway safety costs are estimated by determining the amount of additional truck traffic that will be generated by the abandonments, estimating the accidents that will be generated by this traffic, and multiplying these accidents by their costs. Applying this methodology to shortlines in the study area results in annual safety costs of \$1.3 million. The highway safety benefits are estimated by determining the number of collisions that are averted by eliminating highway-rail crossing accidents on study area shortlines and multiplying these avoided accidents by what they would have cost. Utilizing this approach results in annual safety benefits of \$2.7 million in the study area. Thus the abandonment of all shortline railroads in the study area would result in increased annual highway safety benefits of $1.4 million. There is a net safety benefit after abandonment because the accidents are predicted to be less severe. That is, transporting study area wheat on shortlines (no abandonment scenario) will annually result in .64 fatalities and 3.93 non-fatal injuries, whereas transporting wheat by truck (abandonment scenario) will annually result in .20 fatalities and 3.90 non-fatal injuries.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

7.1.1 Study Area Road Conditions and Financing

If the four shortlines serving the study area are abandoned there will be a large diversion of wheat shipments from railroads to trucks. Much of this additional traffic would move over county roads that are not built to handle a large increment in five axle 80,000 pound trucks. To document the potential challenge facing counties, a survey of study area county road conditions and finances was conducted in the summer of 2001.

For counties with cement roads, 22% of the miles were rated in the poor to very poor categories, 38% were characterized as good or very good, and 40% were rated as fair. For the counties with asphalt roads, 18% of the miles were rated poor or very poor, 55% were classified as good or very good, and 27% were rated as fair. A total of 29% of the 55 sample county representatives rated the condition of their roads as worse than five years ago, 44% said their roads were better or much better, and 27% rated the condition of their roads as unchanged.

If the overall condition of the county's roads had declined in the previous five years, the respondents were asked to specify the reasons for the deterioration. Increases in the number of heavy trucks on the county's roads was ranked as the most important reason for the decline in road condition. The second most important factor was increase in the cost of road maintenance.

The average expenditure of the sample counties for road and bridge maintenance in year 2000 was $1.6 million and the principal revenue source was the property tax. A total of 74% of the county representatives said that the current budget for road and bridge maintenance is insufficient to maintain an adequate level of service on the county's roads. Nearly 68% of the county engineers or road supervisors that indicated that the budget was inadequate said the budget shortfall was between 11 and 30%. Another 25% of the respondents said the budget shortfall was greater than 30%.

To deal with the budget shortfall, one-third of the sample counties had abandoned some roads which collectively amounted to 234 miles. About one-fourth of the county representatives indicated that they had recently considered abandoning a collective total of 421 miles.

For counties that recently experienced a decline in the condition of the county's roads and bridges, the respondents were asked what changes would help restore the condition of these facilities. The most frequently mentioned suggestion was an increase in state and federal aid for county roads. However, the respondents had several other suggestions related to funding of county roads and bridges including the following:

1. More state aid should be provided to low population counties so they could complete larger projects. Also more state aid should be given to low population counties since they have a relatively small tax base to finance many miles of county roads.
2. The matching formula for county bridge projects should be changed from 80% state, 20% local to 90% state, 10% local.
3. Remove the cap on state transfers of federal aid to county roads and bridges.
4. Tax revenue should go directly to a county road and bridge program rather than to the state general fund.
5. Taxes on heavy trucks and diesel fuel should be increased.

However, the suggestions of the respondents were not limited solely to financing. For example, some county engineers and road supervisors suggested better enforcement of the weight limits on county roads and bridges. Others said that the state of Kansas should develop a policy for low volume roads that is less restrictive in its design standards than the policy for state highways. Other respondents recognized the relationship between county road and bridge damage costs and rail service by suggesting that the state of Kansas should develop a policy to stop the decline of rail service.

In general, a substantial number of county road miles in the study area are not in good condition. Current road and bridge maintenance budgets are inadequate in the majority of counties even to maintain the current level of service. The counties are not equipped to deal with a large increment in heavy truck traffic triggered by abandonment of shortline railroads.

7.1.2 Changes in Transportation and Handling Costs Due to Shortline Railroad Abandonment

The analysis simulated the transportation and handling costs of shipping 365.5 million bushels of wheat (the 1998-2001 average wheat production of the study area) through the wheat logistics system to Houston, Texas. After simulated abandonment the number of truck-miles doubles from 7,771,552 to 15,850,420. Shortline car-miles fall from 3,665,988 in the no-abandonment scenario to zero in the post-abandonment scenario. The number of Class I railroad car-miles (76,438,797) is unaffected by shortline railroad abandonment.

After simulated abandonment all the wheat that was shipped by shortline railroad is transported by truck. Total truck costs rise from $34,336,869 in the no-abandonment scenario to $43,498,306 in the post-abandonment case, an increase of $9,161,437. Total shortline railroad costs fall from $10,863,532 in the pre-abandonment case to zero after abandonment. The strong competition between trucks and shortlines for the relatively short-haul intra-Kansas movements of wheat is revealed by comparing the increase in truck costs to the decline in shortline costs. That is, truck costs rise by $9.16 million after abandonment compared to a decline in shortline costs of $10.86 million. Thus the net change is a decrease of $1.7 million ($9.16 million minus $10.86 million). Since Class I railroad costs are not affected by abandonment ($81,390,227 in either case), the total wheat logistics-system transport costs actually fall by $1.7 million after abandonment. However, it should be pointed out that the total transport cost of the no-abandonment scenario ($126.6 million) is only 1.4% greater than the total transport cost of the no-abandonment scenario ($124.9 million).

While there is no difference in the total wheat logistics system transport costs in the two scenarios, this is not the case for wheat handling costs. Wheat shipped by truck has to be trans-shipped twice compared to only once for shortline rail shipment. Wheat is assessed an unload cost when it is received from farmers and a loadout cost when it is subsequently shipped from the country elevator by truck. When the wheat arrives by truck at the shuttle train station or terminal elevator, it is assessed an unload cost. Then the wheat is assessed a loadout cost when it is loaded into unit trains for shipment to Houston. In contrast, wheat shipped by shortline is not unloaded into a terminal elevator and thus has less handling costs.

Wheat handling costs increase from $74,769,192 in the no-abandonment case to $97,132,794 in the post-abandonment scenario, an increase of $22,363,602.

When transport and handling costs are combined, the total wheat logistics system costs rise from $201,359,820 in the pre-abandonment scenario to $222,021,327 in the post-abandonment case, an increase of $20,661,507. The increase in total transport and handling cost of $20.7 million in the after abandonment case is the net effect of an increase of $22.4 million in wheat handling costs and a $1.7 million decrease in transport cost.

The total wheat logistics system cost per bushel rises from $0.551 in the no-abandonment case to $0.607 in the after abandonment situation, a net increase of $0.056 per bushel. If Kansas farmers absorb all the increase in wheat logistics system costs, their income would fall by $20.5 million. This figure is obtained by multiplying study area average wheat production of 365.5 million bushels by the $0.056 increase in cost per bushel.

7.1.3 Shortline Railroad Abandonment and Road Damage Cost

The shortline railroad system in the study area annually saves the state of Kansas $57.8 million dollars in road damage costs. When this figure is reduced by incremental fuel tax revenue due to additional trucking in the post-abandonment scenario, the net road damage cost is $57.5 million. As expected, the road damage costs avoided are proportional to the size of the shortline systems. The Kansas and Oklahoma saves the state $30.6 million in road damage cost, 52.9% of the total savings. The Kyle Railroad saves $15.8 million (27.3% of the total), the Cimarron Valley Railroad $8.5 million (14.8% of the total), and the Nebraska, Kansas and Colorado Railnet $2.9 million or 5% of the total road damage cost savings.

7.1.4 Highway Safety Costs and Benefits of Shortline Railroad Abandonment

Abandonment of shortline railroads will increase highway safety costs due to increased truck traffic density and vehicle miles traveled. The safety costs of the additional truck miles consists of $649,196 for fatalities, $622,380 for non-fatal injury accidents, and $23,735 for property damage only accidents, resulting in a total safety cost of $1,295,361. The safety benefit from fewer highway-railroad crossing accidents after abandonment is $2,698,604. Therefore, abandonment results in a net safety benefit of $1.4 million ($2.7 million minus $1.3 million). There is a small net safety benefit after abandonment because the accidents are predicted to be less severe. That is, transporting study area wheat on shortlines (no-abandonment scenario) will annually result in 0.64 fatalities and 3.93 non-fatal injuries, whereas transporting wheat by truck (abandonment scenario) will annually result in 0.20 fatalities and 3.9 non-fatal injuries.

7.1.5 Summary of Shortline Railroad Abandonment Impacts

The abandonment of shortline railroads in the study area results in an additional $57.8 million in road damage costs, $20.7 million in additional transportation and handling cost, and $1.3 million in incremental highway safety costs. If Kansas farmers absorb all the increase in wheat logistics system costs, Kansas farm income would decline by $20.5 million.

7.2 Recommendations

The study area shortline railroads annually save the state of Kansas nearly $57.8 million in avoided road damage costs. In addition, shortlines reduce the transportation and handling cost of wheat by $20.7 million and prevent $1.3 million in highway safety costs. Thus the state has an economic interest in the preservation of shortline rail service. Accordingly the following policy recommendations should be considered.

Kansas has two shortline railroad assistance plans which are the Federal Local Rail Freight Assistance to States (LRFA) and the State Rail Service Improvement Funds (SRSIF). In 1989, the Kansas legislature granted KDOT the authority to loan Federal Railroad Administration (FRA) funds to shortline railroads through the LRFA program, which provides low interest revolving loans below the prime rate to shortlines. The SRSIF was established in 1999 to provide shortline railroads operating in Kansas with low interest, 10 year revolving loans or grants to be used primarily for track rehabilitation. For SRSIF projects the shortline must pay 30 percent of the cost of the project and the state provides a combination of grants (30 percent) and loans (40 percent) for the remaining 70 percent. The interest rate on the loan portion does not exceed 3 percent.

In order for Kansas shortline railroads to be able to safely and efficiently handle HAL cars and provide better service, the funds in the SRSIF program need to be greatly increased. In order to reduce the impact of SRSIF on debt burdens of shortlines, the state's 70 percent share of track rehabilitation projects should be increased to 80 percent with the grant portion at 40 percent and the loan portion at 40 percent, if SRSIF funds are increased.

The federal government needs to change the Railroad Rehabilitation and Improvement Financing (RRIF) program which has not been used at all in Kansas. The program provides for up to one billion dollars in direct loans and loan guarantees for projects benefitting freight railroads other than Class I carriers (i.e., shortline railroads). Eligible projects include (1) acquisition, improvement or rehabilitation of intermodal or rail equipment or facilities (including tracks, components of tracks, bridges, yards, buildings, and shops); (2) refinancing of outstanding debt incurred for these purposes; or (3) development or establishment of new intermodal or railroad facilities. The maximum repayment period is 25 years and the current interest rate is about 6 percent. One unique feature of the RRIF program is the payment of a credit risk premium prior to an appropriation of funds. The credit risk premium is a cash payment to be provided by the loan applicant or a non-Federal infrastructure partner on behalf of the loan applicant.

The RRIF program could provide a source of loans for Kansas shortline railroads to improve their system infrastructure to accommodate HAL cars and attract more traffic. Currently there are no RRIF loan applicants in Kansas. The federal government needs to modify the provisions of RRIF in order to make it attractive to shortlines. The maximum repayment period could be extended to 30 years and the interest rate reduced to 3 percent to conform to the interest rate available on LRFA and SRSIF loans. The credit risk premium should be modified to be more user friendly since, as noted above, there are currently no RRIF loan applicants in Kansas.

It is recommended that Port Authorities, as an economic development goal, purchase covered hopper cars, new or used, and lease them to shortline railroads for use in Kansas. Given periodic car shortages and railroad congestion, the Class I railroads can not always supply shortline railroads with covered hopper cars in a timely manner. Having an adequate covered hopper car supply to move Kansas grain to market is paramount to the continued success of shortline railroads operating in the state.

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APPENDIX A

COUNTY ROAD AND BRIDGE SURVEY QUESTIONNAIRE

COUNTY ROAD AND BRIDGE SURVEY

County ___________________

Respondent Name __________________________

PART A: CONDITION OF COUNTY ROADS

1. How many miles of road is the county responsible for?

2. How many miles of the county's roads are in the following categories?

   (a) Cement ____________________
   (b) Asphalt ____________________
   (c) Unpaved ____________________

3. For the county's cement roads, what percent of the miles are in the following categories. Total must add to 100 percent.

   (a) very poor ____________
   (b) poor ____________
   (c) fair ____________
   (d) good ____________
   (e) very good ____________

4. For the county's asphalt roads, what percent of the miles are in the following categories. Total must add to 100 percent.

   (a) very poor ____________
   (b) poor ____________
   (c) fair ____________
   (d) good ____________
   (e) very good ____________

5. Has the number of paved miles of the county's roads declined in recent years?
   (a) Paved miles in 1996 ____________________
   (b) Paved miles in 2001 ____________________

6. Which of the following best describes the overall condition of the county's roads compared to five years ago?
   (a) Much worse __________
   (b) Worse __________
   (c) Unchanged __________
   (d) Better __________
   (e) Much better __________

PART B: TRAFFIC

7. Does the county conduct annual traffic counts on its roads?
   (a) Yes __________
   (b) No __________

8. If the answer to the previous question is yes, is it possible to count the number of heavy trucks (i.e. 80,000 pound 5 axle tractor-trailer) operating on the county's roads?
   (a) Yes __________
   (b) No __________

9. If the answer to the previous question is yes, what was the heavy truck count in the following years?
   (a) 2000 ____________________
   (b) 1999 ____________________
   (c) 1998 ____________________
   (d) 1997 ____________________
   (e) 1996 ____________________

10. Does the county have any roads and bridges that are closed to heavy trucks?
   (a) Yes __________
   (b) No __________

11. If the answer to question 10 is yes, how many miles of the county's roads and how many bridges are closed to heavy trucks?

(a) Miles of road ______________________

(b) Number of bridges ______________________

PART C: REVENUE AND EXPENSE

12. What was the county's annual expenditure for road and bridge maintenance in the following years?

(a) 2000 ____________________

(b) 1999 ____________________

(c) 1998 ____________________

(d) 1997 ____________________

(e) 1996 ____________________

13. Is the current budget for road and bridge maintenance sufficient to maintain an adequate level of service on the county roads?

(a) Yes__________
(b) No __________

14. If the answer to the previous question is no, put a checkmark for the response that best describes the maintenance budget shortfall. For example if the budget is 90% of what is needed to provide adequate service, the budget shortfall is 10%.

(a) 10 percent or less ________________

(b) 11 percent to 20 percent ________________

(c) 21 percent to 30 percent ________________

(d) 31 percent to 40 percent ________________

(e) 41 percent or more ________________

15. What are the sources of revenue for the county's road and bridge maintenance budget? Please specify amounts for the most recent year available.

(a) Local property tax ______________________

(b) Local fuel tax ______________________

(c) Grants from the state ______________________

(d) Other (please specify) ______________________

PART D: POLICY

16. If the overall condition of the county's road and bridges has declined in recent years, what are the major reasons. Rank the following reasons in order of importance with the number 1 being the most important to the number 5 which is least important.

(a) Decline in county population (tax base) __________
(b) Decline in state aid for county roads __________
(c) Increase in the cost of road maintenance __________
(d) Increases in the number of heavy trucks on the county's roads __________
(e) Other (please specify) __________

17. If the condition of the county's roads and bridges has declined in recent years, what changes in state transportation policy would help restore the condition of the county's road and bridges? (i.e. increases in state aid for county road and bridge maintenance, higher heavy truck taxes)

18. Has the county "abandoned" any roads in recent years?

(a) Yes__________
(b) No __________

19. If the answer to the previous question is yes, how many miles were abandoned, and what was the reason for the abandonment?

20. Has the county recently considered “abandoning” any of its roads?

(a) Yes__________
(b) No __________

21. If the answer to the previous question is yes, how many miles have been considered for abandonment, and what was the reason for considering abandonment?

APPENDIX B

APPLICATION OF GIS TO THE KANSAS WHEAT LOGISTICS SYSTEM

APPLICATION OF GIS TO THE KANSAS WHEAT LOGISTICS SYSTEM

The data described in Chapter 4 readily lent itself to analysis utilizing a Geographic Information System (GIS). The spatial nature of the Kansas wheat logistics system allowed for the conceptual arrangement of data entities to be unified in a geo-referenced network model. ArcView 3.2 was chosen for the database and spatial analysis needs of this project primarily because of its superior network modeling capabilities, but also for its ease in handling large quantities of geo-referenced data.. The data for this analysis can be broadly divided into spatial data and value data. Spatial data involves the relative geographic positions of points of interest. Spatial data is arranged like a map, with defined distances between all points on the map. The spatial data in this model includes farms, road systems, rail systems, and elevator locations. Each of these sets of information comprises a separate "layer" of information that ArcView stores as a shapefile. Shapefiles allow computers to efficiently process the large amount of information contained in a map layer so that individual features within the layer can be isolated for analysis. Geo-referencing consists of giving identical location reference identities to points on all layers, so that the defined location of point A is at exactly the same location on all layers, point B is at exactly the same location on all layers, and the distance between A and B is exactly the same for all layers. By geo-referencing each of these diverse data sets, the various data layers can be merged in spatial fashion by lining up common locational points much like aligning layers of tracing paper utilizing known points common to each layer. Value information about particular locations is also contained within shapefiles in their attribute tables. Attribute tables are database tables that contain specific data such as the amount of wheat that is generated at an origin point, the handling costs of unloading wheat at a particular elevator, and the quantity of truck traffic that utilizes a road segment.

When all of the data was digitized and geo-referenced for all of the arcs and nodes in the Kansas wheat logistics model, the Network Analyst extension in ArcView was used to determine the routing for each individual trip in the logistics system. The Network Analyst extension has several built-in functions, but the closest facility routine was the function utilized in this study. In the closest facility routine, the route from origin nodes (labeled as events) is determined to the nearest feature of a specified type (labeled as facilities). Unfortunately, the built-in closest facility function in ArcView only renders routing from a single designated event to its closest facility. An internal program, known as an Avenue script, had to be developed in order to speed the process of finding the closest intermediate storage facility for well over 50,000 simulated farms. The original Avenue code entitled Shortest Network Paths, which was published on the ESRI public domain site on September 9, 1999 by Klaus Neudecker, was modified to fit the particular needs of this study. Running the closest facility analysis resulted in an output table containing data relating each event to its closest facility, as well as the trip miles involved in the route.

Having digitized the data for each farm and grain elevator, as well the road and rail network which connected them all, the closest facility analysis was conducted in steps to yield the final estimation of trip miles and transportation costs by various modes in the study area. During Step I, subsequent processing was required to the simulated farms in order to geo-reference the wheat production data. After the wheat production data was determined for each farm section in the land study, another Avenue script was utilized in order to reduce the attributes of the entire farm to a central point in the section. Another Avenue script had to be utilized in order to “snap” the single-point farm to the nearest county road segment to provide the necessary connectivity between production origin and transport arc. The same routine was used to ensure that each intermediate storage facility was “snapped” to a transport arc. Thus, with the farms, elevators and terminals, and the county road segments all connected in a network, the closest facility routine was run in batch mode with each farm-point serving as an event in order to find the closest elevator, along with the trip distance and the inferred routing. The trip distance was then multiplied by the total number of trucks originating from each farm, thereby generating truck-miles. This method identified the number of Step I truck miles by county. This same analysis was also conducted for the subsequent shipment of wheat from elevators on assumed-abandoned shortlines with one exception. The transportation network shapefile was comprised of only state highway segments instead of county road segments. Some state highway segments had to be used to connect farms to intermediate storage facilities, but the corresponding trip data was assumed to occur entirely upon county roads to provide a county road use estimate.

Step II required no spatial analysis. Instead, the handling cost per bushel by elevator type was applied to the amount of wheat at each elevator following Step I analysis. That is, handling costs were computed at $0.09 a bushel for country elevators and $0.07 a bushel for unit train shipping facilities. The entire analysis was conducted utilizing Microsoft Excel.

Step III trip routing involved only rail wheat shipments and the analysis for rail transport was conducted by dividing the study area rail system into six separate rail networks representing the four shortline railroads and the two Class I railroads. Prior to the analysis, the total number of elevators located on study area shortlines were extracted from the elevator shapefile. Next, the rail network for the entire study area was separated into a separate shapefile for each railroad. Furthermore, a separate sub-terminal shapefile was created for those unit train shipping facilities on a specific rail network. Finally, six separate elevator shapefiles were created to locate and extract all of those elevators within ½ mile of a particular railroad. The ½ mile distance was used to capture elevators that were not located precisely when they were geo-referenced. This procedure identified six separate analysis groups (one for each study area railroad) of elevators, unit train shipping locations, and rail segments. The country elevators and unit train facilities were “snapped” to the rail network, and the closest facility routine was run to obtain the trip mileage for intra-Kansas wheat shipments. The Kansas to Houston part of Step III was then estimated utilizing the URCS costs in Table 7. A simple Microsoft Excel calculation provided this piece of the wheat logistics system transportation costs.

Step IV incremental truck miles were estimated utilizing the model outlined in Babcock and Bunch (2002). Wheat at shortline elevators was routed to the nearest unit train facility utilizing the state highway system. Aggregate amounts of wheat at each shortline elevator location were used to determine the truck and ton-miles generated by the simulated shortline abandonment. Truck-miles were further identified by county and for each shortline railroad. The remaining calculations were done utilizing Microsoft Excel by subtracting shortline related transport costs from total wheat logistics system costs, and by adding the additional trip mileage and transport and handling costs associated with the incremental truck traffic resulting from shortline abandonment.

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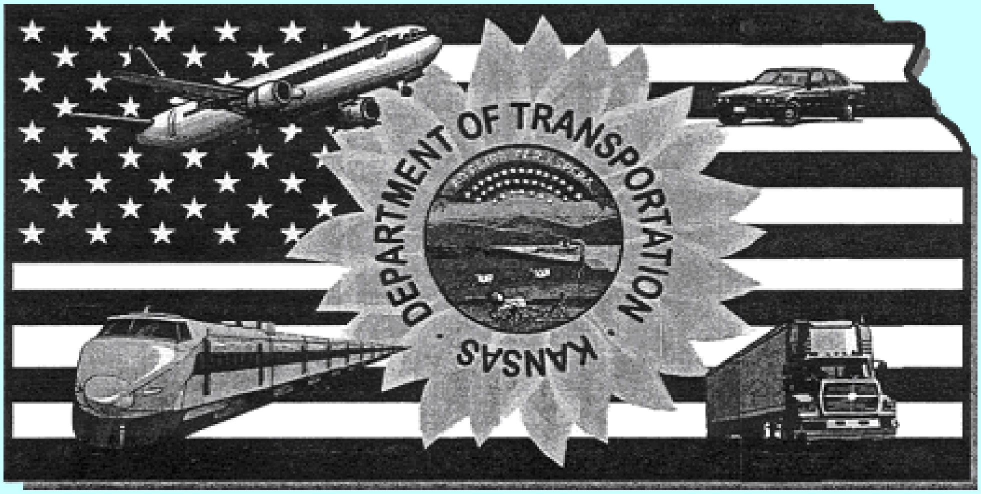
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