Report No. K-TRAN: KSU-10-5 ▪ FINAL REPORT ▪ November 2011

The Economics of Potential Reduction of the Rural Road System in Kansas

Michael W. Babcock, Ph.D.
Abhinav Alakshendra
Kansas State University Transportation Center

A cooperative transportation research program between
Kansas Department of Transportation,
Kansas State University Transportation Center, and
The University of Kansas

AD ASTRA PER ASPERA
Kansas
Department of Transportation

1 Report No. K-TRAN: KSU-10-5	**2 Government Accession No.**	**3 Recipient Catalog No.**
4 Title and Subtitle THE ECONOMICS OF POTENTIAL REDUCTION OF THE RURAL ROAD SYSTEM IN KANSAS		**5 Report Date** November 2011 **6 Performing Organization Code**
7 Author(s) Michael W. Babcock, Ph.D.; Abhinav Alakshendra		**8 Performing Organization Report No.** KSUTC-10-5
9 Performing Organization Name and Address Kansas State University Transportation Center 2118 Fiedler Hall Manhattan, Kansas		**10 Work Unit No. (TRAIS)** **11 Contract or Grant No.** C1826
12 Sponsoring Agency Name and Address Kansas Department of Transportation Bureau of Materials and Research 700 SW Harrison Street Topeka, Kansas 66603-3745		**13 Type of Report and Period Covered** Final Report June 2009–September 2010 **14 Sponsoring Agency Code** RE-0524-01
15 Supplementary Notes For more information write to address in block 9.		

16 Abstract

Benefit–cost analysis was used to examine the question of road closure in the three counties. The cost of road closure is the additional travel cost of rural residents due to more circuitous routing to their destinations. The benefit is the avoided maintenance costs of roads removed from the county network.

In three counties, 10 road segments were selected as potential candidates for simulated closure. This was done to analyze the traffic impacts on alternative roads near the road segments being considered for simulated closure. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads. TransCAD maps and KDOT traffic counts were used to identify candidate roads for simulated closure. Single-access roads (the only road between a specific origin and destination) were not considered for simulated closure.

- A major conclusion is that rural counties will be able to save money by closing some relatively low-volume roads and redirecting the savings toward increasing the quality of the other county roads.
- Counties with relatively extensive road systems (miles of road per square mile) and relatively high population density (i.e., Brown County) are less likely to realize savings from road closure.
- Counties with less extensive road systems and relatively low population density (i.e., Thomas County) are more likely to realize significant savings from closure of relatively low-volume roads.

17 Key Words Low-Volume Roads, Rural, Benefit–Cost, Traffic Volume, Agriculture, Maintenance		**18 Distribution Statement** No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19 Security Classification (of this report) Unclassified	**20 Security Classification (of this page)** Unclassified	**21 No. of pages** 98	**22 Price**

Form DOT F 1700.7 (8-72)

The Economics of Potential Reduction of the Rural Road System in Kansas

Final Report

Prepared by

Michael W. Babcock, Ph.D.
Abhinav Alakshendra

Kansas State University Transportation Center
Manhattan, Kansas 66506

A Report on Research Sponsored by

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

November 2011

PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

NOTICE

The authors and the state of Kansas do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

This information is available in alternative accessible formats. To obtain an alternative format, contact the Office of Transportation Information, Kansas Department of Transportation, 700 SW Harrison, Topeka, Kansas 66603-3745 or phone (785) 296-3585 (Voice) (TDD).

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the state of Kansas. This report does not constitute a standard, specification or regulation.

Abstract

The increasing size of farms in Kansas has led to increasing farm vehicle size as well. Tractor and combine weight and width has increased and the majority of farmers deliver their grain in semi-trucks. Tandem axle trucks are used to deliver farm supplies. The road width and design characteristics of rural roads and bridges are inadequate for the larger and heavier vehicles that are using them. As county population declines, the financial ability of Kansas counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. Many rural Kansas counties don't have the funds to maintain the existing system with the heavier vehicles that are using them. If the county road and bridge system can't be maintained as it is, reducing the size of the system should be considered. This study addressed the benefits and costs of reducing the county network.

The principal objective of the research is to estimate the economic impact on selected county road systems from reducing the size of the road system. The specific objectives include:

- **Objective A:** For a sample of three Kansas counties, measure the benefits and costs of keeping the road system as it currently exists.
- **Objective B:** For the same sample of Kansas counties, measure the benefits and costs of several scenarios of simulated county road closure.

To accomplish the objectives three counties were selected for analysis: Brown County (northeast Kansas), Pratt County (south central Kansas), and Thomas County (northwest Kansas). These counties were selected to obtain geographic variation, and because the study is concerned with rural roads, these counties were selected because they have the greatest agricultural production in their respective regions.

Benefit–cost analysis was used to examine the question of road closure in the three counties. The cost of road closure is the additional travel cost of rural residents due to more circuitous routing to their destinations. The benefit is the avoided maintenance costs of roads removed from the county network.

One way to measure the costs of road closure is through use of a network model for each sample county. The model would estimate the minimum travel cost routings of all the trips in the

county. The network model routes each of the trip classes from the trip origin, through the county road system as it currently exists to the destination at minimum travel cost. Then the network model measures the travel cost without the designated road segments in the network. The difference in the total travel costs of the two scenarios is the travel cost impact of keeping the designated roads in the system as opposed to closing them.

The network model used in the study is TransCAD. TransCAD is a geographic information system software product produced by Caliper Corporation for transportation and public transport applications. In addition to the standard point, line, area and image layers in a GIS map, TransCAD supports route system layers and has tools for creating, manipulating, and displaying routes. TransCAD uses a network data structure to support routing and network optimization models. TransCAD includes trip generation, distribution, mode choice, and traffic assignment models that support transportation planning and travel demand forecasting.

In each county, 10 road segments were selected as potential candidates for simulated closure. Ten road segments were selected in order to analyze the traffic impacts on alternative roads in the local area of the closed road segment. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads. TransCAD maps and KDOT traffic counts were used to identify candidate roads for simulated closure. Single-access roads (the only road between a specific origin and destination) were not considered for simulated closure.

It was assumed that rural residents would use cars and pickup trucks for grocery and pleasure trips while five axle semis and tandem axle trucks are used for grain hauling. In the rural resident survey respondents were asked to indicate their destinations for each type of vehicle. However, to simplify computation only the most important destination for each vehicle type was used. Also to simplify computation all truck types (other than pickup) were combined into one category. Thus there are three vehicle types in the analysis: cars, pickups, and trucks. The maintenance cost per mile was obtained from previous studies and is assumed to be the same in all three counties.

The data to estimate the network model were obtained by questionnaires completed by rural residents of the three counties, grain elevator managers, and county road supervisors. The questionnaires are in Appendices A–E. The rural resident transportation survey has three parts: Transportation Equipment, Outbound Trips, and Inbound Trips. The grain elevator mangers survey also has three parts: Grain Receipts, Market Area, and Fertilizer Delivery to Farms. The county road supervisors of the three counties completed two questionnaires. One is titled County Road Supervisor's Survey and the other is County Maintenance, Construction, and Reconstruction Costs. The first of these surveys has two parts: Current Condition of County Roads, and Revenue and Expense. The second questionnaire has four parts: Maintenance, Construction/Reconstruction Costs, Types of Paved Road Treatments, and Types of Gravel Road Treatments.

In Pratt County, a large generator of truck traffic is Pratt County Feeders, LLC, one of the largest cattle feedlots in Kansas. The manager completed a questionnaire that has five parts: Capacity and Production, Inbound Truck Shipments, Outbound Truck Shipments, Origins of Inbound Truck Shipments, Truck Shipments on the Pratt County Road System.

The principal conclusions of the study are as follows:

1. The table below contains the benefit–cost ratios for simulated closure of roads in the three counties. One set of ratios is calculated assuming annual maintenance cost per mile of $3,000, and the other set assumes $4,000 per mile.

Benefit–Cost Ratios Assuming Annual Maintenance Cost of $3,000 Per Mile

County	Benefits ($)	Costs ($)	Benefit–Cost Ratio
Brown	68,760	226,147	0.30
Pratt	93,810	94,236	0.995
Thomas	84,300	46,385	1.82

Benefit–Cost Ratios Assuming Annual Maintenance Cost of $4,000 Per Mile

County	Benefits ($)	Costs ($)	Benefit–Cost Ratio
Brown	91,680	226,147	0.41
Pratt	125,080	94,236	1.33
Thomas	112,400	46,385	2.42

2. The benefit–cost ratios for Brown County are 0.30 and 0.41. Thus none of the 10 road segments evaluated in Brown County should be closed since the costs of simulated closure exceed the benefits.
3. For Pratt County the benefits of simulated road closure are approximately equal to the cost if maintenance cost per mile is assumed to be a very conservative $3,000. However, if maintenance cost per mile is assumed to be $4,000, the benefit–cost ratio is 1.33. The latter alternative indicates that Pratt County would save money by closing the evaluated road segments since the benefits exceed the costs.
4. The benefit–cost ratios for Thomas County are 1.82 and 2.42 indicating that the evaluated road segments in Thomas County should be closed since the benefits (avoided maintenance costs) exceed the travel costs of rural residents.
5. A major conclusion is that rural counties will be able to save money by closing some relatively low-volume roads and redirecting the savings toward increasing the quality of the other county roads.
6. Counties with relatively extensive road systems (miles of road per square mile) and relatively high population density (i.e., Brown County) are less likely to realize savings from road closure.
7. Counties with less extensive road systems and relatively low population density (i.e., Thomas County) are more likely to realize significant savings from closure of relatively low-volume roads.

Acknowledgments

This research project could not have been completed without the assistance and cooperation of many people. David Nagy of the Kansas Department of Transportation (KDOT) managed the project in a professional manner. David Cronister of KDOT provided a tremendous amount of his time instructing the research team in the use of TransCAD. Crystal Strauss typed the final report. Thanks go to the road supervisors in the three counties (Brown, Pratt, and Thomas), who provided maps, annual reports, and completed two detailed questionnaires. Grain elevator managers supplied data that helped the research team document truck travel in the three counties. Special thanks go to the rural residents of Brown, Pratt, and Thomas counties. Without their cooperation and assistance, this study would not have been possible.

Contents

List of Tables

Chapter 1: Introduction

1.1 Economic Challenges to the Kansas County Road System

When the county road grid was established in Kansas each road was used by a large number of households and farms operating small vehicles. Today each road is used by a small number of households and farms operating large vehicles. The typical vehicle types include automobiles, pickup trucks, farmer-owned tandem axle and semi-trucks, farm combines, and farm tractors pulling various types of farm equipment. Other vehicle types include commercial trucks, garbage trucks, and school buses.

In many counties the road and bridge characteristics are not sufficient to handle the stresses of the larger vehicles. These characteristics include

- Narrow lanes that create safety problems
- Overweight vehicles that break up road surfaces
- Lack of hard surfaces creates rideability problems
- Road widths and design characteristics are inadequate for large farm equipment and heavy trucks.

It is well known that Kansas agriculture has consolidated into fewer, larger farms due to economies of scale from larger farming operations. The increased size of farms has been accompanied by increasing farm vehicle size as well. Tractor and combine weight and width has increased and the great majority of farmers deliver their grain in semi-trucks. Tandem axle trucks are used to deliver farm supplies. Declining rural population has caused school districts to use larger buses to transport fewer children over longer distances to consolidated schools. The road width and design characteristics of rural roads and bridges are inadequate for the larger and heavier vehicles that are using them.

Kansas ranks fourth in the nation in the number of public road miles and bridges. According to the KDOT website, Kansas had 135,019 public road miles in 2005, 92% (124,151) of which were classified as rural. In 2005, Kansas had 25,796 bridges, 22% of which were classified as structurally deficient or functionally obsolete. As county population declines, the financial ability of Kansas counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. Many rural Kansas counties don't have the funds to maintain the existing system with the heavier vehicles that are using the system. If the county road and bridge system can't be maintained as it is, reducing the size of the system should be considered.

1.2 Research Objectives

The overall objective of the research is to estimate the economic impact on selected county road systems from reducing the size of the system. The specific objectives include:

- **Objective A:** For a sample of three Kansas counties, measure the benefits and costs of keeping the road system as it currently exists.
- **Objective B:** For the same sample of Kansas counties, measure the benefits and costs of several scenarios of county road closure.

In order to evaluate the feasibility of road closure, a benefit–cost technique will be used and applied to three Kansas counties. The benefits of rural roads closure are avoided costs to the county of keeping the roads in the system including maintenance, reconstruction, and resurfacing costs. The costs are the additional travel costs of the traveling public due to closure of lightly traveled roads. If the measured benefits exceed the costs, the evaluated roads should be closed or remain in the county road system if the costs of simulated closure exceed the benefits.

The fixed maintenance costs on paved roads include drainage, signing, ditch maintenance, snow removal, and painting lane stripes. The variable maintenance costs on paved roads depend on road surface type and thickness, sub-base thickness, and number and weight of vehicle axle passes. Other costs include road resurfacing, patching, and shoulder resurfacing.

The fixed costs of gravel roads are signing, drainage, snow removal, and weed control. The variable costs include gravel resurfacing and blading. Major reconstruction costs and resurfacing costs vary by road type and traffic volume.

1.3 Methodology and Data

To accomplish the objectives, it is necessary to measure the benefits of closing road segments in the county road system rather than retaining them. The benefits are expected to be the avoided maintenance costs if the designated roads are removed from the system. The costs are the additional travel cost of rural residents from more circuitous routing.

One way to measure these benefits and costs is through use of a network model for each sample county. The model would estimate the minimum travel cost routings of all the trips in the county. The network model routes each of the trip classes from the trip origin, through the county road system to the destination at minimum travel cost. The network model measures the travel cost without the designated road segments in the network. The difference in the total travel costs of the two scenarios is the travel cost impact of keeping the designated roads in the system as opposed to closing them.

The network model used in the study is TransCAD. TransCAD is a geographic information system software product produced by Caliper Corporation for transportation and public transport applications. In addition to the standard point, line, area, and image layers in a GIS map, TransCAD supports route system layers and has tools for creating, manipulating, and displaying routes. TransCAD uses a network data structure to support routing and network optimization models. TransCAD includes trip generation, distribution, mode choice, and traffic assignment models that support transportation planning and travel demand forecasting.

The data requirements for estimating the benefits include the following:

1. The quantity, origins, and destinations of all household and farm travel by vehicle type that originates and terminates in the sample county in a year’s time.
2. For both paved and gravel roads, the costs per mile of each type of vehicle traveling in the county, using the AASHTO estimates, which measure the variable costs of each vehicle which includes fuel, oil, tires, maintenance, and travel time cost. The fixed costs are the sum of time-related depreciation, insurance, and licenses.
3. The mileage and types of roads and the number and size of bridges in the county.
4. The annual maintenance costs per mile for paved and gravel roads.

1.4 Implementing the Methodology

The data to estimate the network model were obtained by questionnaires completed by rural residents of the sample counties, grain elevator managers, and county road supervisors. The questionnaires are in Appendices A–E. The mailing addresses for the rural residents of Pratt and Thomas County were obtained from Farm & Home Publishers for Pratt County and Central Publishing Company, Inc., for Thomas County. In Brown County, the questionnaires were distributed to rural residents by township representatives.

The rural resident transportation survey has three parts: Transportation Equipment, Outbound Trips, and Inbound Trips. The first part asks the respondents what types and amounts of farm equipment, trucks, and automobiles are owned by members of the household. The second part of the rural resident survey requests information on the following:

- Number of tractor, combine, and grain wagon trips on the county roads
- Number of miles of county roads used to make tractor and combine trips
- Number of times the county roads are used to make auto, pickup truck, single axle truck, tandem axle truck, semi truck, and grain wagon trips
- Destinations and number of trips by auto, pickup truck, single axle truck, tandem axle truck, and semi truck

The last part of the rural resident survey asks the respondents how many trips are made to their location in various types of vehicles. The residents are also asked to provide the origins of trips to their location by various types of vehicles.

Managers of grain elevator companies were interviewed by the research team and they also completed questionnaires that have three parts: Grain Receipts, Market Area, and Fertilizer Delivery to Farms. In most cases the grain companies were composed of multiple grain elevators located throughout the sample county. The manager of the entire grain company completed the questionnaire in each case.

The first part of the survey asks the grain company managers for their corn, wheat, sorghum, and soybean receipts for the 2007–2009 period and what percent of their total receipts were delivered to their elevator(s) by various types of trucks. In the next part of the survey the respondents were asked the average distance from which farmers deliver their grain and the number of county road miles by surface type that farmers use to deliver grain to their elevator(s). The respondents also provided data on the number of trips that farmers make to their elevators during harvest and non-harvest periods. The last part of the survey requests data for the percent of the grain company's fertilizer deliveries that were made in various types of trucks. Other information requested in the last part of the questionnaire included the following:

- Number of miles by road surface type that were used to deliver fertilizer to farms
- The average distance (miles) that fertilizer is delivered to farms
- The number of trips made to deliver fertilizer to farms by season of the year

The county road supervisors for Brown, Pratt, and Thomas County were interviewed by the research team and they each completed two questionnaires. One is titled County Road Supervisor's Survey and the other is County Maintenance, Construction, and Reconstruction Costs.

The first County Road Supervisor's Survey has two parts: Current Condition of County Roads and Revenue and Expense. The first part of the questionnaire asks the road supervisors how many miles of road and bridges is the county responsible for (by surface type), and to rate the condition of the county's cement, asphalt, and unpaved roads. The second part of the survey requests the county's annual expenditure for road and bridge maintenance for the 2007–2009 period, and the sources of revenue for the county's road and bridge maintenance budget. The respondents were also asked if the current budget for road and bridge maintenance is sufficient to maintain an adequate level of service on the county roads.

The County Maintenance, Construction, and Reconstruction Costs questionnaire has four parts as follows:

- **Part A:** Maintenance
- **Part B:** Construction/Reconstruction Costs
- **Part C:** Types of Paved Road Treatments
- **Part D:** Types of Gravel Road Treatments

In Part A, the county road supervisors were asked to provide a general description of maintenance activities in the county including chip seals, overlays, and recycle. In Part B, the respondents were asked to give a general description of the construction/reconstruction activities for paved and gravel roads as well as bridges. They were also asked how often these activities occur as well as the cost per mile of paved and gravel roads and the cost per average county bridge. In Part C, the respondents were asked to give a general description of paved road treatments including crack seal, seal coat, overlay, striping and marking, mill and overlay, and patching. They were also requested to provide a general description of gravel road treatments such as blading, re-gravel, reclaiming, reshape cross section, and routine annual maintenance.

In Pratt County, a large generator of truck traffic is Pratt County Feeders, LLC, one of the largest cattle feedlots in Kansas. The manager of the company was interviewed by the research team and he also completed a questionnaire. There are five parts to the questionnaire including the following:

- **Part A:** Capacity and Production
- **Part B:** Inbound Truck Shipments
- **Part C:** Outbound Truck Shipments
- **Part D:** Origins of Inbound Truck Shipments
- **Part E:** Truck Shipments on the Pratt County Road System

In Part A, the respondent is asked to provide data on the number of cattle on feed in the 2007–2009 period, the number of bushels of feed grains delivered to the feedyard in the same period, the number of tons of distillers grain, and the amount of feeder cattle delivered to the feed yard. In Part B, the respondent is asked the percentage of various feed grains delivered to the feedyard in single axle truck, tandem axle truck, and semi-tractor trailer/trucks. Also, data were requested on the percentage of feeder cattle and distillers grain that were delivered to Pratt Feeders by tandem axle trucks and semi-tractor trailer trucks. In Part C of the survey, the manager provided data on the percentage of total finished cattle and manure shipped from the feedyard in tandem axle trucks and semi-tractor trailer trucks. In Part D, the manager indicated the percentages of total inbound feed grains, distillers grain, and feeder cattle that originated at various distances from the feedyard. In Part E, the Pratt Feeders manager was requested to provide the numbers of miles of paved and gravel Pratt County roads used by a typical inbound truck shipment of feed grains, distillers grain, and feeder cattle.

Chapter 2: Literature Review

There is a large literature on various aspects of low-volume roads, and this chapter is not a comprehensive review of that literature. Instead, a small number of previous studies that are more closely related to this study are discussed.

The Minnesota Department of Transportation sponsored a study conducted by Iowa State University published in 2005 titled *Economics of Upgrading an Aggregate Road*. The objective of the study was to identify the methods and costs of maintaining and upgrading a gravel road. The research goal was to provide local officials with methods to determine at what point to upgrade a gravel road. The research involved three parts, with the first one being a historical analysis based on the spending history for low-volume roads in the annual reports of a sample of Minnesota counties. The second part is the development of a method for estimating the cost of maintaining gravel roads. The final part of the study is the development of an economic analysis example that can be used for making specific road investment decisions.

To accomplish the first part of the study, the authors selected 16 Minnesota counties dispersed across the state. The sample was reduced to four counties which supplied detailed maintenance costs per mile from their annual reports for the period 1997–2001. The costs were classified into five categories, including routine annual maintenance, repairs and replacements, betterments, special work, and special agreements. The authors conducted interviews with the road supervisor of each of the four counties and performed descriptive statistical analysis on the historical road maintenance data.

The second part of the study involved development of cost per mile estimates for gravel road maintenance and hot-mix asphalt (HMA) paving and its associated maintenance costs. The calculations are for annual maintenance for one mile of road. They assume routine grading activities each year and re-graveling every five years. Their cost estimates were made to provide a comparison to the historical cost data of the four counties. The estimate for the gravel road was $4,160 per mile, much larger than the cost estimates of the historical analysis.

The HMA surface involves a construction cost of $130,000 per mile and annual maintenance costs of $1,600 per mile. Seven years beyond the initial HMA construction a seal coat is applied at a cost of $6,000 per mile. Over a 25 year period the average annual HMA maintenance cost is $2,460 per year compared to $4,160 per year for gravel road maintenance.

The final part is the development of an economic analysis example that can be used for making specific road investment decisions. The authors conduct a present value analysis of gravel road maintenance costs and HMA costs over a 30 year period. They found that the net present worth of gravel road maintenance was about $68,000, while the corresponding value for the HMA paving option was approximately $92,000.

The authors concluded that the cost of maintaining a gravel road increases with traffic volume. The road becomes rougher more quickly, requiring more frequent surface smoothing. Also more gravel is thrown off the road requiring gravel replacement. They discovered that the proportion of roads that are currently paved in the four counties increases with traffic volume. For roads with traffic of 150 to 199 vehicles per day, more than half of the roads were paved. The authors concluded that the historical costs to maintain both gravel and bituminous roads were between $1,500 and $2,500 per mile. They found historical costs of the four counties may underestimate gravel road maintenance costs, especially for high-volume roads. The authors concluded that maintenance cost savings alone can't justify the investment in an HMA upgrade, although upgrading could be justified based on factors that the authors didn't quantify.

The South Dakota Department of Transportation sponsored a study conducted by Applied Pavement Technology Inc. in 2004 titled *Local Road Surfacing Criteria*. The objective of the study was to create a process that allows the user to compare the costs associated with different types of roads in order to provide assistance in deciding which surface type: hot-mix asphalt (HMA), blotter, gravel or stabilized gravel is most economical under a certain set of circumstances. The specific objectives of the study included:

1. To model transport agency costs as a function of surfacing type and other potentially significant variables, such as materials availability, structural condition, traffic, and environmental factors.
2. To model certain user costs as a function of surfacing type and other potentially significant variables, such as materials availability, structural condition, traffic, and environmental factors.

3. To develop practical methodologies for using transport agency and user cost models to determine when to maintain, upgrade, or downgrade road surface types on local road segments.

To achieve the objectives, the authors used life-cycle cost analysis (LCCA) that focuses on selecting the most cost effective road surface to meet a specific need. The LCCA includes agency costs or the funds expended by the local agency to build and maintain the given roadway, as well as user costs.

Twenty-three of 66 counties in South Dakota participated in the study. These counties were provided with survey forms requesting specific section information including initial cost, maintenance costs and frequency, and other information to implement the agency cost models. To develop the user cost models, accident data and ADT information for each pavement section included in the study was provided by the South Dakota DOT.

The results of the LCCA for each section were combined for use in model development to determine whether statistically significant relationships existed between variables including surface type, ADT, terrain type, subgrade type, and truck traffic. The final results showed that ADT is statistically significant in calculating agency and vehicle operating costs on HMA, blotter, and gravel roads. None of the variables had a statistically significant relationship to crash costs. The resulting models were incorporated into a practical methodology that uses agency and user costs to determine when to maintain, upgrade, or downgrade surface types on local road segments.

Jerry Anderson and John Sessions used mixed integer linear programming (MIP) to analyze the intermittent road management problem in *Managing Low-Volume Road Systems Intermittent Use*, published as Transportation Research Record 1291 in 1991. The paper is written in the context of timber harvesting regions. The authors note that from a known schedule of entries into an existing road system, the problem is to determine which roads are to remain open and which are to be closed and for how long. The objective is to minimize the discounted value of transportation costs, road opening costs, road closing costs, and road maintenance costs. Minimizing discounted costs is meant to minimize the sum of truck transportation, road opening, road closing, and road maintenance costs over a specified time horizon taking into account the time value of money.

The objective function of the MIP is the present value of the sum of the above four cost components. In addition to the objective function, there are four kinds of relationships (constraints) in the problem. These are relationships to (a) conserve flow at each node in the road network, (b) to signal which period the road is open, (c) to signal which period the road is to be closed, and (d) to signal which period the road is to be opened. These relationships are necessary to insure that roads are opened when they must carry traffic and that roads can be closed when there is no traffic. The objective function is the criterion that is used to determine which roads are open, which are closed and for how long.

The authors then discuss an example that involves a 15-road segment, 10-node, 3-period problem to demonstrate the model. All roads are initially assumed to be open. The problem is solved using the linear programming software LINDO. The authors then compute the minimum value of simultaneous consideration of all four costs in the objective function. The solution also indicates the open road segments in the network that minimizes costs. Next, they compute the total costs and open road segments if opening and closing costs are not considered simultaneously with transport and road maintenance costs. The total costs are 13% higher than the optimal solution that considers all four costs simultaneously.

The authors devote considerable discussion to techniques to reduce computing time and costs, which at the time the paper was written, were significant for solving MIP problems. This is less of a problem today given the advances in computer technology.

In *The Economics of Reducing the County Road System: Three Case Studies in Iowa*, C. Phillip Baumel, Cathy A. Hamlett, and Gregory Pautsch estimated the benefits of keeping groups of existing roads in the county road system. The purpose of the study is to develop guidelines for local road supervisors and county engineers in evaluating local rural road investment or disinvestment proposals and to provide information to state legislatures in developing local rural road and bridge policies.

The authors selected three case study areas in Iowa. One has a relatively high agricultural tax base, a high percentage of paved roads, and relatively few bridges. The second area has a relatively low agricultural tax base, hilly terrain, a low percentage of paved roads, and a large number of bridges. The third area has a relatively high agricultural tax base, a high percent of paved roads, and a large number of non-farm households with commuters to nearby cities. The authors used a questionnaire to collect data from farm and non-farm households in the three study areas. Data were obtained on the number of trips by origin, destination, and vehicle type.

The authors removed groups of roads in each study area to estimate the benefits and the costs of keeping each group of roads in the study area road system. The benefits were defined as the savings to the traveling public from keeping the selected groups of roads in the road system. A benefit–cost ratio was estimated for each group of roads.

The authors concluded that the major sources of vehicle miles on county roads are automobiles used for household purposes and pickup truck travel for farm purposes. They also found that farm-related travel represents a relatively small percent of total travel miles but a relatively high percent of total travel costs. Further, they discovered that in areas with a large non-farm population, only a small number of roads can be abandoned without increasing vehicle travel cost more than the saving from eliminating them. They also found that in areas with a relatively small rural population and a large percent of gravel roads, only a small number of roads with no property access can be abandoned before the additional travel costs exceed the cost saving from eliminating the roads from the system. The authors discovered that in areas with a small rural population and a high percent of paved roads, a relatively large number of miles of county roads with no property access can be abandoned, and the savings from abandoning the roads will exceed the additional travel costs.

Sunanda Dissanayake and Litao Liu analyze the effects of speed limits on 41 locations in seven Kansas counties in *Speed Limit-Related Issues on Gravel Roads*, published in March 2009. The authors point out that Kansas has 75,000 miles of gravel roads, and most of them don't have posted speed limits. Instead, they are regulated with a 55 mph blanket speed limit established by Kansas statutes. Conditions of these gravel roads change with time, space, and quality of maintenance, making it even more necessary to control traffic speeds on these roads. The authors evaluated the effects of currently posted lower speed limits in some Kansas counties based on traffic characteristics and safety on gravel roads, with the intention of providing guidelines for setting speed limits on gravel roads in Kansas.

Field speed studies with automatic speed counters were conducted to study traffic characteristics of gravel roads. The authors used this data to calculate 85^{th}-percentile speed and mean speed on 40 gravel sections in seven Kansas counties. Crash data was also collected.

Dissanayake and Liu conducted a t-test to determine if there are differences in the mean speed between roads with no posted speed limits and those with a 35 mph speed limit. They found no significant difference in the mean speeds of the two road groups. Moreover the mean speed on sections with a 35 mph speed limit was a little higher than the speed on sections without posted speed limits.

The authors specified linear models to predict 85^{th}-percentile speed and mean speed on gravel roads. They found that traffic speeds are not significantly affected by the speed limit, but are related to road width, surface classification, and percentage age of large vehicles in the traffic stream.

Dissanayake and Liu conducted Chi-square tests with crash data and the results indicated that the posted 35 mph speed limit had not resulted in either a smaller total number of crashes or decreased the proportion of severe crashes, compared to gravel roads with no posted speed limit. Logistic regression models were also developed on four levels of crash severity, which indicated that gravel roads with higher speed limits have a higher probability of injury crashes.

The authors found some interesting results on average daily traffic (ADT) including the following:

1. ADT varied from 16 to 333 vehicles per day.
2. 78% of the gravel roads in the sample had ADT of less than 100 vehicles per day.
3. The percentage of heavy trucks varied from 4.1% to 45.8% with a mean of 20% of daily traffic.
4. The 85^{th} -percentile speed ranged from 27 mph on an urban gravel road to 67 mph on a sand surface gravel road.

The authors concluded that it does not appear that reducing the speed limit and posting it with signs is going to improve either traffic operational or safety characteristics on gravel roads in Kansas. The statutory set and unposted speed limit of 55 mph appears to be functioning at an acceptable level on most of the gravel roads examined in this study.

Steven D. Hanson, Cathy A. Hamlett, Gregory Pautsch, and C. Phillip Baumel describe the variable costs of the predominant types of vehicles operating on Iowa rural county roads in "Vehicle Travel Costs on Paved, Granular, and Earth Surfaced County Roads," in *Journal of the Transportation Research Forum* (1985). The authors calculate the variable costs for the following vehicle types:

- Automobiles
- Pickup trucks
- School buses
- Commercial trucks
- Garbage trucks
- Farmer-owned trucks
- Combines
- Farm tractors

Operating costs are estimated for each of the above vehicles on different road surfaces. Variable cost was defined as the sum of fuel, oil, tire, maintenance, and time costs and was assumed to be a linear function of the miles traveled on each road surface type.

The variable costs for paved surfaces were estimated for 14 types of road vehicles and 34 types and sizes of farm vehicles. The variable costs for gravel and earth surfaces were calculated by multiplying the variable costs for paved surfaces by adjustment factors, available from previous research for the road vehicles and calculated by the authors for farm vehicles.

The authors found that cost per mile is lowest on paved surfaces for all vehicles. For automobiles, pickup trucks, and commercial vans, the costs per mile increase 38–40% on gravel surfaces and 77–80% on earth surfaces. The costs per mile for farmer-owned tandem trucks increased 42–45 % on gravel and 84–91% on earth surfaces. Both farmer-owned and commercial semi tractor trailer costs rose 50% on gravel and 100% on earth surfaces relative to the costs of paved surfaces.

The authors concluded that variable cost per mile of vehicles operating on Iowa county roads varies widely by type of vehicle, size of vehicle, and type of surface. There is much less variance in cost per mile resulting from the size of the load hauled.

In an unpublished 1990 study, Peter S. Helmberger, Jerry Fruin, and Dan Halbach of the University of Minnesota develop a method to assess the economic impact of a rural road management study in *Net Benefits of Rural Road Management Strategies.* The strategy considers rural road abandonment and/or improvement, and it is employed in a case study of a Minnesota county. Specific objectives include the following:

1. Accurately model traffic flows in a simulated township which is based on data from the northern third of Polk County, Minnesota.
2. Estimate the total travel costs per mile for each vehicle type that uses the county's roads.
3. Estimate the total maintenance cost for maintaining one mile of both county and township roads.
4. Use the model to reroute traffic flows resulting from an abandonment/improvement scenario and estimate the changes in both total travel cost and total maintenance costs.
5. Examine the results and evaluate the resulting benefits and costs.

The management scenarios used in the study include the following:

1. The baseline scenario simulates traffic flows prior to any change in strategy, using data obtained from a survey. The scenario develops travel and maintenance costs to examine changes in these costs of various scenarios.
2. Minimum Mileage System. This scenario eliminates all links that are dead ends. It provides access for each building site to the road system without redundancy.

3. All Paved System. This scenario upgrades the road network and brings all bridges in the system up to acceptable standards.
4. Improve and Remove. This scenario is a combination of rural road and bridge improvements and closures.

The authors develop a net benefit model to estimate the impact on travel and maintenance cost of the various scenarios. The costs are the annual cost of maintaining the road system both before and after the road management scenario is adopted. These costs include the fixed maintenance costs due to weather and time, the variable maintenance costs depending on traffic levels, and the costs of periodic reconstruction and resurfacing. The fixed maintenance costs include drainage, signing, weed control, snow and ice removal, patching, reshaping, and clearing ditches and culverts. The variable maintenance costs include blading on gravel roads and repairs and replacement on paved roads.

The authors point out that the net benefit of a scenario depends on the relationship between travel cost and maintenance costs. A reduction of total road mileage in the system increases travel costs but decreases maintenance costs. The net benefit depends on the relative size of the two effects. The result of the net benefit analysis of the various scenarios allows the scenarios to be ranked in order of the greatest net benefit.

The total maintenance and travel cost of the baseline scenario was $122,806 per year. The Minimum Mileage scenario had total cost of $99,234, or $23,572 below the baseline cost. The costs of the All Paved scenario were $488,524, or $365,768 above the baseline costs. A scenario that reduces county road mileage with no adverse effect on travel costs resulted in total costs of $98,373, or $24,433 below the baseline costs. Thus the study demonstrated that net benefits can be increased by reducing the mileage of the county road system.

The publication titled, "When to Pave a Gravel Road" is Appendix D to a report by the Kentucky Transportation Center, University of Kentucky. The report notes that two-thirds of the road miles in the U.S. are low volume roads. Further, higher volumes and greater weights of truck traffic are putting an increasing strain on local road maintenance and reconstruction budgets.

The authors note several advantages of gravel roads such as lower construction and maintenance costs. Potholes can be patched more effectively, and speeds are less than paved roads. The report considers 10 answers to the question “Should we pave this road?”

In the process of answering the 10 questions the report makes several interesting observations including:

1. The average daily traffic volume (ADT) used to justify paving generally range from a low of 50 vehicles per day to 500. However, ADT is merely a guide and other factors such as types of traffic and the functional importance of the road need to be considered.
2. Due to safety considerations, no road should be paved that is less than 22 feet wide. Thus most gravel roads need to be widened before paving. Also, bridges on the road may need widening.
3. In deciding whether to pave a gravel road, total road costs and maintenance costs need to be analyzed. Maintenance costs for both paved and gravel roads include maintaining shoulders, keeping ditches and culverts clean, maintaining road signs, and replacing signs. The maintenance costs for paved roads only also involve patching, resealing, and striping. Gravel roads require regraveling, grading, and stabilization of soils or dust control.
4. The authors calculate an example comparing the maintenance costs per mile of paved and gravel roads and conclude that gravel roads have lower maintenance and construction costs.
5. However the report points out that vehicle costs for the road user are two to three times higher for a gravel road compared to a paved road. This is the case because there is greater rolling resistance and less traction on a gravel road which increases fuel consumption. The roughness of the surface contributes to additional tire wear and influences vehicle maintenance and repair costs. Dust causes extra engine wear, oil consumption, and maintenance costs. Passenger car

> user costs are 40% higher on a gravel road than a paved road. Thus when user costs are considered, paving the roadway may minimize the combined highway agency costs and user costs.

Peter E. Sebaaly, Raj Siddharthan, and David Huft evaluate the impact of agricultural equipment on the actual response of low volume roads in *Impact of Heavy Vehicles on Low Volume Roads,* published in 2003 by the Transportation Research Board as Transportation Research Record 1819. To accomplish this objective, one gravel section and one blotter section were instrumented in South Dakota and tested under various types of agricultural equipment. Field tests were carried out in the Fall 2000, Spring 2001, and Summer 2001. Testing in different seasons offered the opportunity to evaluate the impact of heavy equipment on low volume roads in high and low temperatures and wet and dry conditions.

The authors indentified agricultural equipment that frequently operates on low-volume roads in South Dakota. The equipment selected for field testing included the following:

- Terragator 8103 (three wheels)
- Terragator 8144 (four wheels)
- Grain cart (single axle)
- Tracked tractor

Terragators are used to apply agricultural chemicals in the field. Grain carts are employed to transport grain in the field from combines to trucks. Tractors are used to pull equipment in the field. The same equipment was tested on both the gravel and blotter sections during all three seasons. Each vehicle load combination was driven at its normal operating speed for a minimum of five replicate runs. The impact of the equipment on the road was measured with pressure cells and deflection gauges. To realistically simulate field conditions the equipment was loaded with actual cargo. Terragators were loaded with water, the grain cart was loaded with grain, and the single axle truck was loaded with sand.

The authors pointed out that the objective of the field test data is to assess the relative impact of the various vehicles compared with the standard 18,000 lb single axle truck (loaded dump truck). To do this the authors used a response ratio, defined as the ratio of pavement response under each combination of vehicle-load level divided by the pavement response under the 18,000 lb single axle truck. The authors concluded the following based on the field test:

- The tracked tractor is not more damaging than the 18,000 lb single-axle truck during all seasons.
- Terragators 8103 and 8144 unloaded are more damaging than the 18,000 lb single-axle truck during the spring and summer seasons.
- Terragators 8103 and 8144 loaded are more damaging than the 18,000 lb single-axle truck during all three seasons.
- The grain cart is more damaging than the 18,000 lb single-axle truck during the spring and summer seasons.
- The grain cart loaded over the legal limit is more damaging than the 18,000 lb single-axle truck during all three seasons.

The authors concluded that the impacts of agricultural equipment on low-volume roads depends on factors such as season, load level, thickness of crushed aggregate base (CAB), and soil type. They said damage can be reduced with a thicker CAB or by subjecting the agricultural equipment to the legal load limit, i.e. about 20,000 lb.

In "Modeling the Rationalization of Rural Road Networks: The Case of Saskatchewan," Paul Christensen, James Nolan, and Gordon Sparks develop a mathematical model of rural road investment/abandonment based upon traffic flows and the cost of maintaining a given road surface type. The authors say that by incorporating demand, maintenance costs, and routing decisions they hope to develop a systematic approach to the problem of rural road abandonment and make planning decisions easier and more politically justifiable. They also extend the application of formal network modeling to rural road problems.

The authors use a network model in which trips origins are nodes and the lines connecting the nodes are arcs. Their model contains a set of road decisions (M) where the set M includes

- The status quo (the original road types assigned to each arc and may include gravel, pavement, or thin asphalt surface).
- Abandonment.

- Upgrade of road surface.

The model contains traffic categories termed (K) where the set K includes passenger movements between various nodes and freight movements between them. The model has traffic flows assigned to each model arc. The traffic flow variable denotes the amount of traffic flow over a specific arc belonging to traffic category (K) and road type m. The model also contains unit average variable costs that account for all variable user and road damage costs associated with particular road types and traffic categories. Multiplying the traffic flows assigned to each model arc by the unit variable cost results in total annual cost in dollars per kilometer. Multiplying this total cost measure by the length of the arc in kilometers results in the total annual variable cost corresponding to traffic flows across the arc.

The unit capital cost denotes either the remaining worth of an existing road segment (i.e. the arc) or the capital cost required to abandon or upgrade the road segment. To obtain total capital cost corresponding to each segment, the authors multiply the unit capital cost by a binary variable where its value can be zero or one for each possible road decision (status quo, abandonment or upgrade). Multiplying the result by segment length provides total capital cost per segment. The authors close the model by multiplying base annual maintenance cost corresponding to each road segment and road type by length of the road segment to obtain base annual maintenance cost.

The authors introduce constraints limiting the upgrade or abandonment of road segments that include budget money at time zero and physical resources (kilometers by road type at time zero). The model then determines the total cost minimizing network configuration. The authors then make some assumptions in order to calibrate a base solution and then estimate some scenarios with alternative values of key variables.

The network configurations examined by the authors involved a considerable amount of road abandonment and rerouting of users to their destinations. They found that the scenario with an unconstrained capital budget resulted in the most convenient network configuration for users. They indicate that the future of the rural road network in Saskatchewan will involve a tradeoff between cost and convenience.

Chapter 3: Socioeconomic Profiles of Sample Counties

3.1 Similarities and Differences of Sample Counties

The counties selected for analysis are Brown County (northeast Kansas), Pratt County (south central Kansas), and Thomas County (northwest Kansas). The county's were selected to obtain geographic variation, and because the study is concerned with rural roads, these counties were selected because they have the greatest agricultural production in their respective regions.

The populations of the counties are similar (between 7,300 and 9,900) but they vary greatly in size and population density. Brown County has 571 square miles and 18.8 people per square mile, while Thomas County has 1,075 square miles and only 7.6 people per square mile. The largest city in each county is the county seat, but there is variation in the percent of total county population concentrated in these cities. In Pratt County, the city of Pratt accounts for nearly 68% of total county population while Colby represents 66% of Thomas County population. Rural township residents account for about 25% of the population in these two counties. However, in Brown County, Hiawatha represents only 31% of the county population with rural townships accounting for about 37%.

Total 2009 employment in Brown, Pratt, and Thomas counties was 7,442, 6,860, and 4,961, respectively. In 2009, the unemployment rates in the three counties were less than the Kansas unemployment rate (6.7%), ranging from a low of 3.6% (Thomas County) to a high of 5.5% (Brown County). Local government was the largest employer in all three counties ranging from 14.3% of total county employment (Pratt County) to 23.8% (Brown County). Other large industry employers in Brown County were health care and social assistance (12.0% of total county employment) and manufacturing (9.2%). In Pratt County, retail trade (12.8%) and health care and social assistance (11.6%) were significant employment industries. Retail trade (14%) and accommodations and food service (10.3%) were major employers in Thomas County.

In 2008, per capita income in Pratt and Thomas County was about the same as Kansas ($38,886) with incomes of $38,638 and $38,183, while per capita income was nearly 10% less than Kansas as a whole in Brown County ($35,019). Median personal income in all three counties was substantially less than the statewide figure of $50,174. In contrast, the 2008 median personal income in Brown, Pratt, and Thomas counties was $38,162, $44,498, and $45,735 respectively.

As noted above, all three counties have large agricultural production. In Brown County, the 2007–2009 average total production of corn, wheat, sorghum, and soybeans was 21.5 million bushels with corn accounting for 75% and soybeans 23% of the total. The 2007–2009 average total production for the same four crops in Pratt County was 18.7 million bushels with corn accounting for 55% of the total production and wheat representing 30%. The corresponding figure for Thomas County was 30.8 million bushels with corn and wheat accounting for 63% and 25% of total average production.

A detailed discussion of each county is in Section 3.2 of this report.

3.2 Brown County

Brown County, located in northeast Kansas, is one of 105 Kansas counties. It has a land area of 571 square miles and a population density of 18.8 people per square mile (U.S. Census Bureau, *State and County Quick Facts*, http://quickfacts.census.gov).

The county population is geographically concentrated in Hiawatha (the county seat) and Horton which account for 32.1% and 18% of the 2009 Brown County population. The county population distributed by city and rural residents is in Table 3.1.

TABLE 3.1
2009 Brown County Population by City and Township

City	Population	% of Brown County Population
Hiawatha	3,182	31.1
Horton	1,782	18.0
Everest	294	3.0
Fairview	250	2.5
Morrill	244	2.5
Robinson	192	1.9
Reserve	93	0.9
Powhattan	85	0.8
Willis	64	0.6
Hamlin	49	0.5
Sabetha (part)	37	0.4
Township (Rural Residents)	3,655	36.8
Total	9,927	100.0

Source: *2009–2010 Governors Economic and Demographic Report, Appendix F.*

As indicated in Table 3.1, Everest, Fairview, Morrill, Robinson, Reserve, Powhattan, Willis, Hamlin, and Sabetha (part) collectively account for 13.1% of the county population, with 36.8% located in rural areas of the county.

Brown County population by age indicates that the county has a higher average age (40 years) than Kansas (36.2 years) and the U.S. (36.2 years) (http://www.epodunk.com). Table 3.2 contains the distribution by age of the Brown County 2000 population.

TABLE 3.2
2000 Distribution of Brown County Population by Age (Percent)

Age	Brown County	Kansas	U.S.
15 or younger	21.0	21.9	21.4
16–24	12.7	14.9	13.9
25–44	24.0	28.6	30.2
45–64	22.7	21.4	22.0
65+	19.5	13.3	12.4

Source: Epodunk, Population Overview (http://www.epodunk.com).

Examination of the data in Table 3.2 indicates that Brown County has nearly 20% of its population, age 65 and over (19.5%) compared to Kansas (13.3%) and the U.S. (12.4%).

TABLE 3.3
2009 Brown County, Kansas, and U.S. Population by Race (Percent)

Race	Brown County	Kansas	U.S.
White*	83.9	79.9	65.1
Black	1.8	6.2	12.9
Hispanic**	3.6	9.3	15.8
American Indian	9.2	1.0	1.0
Asian	0.5	2.3	4.6
Other	1.0	1.3	0.6

*White persons, not Hispanic

**Persons of Hispanic or Latino origin

Source: U.S. Bureau of the Census, State and County Quick Facts, http://quickfacts.census.gov

Table 3.3 contains 2009 population by race for Brown County, Kansas, and the U.S. Examination of Table 3.3 indicates that Brown County and Kansas have a significantly higher percent of white population than the U.S. Brown County has a significantly lower percentage of black and Hispanic residents than Kansas and the U.S., but a much higher percentage of American Indian residents.

The distribution of Brown County population by gender in 2009 was 51.4% female and 48.6% male, about the same as Kansas and the U.S. (U.S. Bureau of the Census, *State and County Quick Facts*, http://quickfacts.census.gov).

Table 3.4 contains 2009 Brown County employment by industry. Inspection of the data indicates that the major employers are local government (23.8%), health care and social assistance (12.0%), manufacturing (9.2%), construction (8.7%), retail trade (8.1%), and farm-agriculture (6.7%). Total employment was 7,442. In 2009 the unemployment rate in Brown County was 5.5% compared to 6.7% for Kansas as a whole (USDA, Economic Research Service. *County-Level Unemployment and Median Household Income for Kansas*, http://www.ers.usda.gov).

TABLE 3.4
Brown County Employment by Industry, 2009

Industry	Employment	% of Total
Farm Employment	512	6.88
Forestry, Fishing, Related Activities	D	–
Mining	D	–
Utilities	D	–
Construction	647	8.69
Manufacturing	688	9.24
Wholesale Trade	173	2.32
Retail Trade	603	8.10
Transportation and Warehousing	D	–
Information	71	0.95
Finance and Insurance	350	4.70
Real Estate and Rental and Leasing	151	2.03
Professional, Scientific, and Technical Services	166	2.23
Management of Companies, Enterprises	D	–
Administrative and Waste Services	D	–
Education Services	17	0.23
Health Care and Social Assistance	894	12.01
Arts, Entertainment, and Recreation	15	0.20
Accommodation and Food Service	400	5.37
Other Services, except Public Admin	351	4.72
Government and Government Enterprises	1,981	26.62
Federal	138	1.85
State and Local	1,843	24.76
State	74	0.99
Local	1,769	23.77
Total Employment	7,442	

D: Employment not disclosed due to data confidentiality rules
Source: U.S. Department of Commerce, Bureau of Economic Analysis. *CA25N - Total Full-Time and Part-Time Employment by NAICS Industry*. (http://www.bea.gov/regional/reis).

Table 3.5 displays 2008 per capita personal income and median family income for Brown County, Kansas, and the U.S.

TABLE 3.5
2008 Per Capita Personal Income and Median Household Income for Brown County, Kansas, and the U.S. (U.S. Dollars)

Income	**Brown County**	**Kansas**	**U.S.**
Per Capita Personal Income	35,019	38,886	40,166
Median Household Income	38,162	50,174	52,029

Source: U.S. Census Bureau, *State and County Quick Facts*, http://quickfacts.census.gov.

The data in Table 3.5 indicates that 2008 Brown County per capita personal income is 9.9% less than Kansas and 12.8% less than the U.S. The income disparity is even larger for median household income as Brown County is 23.9% less than Kansas and 26.6% less than the U.S.

Agriculture is an important industry in Brown County. In 2007, there were 637 farms covering 346,758 acres. The market value of crops was $86.5 million and $29.8 million for livestock (Kansas Department of Agriculture, *Kansas Farm Facts 2010*). Table 3.6 contains Brown County crop production for the 2007–2009 period.

TABLE 3.6
Brown County Crop Production, 2007–2009 (Thousands of Bushels)

Year	Wheat	Corn	Sorghum	Soybeans	Total
2007	449	13,654	66.8	4,906.8	19,076.6
2008	390	14,460	71.2	3,877.0	18,798.2
2009	275	20,400	0	6,020	26,695
Average	371.3	16,171.3	69	4934.6	21,523.3

Source: Kansas Department of Agriculture, *Kansas Farm Facts 2008 and 2009*

During the period wheat production averaged 371.3 thousand bushels, corn 16.17 million, sorghum 69 thousand, and soybeans 4.93 million bushels. Total production of the four crops averaged 21.52 million bushels of which corn accounted for 75.1% and soybeans 22.9%.

Brown County crops are stored and marketed by Ag Partners Coop, Fairview Mills, Morrill Elevator Inc, and Farmers Coop Elevator (Sabetha). These four grain companies collectively operate 10 grain elevators with a total storage capacity of 9.6 million bushels (Kansas Grain and Feed Association, *2010 Official Kansas Directory*).

The Brown County road system is a township system whereby the county operates and maintains a system of designated county roads and each of 10 townships operates and maintains the roads in the township designated as township roads. The county road system is composed of 270.5 miles of asphalt road, four miles of gravel road and a mile of earth road. The township road system consists of 536 miles of gravel road and 228 miles of earth road. Thus the Brown County/Township road system includes 270.5 miles of asphalt, 540 miles of gravel, and 229 miles of earth road for a total road system of 1,039.5 miles.

The annual combined county/township road and bridge operating budget increased by only 7.4% between 2006 ($2,899,613) and 2009 ($3,114,661). The average budget during the period was $2,928,835. The Brown County annual road maintenance and construction costs for the 2006–2009 period are displayed in Table 3.7.

TABLE 3.7
Brown County Road Maintenance and Construction Expenses, 2006–2009 (U.S. Dollars)

Annual Maintenance					
	County			Township	
Year	**Asphalt**	**Gravel**	**Bridges**	**Gravel/Earth**	**Total**
2006	976,971	27,854	38,123	811,552	1,185,446
2007	1,189,091	83,748	42,076	714,255	2,029,170
2008	1,428,045	63,034	45,357	817,692	2,354,128
2009	1,259,091	166,768	46,033	976,996	2,448,888
4 Year Average	1,213,286	85,351	42,897	830,124	2,171,658

Annual Construction				
	County		Township	
Year	**Roads**	**Bridges**	**Roads**	**Total**
2006	164,474	61,900	68,061	294,435
2007	141,750	84,504	63,320	289,574
2008	93,251	112,000	105,935	311,186
2009	206,747	54,066	82,965	343,778
4 Year Average	151,556	78,117	80,070	309,743

Source: Brown County Engineers/Road Supervisors Annual Report, 2006–2009 issues

Examination of Table 3.7 indicates that county maintenance expenditures reflect road miles by surface type as 87.6% of the average county annual maintenance expenditures are for asphalt roads.

3.3 Pratt County

Pratt County is located in south central Kansas. It has a land area of 735 square miles and a population density of 13 people per square mile compared to 32.9 for Kansas and 79.6 for the U.S. (http://www.epodunk.com).

The county population is geographically concentrated in Pratt, which is the county seat and accounts for 68% of county population. The county population distributed by city and rural residents is in Table 3.8.

TABLE 3.8
2009 Pratt County Population by City and Township

City	Population	% of Pratt County Population
Pratt	6,315	67.9
Iuka	180	1.9
Preston	159	1.7
Sawyer	119	1.3
Coats	108	1.2
Cullison	95	1.0
Byers	49	0.5
Township (Rural Residents)	2,279	24.5
Total	9,304	100.0

Source: *2009–2010 Governors Economic and Demographic Report, Appendix F.*

As indicated by Table 3.8, Iuka, Preston, Sawyer, Coats, Cullison, and Byers collectively account for 7.6% of the county population, with 24.5% located in rural areas of the county.

Pratt County population by age indicates that the county has a higher average age (40 years) than Kansas (36.2 years) and the U.S. (36.2 years) (http://www.epodunk.com).

TABLE 3.9
2000 Pratt County, Kansas, and U.S. Population by Age (Percent)

Age	Pratt County	Kansas	U.S.
15 or younger	19.3	21.9	21.4
16–24	14.6	14.9	13.9
25–44	24.0	28.6	30.2
45–64	22.8	21.4	22.0
65+	19.2	13.3	12.4

Source: Epodunk, Population Overview (http://www.epodunk.com).

As indicated by Table 3.9, the percent of the population age 65 and over is 19.2% in Pratt County compared to only 13.3% in Kansas and 12.4% in the U.S. as a whole.

TABLE 3.10
2009 Pratt County, Kansas, and U.S. Population by Race (Percent)

Race	Pratt County	Kansas	U.S.
White*	91.5	79.9	65.1
Black	1.2	6.2	12.9
Hispanic**	5.2	9.3	15.8
American Indian	0.5	1.0	1.0
Asian	0.6	2.3	4.6
Other	1.0	1.3	0.6

*White persons, not Hispanic

**Persons of Hispanic or Latino origin

Source: U.S. Bureau of the Census, *State and County Quick Facts*, http://quickfacts.census.gov

Table 3.10 contains 2009 population by race for Pratt County, Kansas, and the United States. The data indicates that Pratt County has a much higher percentage of white residents (91.5%) than Kansas (79.9%) and the U.S. (65.1%) and a correspondingly lower percentage of black and Hispanic population than Kansas and the U.S.

The distribution of Pratt County population by gender in 2009 was 51.0% female and 49.0% male (U.S. Bureau of the Census, *State and County Quick Facts*, http://quickfacts.census.gov).

Table 3.11 displays Pratt County employment by industry for 2009. The principal industries are local government and government enterprises (14.3%), retail trade (12.8%), health care and social assistance (11.6%), mining (9.7%), agriculture/farm (7.4%), and accommodation and food service (7.8%). Total employment was 6,860. In 2009, unemployment in Pratt County averaged 4.9% compared to 6.7% for Kansas, and 9.3% for the U.S. (USDA, Economic Research Service. *County-Level Unemployment and Median Household Income for Kansas*, http://www.ers.usda.gov).

TABLE 3.11
Pratt County Employment by Industry, 2009

Industry	Employment	% of Total
Farm Employment	505	7.36
Forestry, Fishing, Related Activities	D	–
Mining	665	9.69
Utilities	D	–
Construction	364	5.31
Manufacturing	108	1.57
Wholesale Trade	124	1.81
Retail Trade	876	12.77
Transportation and Warehousing	D	–
Information	54	0.79
Finance and Insurance	301	4.39
Real Estate and Rental and Leasing	145	2.11
Professional, Scientific, and Technical Services	219	3.19
Management of Companies, Enterprises	69	1.01
Administrative and Waste Services	137	2.00
Education Services	30	0.44
Health Care and Social Assistance	798	11.63
Arts, Entertainment, and Recreation	51	0.74
Accommodation and Food Service	533	7.77
Other Services, except Public Admin	352	5.13
Government and Government Enterprises	1,253	18.27
Federal	79	1.15
State and Local	1,174	17.11
State	196	2.86
Local	978	14.26
Total Employment	6,860	

D: Employment not disclosed due to data confidentiality rules

Source: U.S. Department of Commerce, Bureau of Economic Analysis. *CA25N - Total Full-Time and Part-Time Employment by NAICS Industry*. (http://www.bea.gov/regional/reis).

In 2008, per capita personal income in Pratt County was $38,638, and median household income was $44,498 (U.S. Bureau of the Census, Housing and Household Economic Statistics Division. *Small Area Income and Poverty Estimates*, http://www.census.gov/hhes/www/saipe/county). The corresponding figures for Kansas were $38,886 and $50,174 (U.S. Census Bureau, Housing and Household Economic Statistics Division, *Small Area Income and Poverty Estimates*, http://www.census.gov/hhes/www/saipe/county.html).

Agriculture is an important industry in Pratt County. In 2007, there were 538 farms covering 480,162 acres. The market value of crops was nearly $63 million and for livestock was $110.6 million (Kansas Department of Agriculture, *Kansas Farm Facts 2010*, p. 7). Table 3.12 contains Pratt County crop production for the 2007–2009 period.

TABLE 3.12
Pratt County Crop Production, 2007–2009 (Thousands of Bushels)

Year	Wheat	Corn	Sorghum	Soybeans	Total
2007	3,362	10,180	1,996.1	688.6	16,226.7
2008	6,719	9,370	2,599.5	689*	19,377.5
2009	6,610	11,150	2,090	689*	20,539
Average	5,564	10,233	2,228.5	689	18,714.4

*No data was found for soybeans in 2008 or 2009 in Kansas Farm Facts. Thus the 2007 production was assumed.
Source: Kansas Department of Agriculture, *Kansas Farm Facts 2008 and 2009*

During the period, wheat production averaged 5.56 million bushels, corn 10.23 million, sorghum 2.2 million, and soybeans 689 thousand bushels. Total production of the four crops averaged 18.71 million bushels of which corn accounted for 54.7% and wheat 29.7%.

Pratt County crops are stored and marketed by ADM Grain, Cairo Coop Exchange, Kanza Coop Association, and Farmers Coop Equity Exchange. These four grain companies collectively operate 23 grain elevators with total storage capacity of 20.2 million bushels (Kansas Grain and Feed Association, *2010 Kansas Official Directory*).

The Pratt County road system is a consolidated unit system whereby the county operates and maintains all the county's roads. Townships do not have separate road maintenance budgets. The county road budget increased from $2,496,500 in 2006 to $3,570,000 in 2009, a 43%

increase. The average budget during the period was $3,067,375. The county road system consists of 1,400 miles of which 138 miles is asphalt and 1,262 miles is gravel surface (County Engineers/Road Supervisors Annual Report, 2006–2009). Pratt County annual road maintenance and construction costs for the 2006–2009 period are displayed in Table 3.13.

TABLE 3.13
Pratt County Road Maintenance and Construction Expenses, 2006–2009 (U.S. Dollars)

	Annual Maintenance			
Year	**Asphalt**	**Gravel**	**Bridges**	**Total**
2006	230,169	902,200	9,145	1,141,514
2007	50,781	1,376,452	37,239	1,464,472
2008	105,310	1,586,775	47,417	1,739,502
2009	63,317	2,245,167	35,628	2,344,112
4-Year Average	112,394	1,527,649	32,357	1,672,400

Annual Construction

Year	**Road Construction**
2006	985,300
2007	886,894
2008	1,316,338
2009	950,415
4-Year Average	1,034,737

Source: Pratt County Engineers/Road Supervisors Annual Report, 2006–2009 issues

Examination of Table 3.13 indicates that expenditures for maintenance reflect the road miles by surface type as 91.3% of the average annual maintenance expenditures are for gravel roads.

3.4 Thomas County

Thomas County, located in northwest Kansas, has a land area of 1,075 square miles and a population density of 7.6 people per square mile compared to 32.9 for Kansas and 79.6 for the U.S. (U.S. Bureau of the Census, *State and County Quick Facts*, http://quickfacts.census.gov).

Colby is the county seat and accounts for two-thirds of Thomas County 2009 population of 7,343. The county population distributed by city and rural residents is in Table 3.14.

TABLE 3.14
2009 Thomas County Population by City and Township

City/Township	Population	% of Thomas County Population
Colby	4,834	65.8
Brewster	251	3.4
Rexford	145	2.0
Gem	88	1.2
Menlo	53	0.7
Oakley (part)	49	0.7
Township (Rural Residents)	1,923	26.2
Total	7,343	100.0

Source: *2009–2010 Governors Economic and Demographic Report, Appendix F.*

As indicated by Table 3.14, Brewster, Rexford, Gem, Menlo, and Oakley (part) collectively account for only 8% of the county population, while 26.2% are located in the rural part of the county.

Table 3.15 contains Thomas County population by age. Unlike Brown and Pratt County which had a higher average age in 2000 than Kansas and the U.S., there is virtually no difference in the average age of Thomas County (36.4 years), Kansas (36.2 years) and the U.S. (36.2 years) (http://www.epodunk.com).

TABLE 3.15
2000 Thomas County, Kansas, and U.S. Population by Age (Percent)

Age	Thomas County	Kansas	U.S.
15 or younger	21.4	21.9	21.4
16–24	18.4	14.9	13.9
25–44	24.4	28.6	30.2
45–64	21.2	21.4	22.0
65+	14.6	13.3	12.4

Source: Epodunk, *Population Overview* (http://www.epodunk.com).

As indicated by the data in Table 3.15, there is very little difference in the age distribution of the Thomas County and Kansas population. Thomas County has a higher percentage (18.4%) than the U.S. (13.9%) of people age 16–24. However, Thomas County has a lower percentage (24.4%) than the U.S. (30.2%) of people age 25–44.

Table 3.16 contains 2009 population by race for Thomas County, Kansas, and the U.S.

TABLE 3.16
2009 Thomas County, Kansas, and U.S. Population by Race (Percent)

Race	**Thomas County**	**Kansas**	**U.S.**
White*	93.7	79.9	65.1
Black	0.8	6.2	12.9
Hispanic**	3.6	9.3	15.8
American Indian	0.5	1.0	1.0
Asian	0.4	2.3	4.6
Other	1.0	1.3	0.6

*White persons, not Hispanic

**Persons of Hispanic or Latino origin

Source: U.S. Bureau of the Census, *State and County Quick Facts*, http://quickfacts.census.gov

The data in Table 3.16 reveals that Thomas County has a much higher percentage (93.7%) of white residents than Kansas (79.9%) and the U.S. (65.1%) and a correspondingly lower percentage of black (0.8%) and Hispanic (3.6%) population than Kansas (6.2% and 9.3%) and the U.S. (12.9% and 15.8%).

The distribution of Thomas County population by gender in 2009 was 51.3% female and 48.7% male (U.S. Bureau of the Census, *State and County Quick Facts*, http://www.quickfacts.census.gov).

Table 3.17 displays 2009 Thomas County employment by industry.

TABLE 3.17
Thomas County Employment by Industry, 2009

Industry	Employment	% of Total
Farm Employment	488	9.84
Forestry, Fishing, Related Activities	D	–
Mining	D	–
Utilities	43	0.87
Construction	234	4.72
Manufacturing	78	1.57
Wholesale Trade	415	8.36
Retail Trade	693	13.97
Transportation and Warehousing	87	1.75
Information	109	2.20
Finance and Insurance	136	2.74
Real Estate, Rental and Leasing	40	0.81
Professional, Scientific, and Technical Services	98	1.98
Management of Companies, Enterprises	0	–
Administrative and Waste Services	39	0.79
Education Services	D	–
Health Care and Social Assistance	D	–
Arts, Entertainment, and Recreation	37	0.75
Accommodation and Food Service	509	10.26
Other Services, except Public Admin	292	5.89
Government and Government Enterprises	1,001	20.18
Federal	73	1.47
State and Local	928	18.71
State	138	2.78
Local	790	15.92
Total Employment	4,961	

D: Employment not disclosed due to data confidentiality rules

Source: U.S. Department of Commerce, Bureau of Economic Analysis. *CA25N - Total Full-Time and Part-Time Employment by NAICS Industry*. (http://www.bea.gov/regional/reis).

Table 3.17 data indicate that Thomas County's major employers are local government and government enterprises (15.9%), retail trade (14%), accommodation and food service (10.3%), agriculture/farm (9.8%), and wholesale trade (8.4%). Total employment was 4,961. In 2009, unemployment in Thomas County averaged 3.6%, significantly less than Kansas (6.7%) and the U.S. (9.3%) (U.S.D.A., Economic Research Service. *County Level Unemployment and Median Household Income for Kansas*, http://www.ers.usda.gov).

In 2008, per capita personal income in Thomas County was $38,183, and median household income was $45,735 (U.S. Bureau of the Census, Housing and Household Economic Statistics Division, *Small Area Income and Poverty Estimates*, http://census.gov/hhes/www/saipe/county.html). The corresponding figures for Kansas were $38,886 and $50,174 (U.S. Census Bureau, Housing and Household Economics Statistics Division, *Small Area Income and Poverty Estimates*, http://census.gov/hhes/www/saipe/county.html).

Agriculture is an important industry in Thomas County. In 2007, there were 464 farms covering 657,471 acres. The market value of crops was $129.5 million and livestock was $81.5 million (Kansas Department of Agriculture, *Kansas Farm Facts 2010*, p. 7). Table 3.18 displays Thomas County crop production for the 2007–2009 period.

TABLE 3.18
Thomas County Crop Production, 2007–2009 (Thousands of Bushels)

Year	Wheat	Corn	Sorghum	Soybeans	Total
2007	8,215	22,791	3,150.1	505	34,661.1
2008	6,731	16,708	3,150.1	505	27,094.1
2009	7,985	19,150	3,150.1	505	30,790.1
Average	7,643.7	19,549.7	3,150.1	505	30,848.4

*The 2010 Farm Facts didn't publish the 2008 and 2009 production of sorghum and soybeans due to insufficient or confidential data. Therefore the 2007 production was assumed to approximate the 2008 and 2009 production.
Source: Kansas Department of Agriculture, *Kansas Farm Facts 2008 and 2009*

During the period, wheat production averaged 7.6 million bushels, corn 19.55 million, sorghum 3.15 million, and soybeans 505 thousand bushels.

Thomas County crops are stored and marketed by ADM Grain, Frontier Ag Inc, Bartlett Grain, Cooper Grain, Cornerstone Ag, LLC, and Hi Plains Coop Assn. These six grain companies collectively operate 39 grain elevators with total storage capacity of 49.4 million bushels, although not all of the elevators operated by these grain companies are located in Thomas County (Kansas Grain and Feed Association, *2010 Kansas Official Directory*).

The Thomas County road system is county/township system whereby the county operates and maintains a system of designated county roads and each of the 13 townships operates and maintains the roads in the township that are designated as township roads. The Thomas County road system consists of 118.3 miles of asphalt road, 113.8 miles of gravel road, 47 miles of gravel road in East Hale township, and 125 miles of gravel road in Rovohl township, a total of 404.1 miles. The Thomas County annual road and bridge maintenance costs are in Table 3.19.

TABLE 3.19
Thomas County Road Annual Maintenance Expenses, 2006–2009 (U.S. Dollars)

Year	Asphalt	Gravel	Bridges	Total
2006	558,522	132,791	1,650	692,963
2007	553,017	136,555	–	689,572
2008	766,000	172,700	–	938,700
2009	763,055	124,331	–	887,386
4 Year Average	660,149	141,594	413	802,156

Source: *Thomas County Engineers/Road Supervisors Annual Report*, 2006–2009 issues

The Thomas County annual road and bridge and operating budget increased from $1,245,919 (2006) to $1,303,200 (2008), a 4.6% increase. However, in 2009 the budget was $1,264,563, only 1.5% higher than the 2006 budget.

Examination of Table 3.19 indicates that Thomas County devotes an average of 82.3% of its average annual maintenance expenses to asphalt roads. Only $1,650 was spent on bridge maintenance in the 2006–2009 period. In 2006, the county spent $210,100 for road construction/reconstruction, but nothing in the 2007–2009 era.

Chapter 4: Procedure and Results

4.1 Procedure

In this chapter the procedures used to measure the benefits and costs of simulated county road closure are discussed. The cost of road closure is the additional travel cost of rural residents due to more circuitous routing to their destinations. The benefit is avoided road maintenance costs of roads removed from the county network. TransCAD calculates the total travel cost for all rural resident trips assuming the county road network as it currently exists. Then selected low-volume road segments are removed from the network and TransCAD recalculates total travel cost for rural resident trips. The difference between the two travel cost simulations is the cost of the assumed closed roads. The benefit of road closure is the avoided maintenance and reconstruction costs of the closed road segments. Total benefit is calculated by multiplying the number of miles assumed to be closed by the avoided maintenance cost per mile.

TransCAD creates maps to aid the selection of low-volume road segments for potential deletion from the county road network coupled with rerouting of the low-volume traffic to alternative roads.

In each county, 10 road segments were selected as potential candidates for simulated closure. This was done to analyze the traffic impacts on alternative roads near the road segments being considered for simulated closure. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads. TransCAD maps and KDOT traffic counts were used to identify candidate roads for simulated closure.

The identification of the 10 road segments and calculation of traffic rerouting as a result of simulated closure was a three-step process. In the first stage, relatively low-volume roads were identified by KDOT traffic count data. Single-access roads (the only road between a specific origin and destination) were eliminated as candidates for simulated closure. The second stage involved identification of the roads whose traffic would be affected by closure of an area road segment. For example, it was assumed that by closing a road segment, in most cases, traffic on a parallel road would increase. In the third stage, TransCAD rerouted all the previous traffic on the closed road segment to determine the traffic impact on other roads after the candidate road is deleted from the network. Since traffic on the closed segment is relatively low, the impact on the traffic on roads in the vicinity of the closed road is small.

The rural resident survey asks rural residents to provide data on their travel patterns required to implement the transportation model. To maintain confidentiality of the respondents, section, range, and township were used as the household identification variable or the origin of trips. The survey asked rural residents to identify the vehicles they operate on the county roads, the level of use of these roads, and the destinations of their trips. The destinations were converted into section, range, and township in order to match the destinations with the origins.

Based on destination information, level of use of county roads, types of vehicles used, and trip origins an Origin-Destination (O and D) matrix can be obtained. To create the O&D matrix, origin and destination information was used along with the average number of daily trips. The most important variable in the O&D matrix is the travel cost which is the total cost to travel from the origin to the destination. The rural resident survey provided length of trip information. Thus, in order to determine travel cost, free flow speed (the posted speed limit) was used. TransCAD reroutes traffic after deleting the selected roads from the county network. The simulated closure of roads impacts the travel cost for some rural residents since traffic is directed to alternate roads. TransCAD then calculates the travel cost for each of the 10 simulated road closures, which are summed to obtain total travel cost.

It was assumed that rural residents would use cars and pickup trucks for grocery and pleasure trips while five axle semis and tandem axle trucks are used for grain hauling. In the rural resident survey, respondents were asked to indicate their destinations for each type of vehicle. However, to simplify computation, only the most important destination for each vehicle type was used. Also to simplify computation, all truck types (other than pickup) were combined into one category. Thus there are three vehicle types in the analysis: cars, pickups, and trucks. The maintenance cost per mile was obtained from previous studies and is assumed to be the same in all three counties.

4.2 Brown County Results

As noted in the previous section, we simulated the closure of 10 Brown County road links (segments) varying in length from a minimum of two miles to a maximum of 6.51 miles. Table 4.1 lists all the links selected for simulated closure and the length of each link.

TABLE 4.1
Deleted Links in Brown County

Link	Miles
1	3.37
2	3.96
3	2.04
4	4
5	4
6	4.44
7	3
8	2
9	4.95
10	6.51
Total (Miles)	38.27

Among the three selected counties, Brown County has the most extensive road network in terms of the ratio of the number of miles of road to the total area of the county. For this reason, Brown County had the highest mileage of simulated closure of the three counties in the analysis. The majority of links selected for simulated closure are in the northwest and southwest parts of the county as most of the rural resident survey data was concentrated in these parts of the county. Every road segment selected for simulated closure has a superior or equivalent quality alternate route. For example, if link 1 is a gravel road, then the alternate route is paved or an equivalent gravel route.

4.2.1 Alternate Routes: Brown County

When road links from the Brown County road system were deleted from the network, one of the major challenges was identification of the other roads which were affected by the simulated closure of the road link. Identification of alternate routes was essential because of the need to estimate the traffic flow on the alternate roads. First, the traffic flow (Average Daily Traffic, ADT) on the selected alternate route was calculated using TransCAD with all the existing roads in the network. After deletion of the link from the system the traffic on the alternate routes was recalculated. This results in the traffic flow on the alternate routes before and after deletion of the road link. Table 4.2 presents the percentage change in the traffic flow on the alternative routes after the selected links are deleted from the Brown County road network.

The data in Table 4.2 indicate that traffic volume per day is high on some of the alternative routes. The reason is that these alternative routes have better roads than the deleted links and some of the alternate route includes a state highway. The percentage change in ADT is less than 10% for eight of the 10 alternate routes and seven of the 10 have less than a 4% change in ADT. The percentage increase in ADT for alternative route 6 is 123.6%. The ADT on alternate routes 8 and 9 decreased slightly.

TABLE 4.2
Brown County Traffic Variation on the Alternate Routes (ADT)

Alternate Route	Traffic Range Before Deletion (ADT)	Traffic Range After Deletion (ADT)	ADT Percentage Change
1	>100 & <200	>100 & <200	3.47
2	>300 & <400	>300 & <400	19.06
3	>100 & <200	>100 & <200	8.47
4	>400	>400	3.12
5	>300 & <400	>300 & <400	3.25
6	>300 & <400	>400	123.58
7	>400	>400	1.94
8	>400	>400	-1.07
9	>400	>400	-0.77
10	>400	>400	2.95

ADT: Average Daily Traffic

The Brown County road system has higher traffic volume than Pratt and Thomas County since the population density is much higher. Other factors responsible for high ADT on Brown County alternate routes are inclusion of state highways in the alternate route and the distance from major towns of the alternate route.

Table 4.2 illustrates the variation in the traffic on alternative routes when the selected links are deleted from the network. Also, the data in Table 4.2 is a good indicator of whether selected links should be deleted from the county road network in the first place. For example, after link 6 is deleted, alternative route 6 experiences a large surge in ADT. Similarly, alternative route 2 experiences nearly a 20% increase in ADT after link 2 is eliminated from the network. In these cases, the traffic diversion to the alternative route is high and congestion on the road increases. Thus links 2 and 6 should not be deleted from the Brown County road system. It was decided that a 15% change in the ADT on alternative routes after the link is deleted would be the threshold level to determine whether a link should be deleted or remain in the county road network. If the change in ADT on the alternative route after the link is deleted is greater than 15%, then the link should remain in the county road system. This threshold level of ADT provides an extra level of analysis to supplement the cost–benefit analysis in deciding whether to delete the link from the county road system.

Table 4.3 provides the ADT for the links considered for simulated closure. An important factor to point out is that these ADT numbers are a close approximation of the actual ADT since study resources to obtain the exact ADT were insufficient. Links 8 and 9 carry larger traffic, so they cannot be considered to be low-volume roads and thus should not be deleted from the road system. It was decided that links should remain in the county road system if the total ADT on the link is higher than 60. This was the case for all three counties.

TABLE 4.3
Traffic on the Selected Links to be Deleted in Brown County

Link	Total ADT	Car ADT	Pickup ADT	Truck ADT
1	60	14	24	22
2	**51**	**15**	**19**	**17**
3	58	24	19	15
4	35	13	13	9
5	53	20	19	14
6	**34**	**13**	**12**	**9**
7	34	10	13	44
8	**184**	**98**	**57**	**59**
9	**151**	**67**	**50**	**34**
10	48	19	17	12

An examination of Table 4.3 reveals the number of pickup trucks is very close to the number of cars using the roads. This interesting trend may be because rural residents are using their pickup trucks for dual purpose trips such as combining their shopping trips with farm trips. Also, the number of trucks on some links is high, which is unusual. A possible reason for this could be the high concentration of rural resident data in one half of the county. The number of grain elevators is high in that part of Brown County where most of the survey data originates.

4.2.2 Brown County Cost–Benefit Analysis

The central goal of this study is to provide an economic rationale to reduce or not to reduce the road system in the selected counties. Cost–benefit analysis provides a framework for achieving this goal by placing a dollar value on the costs and benefits.

The benefit of deleting a road segment is the avoided maintenance cost of these roads. The maintenance costs are large and recurring in nature. The academic literature provides a large range from $3,000 to $6,000 per mile for gravel roads each year. Road maintenance data was obtained from county road supervisors of each county, and some variation was found between counties and between years. It was decided to use two estimates of annual maintenance expense of $3,000 and $4,000 per mile per year.

In calculating the benefits, links 2, 6, 8, and 9 were not considered in the calculation for reasons explained above. When maintenance cost per mile are valued at the very conservative figure of $3,000 per mile, the benefits are $68,760 and rise to $91,680 for maintenance cost per mile of $4,000. The benefits for each link are in Table 4.4.

TABLE 4.4
Benefits From the Deletion of Selected Links From Brown County

Link	Miles	Benefits @ $3,000 per mile ($)	Benefits @ $4,000 per mile ($)
1	3.37	10,110	13,480
2	**0**	**0**	**0**
3	2.04	6120	8160
4	4	12000	16000
5	4	12000	16000
6	**0**	**0**	**0**
7	3	9000	12000
8	**0**	**0**	**0**
9	**0**	**0**	**0**
10	6.51	19530	26040
Total	22.92	68,760	91,680

The cost of deleting a road segment from the network is the additional travel cost borne by the road users due to more circuitous routes to destinations. To calculate total costs, an estimate is needed of the additional miles traveled after the link is deleted. This information is in Table 4.5.

TABLE 4.5
Extra Miles Traveled Due to Road Closure in Brown County

Link	Distance Traveled Before Link is Deleted	Distance Traveled After Link is Deleted	Extra Miles Traveled Due to Road Closure
1	3.37	5.46	2.09
2	0	0	0
3	2.04	4	1.96
4	4	6.02	2.02
5	4	5.99	1.99
6	0	0	0
7	3	5	2
8	0	0	0
9	0	0	0
10	6.51	8.6	2.09
Total	22.92	35.07	12.15

Table 4.5 contains the additional miles traveled when a link is deleted from the road system. These calculations are performed by TransCAD. In these calculations TransCAD calculates the shortest route from origin to destination. As indicated in Table 4.5 the additional miles traveled for links 2, 6, 8, and 9 are zero, because these links are not subject to closure for reasons explained above.

Operating cost per vehicle per mile for each of the three vehicle types is needed to calculate the total cost of simulated road closure. The operating costs per mile of the three vehicle types is from the AASHTO estimates. For cars, the cost per mile for gravel roads is 76.5¢; for pickup trucks 92.3¢, and for trucks 159.7¢. The operating cost per mile for trucks is the average of the tandem truck and semi-trailer costs per mile on gravel roads. To obtain the total cost by vehicle type, the following equation is used:

Total Cost = ADT x Operating Cost Per Mile x 365 Days x Average Extra Miles Traveled / 100

Equation 4.1

The results are in Table 4.6. The total annual costs of simulated closure of six Brown County links is $226,147. Thus the ratio of costs to benefits assuming $3,000 per mile maintenance cost is 3.29 ($226,147 / $68,760) and 2.47 ($226,147 / $91,680) when $4,000 per mile is assumed. Thus road maintenance per mile would have to increase to about $9,900 in order for the benefits to equal the costs. The conclusion is that all of the simulated links should remain in the Brown County road system.

TABLE 4.6
Annual Cost of Operating Vehicles in Brown County After Simulated Road Closure

Vehicle Type	ADT	Operating Cost Per Mile	Number of Days	Average Extra Miles Traveled*	Total Cost ($)
Cars	100	76.5¢	365	2.025	56,543
Pickup Trucks	105	92.3¢	365	2.025	71,632
Trucks	83	159.7¢	365	2.025	97,972
Total Cost					226,147

*The sum of extra miles traveled due to simulated closure for links 1, 3, 4, 5, 7, and 10 which is 12.15 (Table 4.5) divided by 6.

4.3 Pratt County Results

Table 4.7 lists the road links simulated for closure in the Pratt County road system. Similar to Brown County, 10 links were deleted that range in length from a minimum 2.1 miles to a maximum of seven miles. The average length of the links assumed to be closed is about 3.5 miles or a total 34.3 miles. Link 1 is relatively large and was selected since this area of the county has an extensive road network and there are a number of better or equivalent quality alternative routes in the area. All the other links simulated for closure are close to the average. Unlike Brown County, the selected road segments are located in every part of Pratt County since the data in the rural resident survey was available for all areas of the county.

TABLE 4.7
Deleted Links in Pratt County

Link	Miles
1	7.01
2	3.03
3	4.08
4	2.11
5	3
6	3.01
7	2.98
8	3.02
9	3.03
10	3.02
Total (Miles)	34.29

4.3.1 Alternative Routes: Pratt County

Table 4.8 provides the percentage change in ADT on the alternative routes after the road segment is deleted from the Pratt County road system. Eight of the 10 alternative routes experience less than a 5% change in ADT between existing ADT on these alternate routes and ADT after simulated closure of the 10 links. Six of the 10 alternative routes have less than a 2% change in ADT. Alternative route 10 ADT increases by 40.5%. However, since the ADT before simulated closure was less than 100 vehicles per day, the change is not significant in absolute terms.

TABLE 4.8
Pratt County Traffic Variation on the Alternate Routes (ADT)

Alternate Route	Traffic Range Before Deletion (ADT)	Traffic Range After Deletion (ADT)	ADT Percentage Change
1	>100 & <200	>200 & <300	3.86
2	<100	<100	1.35
3	>100 & <200	>100 & <200	1.69
4	>100 & <200	>100 & <200	0.35
5	>100 & <200	>100 & <200	0.23
6	<100	<100	4.72
7	<100	<100	11.76
8	>400	>400	0.55
9	>100 & <200	>100 & <200	1.96
10	<100	<100	40.47

ADT: Average Daily Traffic

The only alternative route with more than a 15% change in ADT is alternative route 10. Thus link 10 is eliminated for simulated closure and remains in the Pratt County road system. The other nine links are candidates for closure.

Table 4.9 contains the ADT for links which were selected for simulated closure (excluding link 10) Note that most of the ADT is accounted for by cars. There is very little truck traffic on these links.

TABLE 4.9
Traffic on the Selected Links to be Deleted in Pratt County

Link	Total ADT	Car ADT	Pickup ADT	Truck ADT
1	29	18	7	4
2	4	4	0	0
3	17	12	4	1
4	5	4	1	0
5	1	1	0	0
6	11	7	3	1
7	53	42	7	4
8	19	18	1	0
9	20	14	4	2
10	**35**	**25**	**7**	**3**

4.3.2 Benefit–Cost Analysis: Pratt County

The benefit–cost procedure for Pratt County is the same as that of Brown County. Table 4.10 contains the benefits of simulated closure of links 1 through 9. Benefits for link 10 are zero since link 10 is not a candidate for simulated closure. Assuming annual maintenance cost per mile of $3,000 the benefits are $93,810 and $125,080 when $4,000 per mile is assumed.

To calculate total costs an estimate is needed of the additional miles traveled after the link is deleted. This data is in Table 4.11.

TABLE 4.10
Benefits From the Deletion of Selected Links From Pratt County

Link	**Miles**	**Benefits @ $3,000 per mile ($)**	**Benefits @ $4,000 per mile ($)**
1	7.01	21,030	28,040
2	3.03	9,090	12,120
3	4.08	12,240	16,320
4	2.11	6,330	8,440
5	3	9,000	12,000
6	3.01	9,030	12,040
7	2.98	8,940	11,920
8	3.02	9,060	12,080
9	3.03	9,090	12,120
10	0	0	0
Total	31.27	93,810	125,080

Table 4.12 contains the annual cost of operating the three vehicle types on Pratt County roads when nine of the 10 links are deleted from the network.

TABLE 4.11
Extra Miles Traveled Due to Road Closure in Pratt County

Links	Distance Traveled Before Link is Deleted	Distance Traveled After Link is Deleted	Extra Miles Traveled Due to Road Closure
1	7.01	8.99	1.98
2	3.03	4.97	1.94
3	4.08	5.66	1.58
4	2.11	3.81	1.7
5	3	4.86	1.86
6	3.01	5.07	2.06
7	2.98	5	2.02
8	3.02	5.03	2.01
9	3.03	5.01	1.98
10	0	0	0
Total	31.27	48.4	17.13

The total cost of deleting nine links in Pratt County is computed using Equation 4.1. The total cost of simulated closure is in Table 4.12.

TABLE 4.12
Annual Cost of Operating Vehicles in Pratt County After Simulated Road Closure

Vehicle Type	ADT	Operating Cost Per Mile, ¢	Number of Days	Average Extra Miles Traveled*	Total Cost ($)
Cars	120	76.5	365	1.90	63,663
Pickup Trucks	27	92.3	365	1.90	17,283
Trucks	12	159.7	365	1.90	13,290
Total Cost					94,236

*The sum of extra miles traveled due to simulated closure of links 1 through 9 which is 17.13 (Table 4.10) divided by 9.

If it is assumed that annual maintenance cost per mile is $3,000 the ratio of benefits to costs is 0.995 ($93,810 / $94,236). The costs exceed the benefits by only $426. If annual maintenance cost per mile is assumed to be $4,000 the benefit–cost ratio is 1.33 ($125,080 / $94,236). Thus if the very conservative maintenance cost of $3,000 is assumed the benefits of road closure approximately equal the costs. However, if $4,000 is assumed to be the annual maintenance costs the benefits exceed the costs by $30,844 so all nine of the links should be closed.

4.4 Thomas County Results

Thomas County has the largest area of the three counties in the analysis. However, the Thomas County road network is not as extensive as the other two counties, meaning the number of alternative routes for a deleted link is not as large as the other counties. Thus the number of miles of Thomas County roads selected for simulated closure is the smallest of the three counties in the analysis, or 31.1 miles compared to 38.3 miles for Brown County and 34.3 miles for Pratt County. Table 4.13 contains the lengths of the 10 links selected for simulated closure.

TABLE 4.13
Deleted Links in Thomas County

Link	Miles
1	1.95
2	3.02
3	4.05
4	4.02
5	3.04
6	2
7	3.03
8	2.99
9	3.01
10	4
Total	31.11

The length of road segments range from a minimum of 1.95 miles to a maximum of 4.05 miles, with an average of 3.1 miles. Links were chosen which have a superior or equivalent route to destinations. Since residents in all areas of the county completed the rural resident survey, the selected links are located in all areas of the county.

4.4.1 Alternative Routes: Thomas County

Table 4.14 contains the ADT range on alternative routes for the current Thomas County network. It contains ADT on the alternative routes before and after the selected road segments (links) are deleted from the network as well as the resulting percentage change in ADT. Nine of the 10 alternative routes experience an ADT percentage change of less than 4%. Four of the 10 changed less than 1%.

TABLE 4.14
Thomas County Traffic Variation on the Alternate Routes (ADT)

Alternate Route	Traffic Range Before Deletion (ADT)	Traffic Range After Deletion (ADT)	ADT Percentage Change
1	<100	<100	2.88
2	<100	<100	10.72
3	<100	<100	3.05
4	>200 & <300	>200 & <300	3.87
5	>400	>400	0.65
6	>100 & <200	>100 & <200	0.26
7	>200 & <300	>200 & <300	2.47
8	<100	<100	3.7
9	>300 & <400	>300 & <400	-0.03
10	<100	<100	0.54

ADT: Average Daily Traffic

Although Thomas County is the largest of the three counties in the analysis its traffic counts are the lowest of the three counties. One possible reason is the low population density of the county. The population density of Thomas County is only about eight people per square mile resulting in a relatively low ADT on many Thomas County rural roads.

Table 4.15 contains the ADT by vehicle type on each of the 10 selected links in Thomas County. Total ADT for link 9 is 80, which exceeds the ADT threshold of 60 as candidates for simulated closure. Link 9 is not a candidate for closure, because it is not a low ADT road and should remain in the Thomas County road network. The total ADT in Thomas County (excluding link 9) is much less than Brown County. With the exception of links 4 and 7, total ADT on the remaining seven links is six or less.

TABLE 4.15
Traffic on the Selected Links to be Deleted in Thomas County

Link	Total ADT	Car ADT	Pickup ADT	Truck ADT
1	2	1	0	1
2	4	2	1	1
3	2	2	0	0
4	16	8	4	4
5	2	1	0	1
6	6	3	2	1
7	32	18	8	6
8	1	1	0	0
9	**80**	**45**	**20**	**15**
10	1	1	0	0

4.4.2 Benefit–Cost Analysis: Thomas County

The benefit–cost analysis for Thomas County employs the same procedure as the other two counties. Table 4.16 contains the benefits of deleting nine of the 10 Thomas County links from the road network. The benefits when maintenance costs per mile are assumed to be $3,000 are $84,300 and $112,400 if $4,000 per mile is assumed.

TABLE 4.16
Benefits From the Deletion of Selected Links From Thomas County

Link	Miles	Benefits @ $3,000 per mile ($)	Benefits @ $4,000 per mile ($)
1	1.95	5,850	7,800
2	3.02	9,060	12,080
3	4.05	12,150	16,200
4	4.02	12,060	16,080
5	3.04	9,120	12,160
6	2	6,000	8,000
7	3.03	9,090	12,120
8	2.99	8,970	11,960
9	0	0	0
10	4	12,000	16,000
Total	28.1	84,300	112,400

To calculate total costs an estimate is needed of the additional miles traveled after the link is deleted. This data is in Table 4.17.

TABLE 4.17
Extra Miles Traveled Due to Road Closure in Thomas County

Link	Distance Traveled Before Link is Deleted	Distance Traveled After Link is Deleted	Extra Miles Traveled Due to Road Closure
1	1.95	3.95	2
2	3.02	5	1.98
3	4.05	5.98	1.93
4	4.02	6	1.98
5	3.04	4.98	1.94
6	2	4	2
7	3.03	4.93	1.9
8	2.99	5	2.01
9	0	0	0
10	4	5.98	1.98
Total	28.1	45.82	17.72

The total cost of deleting nine of the 10 links in Thomas County is computed using Equation 4.1. The total cost of simulated closure of the nine links is in Table 4.18.

If the annual maintenance costs per mile are assumed to be $3,000, the benefit–cost ratio is 1.82 ($84,300 / $46,385). If the annual maintenance cost per mile is $4,000, the benefit–cost ratio is 2.42 ($112,400 / $46,385). The conclusion is that even with the very conservative maintenance figure of $3,000 per mile, the benefits of road closure significantly exceed the costs. Thus, nine of the 10 links in Thomas County should be closed.

TABLE 4.18
Annual Cost of Operating Vehicles in Thomas County After Simulated Road Closure

Vehicle Type	ADT	Operating Cost Per Mile (¢)	Number of Days	Average Extra Miles Traveled*	Total Cost ($)
Cars	37	76.5	365	1.97	20,353
Pickup Trucks	15	92.3	365	1.97	9,955
Trucks	14	159.7	365	1.97	16,077
Total Cost					46,385

*The sum of extra miles traveled due to simulated closure of links 1 through 8 plus link 10 which is 17.72 (Table 4.17) divided by 9.

Chapter 5: Conclusion

5.1 Study Framework

The increasing size of farms in Kansas has led to increasing farm vehicle size as well. Tractor and combine weight and width has increased and the majority of farmers deliver their grain in semi-trucks. Tandem axle trucks are used to deliver farm supplies. The road width and design characteristics of rural roads and bridges are inadequate for the larger and heavier vehicles that are using them. As county population declines the financial ability of Kansas counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. Many rural Kansas counties don't have the funds to maintain the existing system with the heavier vehicles that are using them. If the county road and bridge system can't be maintained as it is, reducing the size of the system should be considered. This study addressed the benefits and costs of reducing the county network.

To accomplish this, three counties were selected for analysis: Brown County (northeast Kansas), Pratt County (south central Kansas), and Thomas County (northwest Kansas). These counties were selected to obtain geographic variation; and because the study is concerned with rural roads, these counties were selected because they have the greatest agricultural production in their respective regions.

The populations of the counties are similar (between 7,300 and 9,900) but they vary greatly in size and population density. Brown County has 571 square miles and 18.8 people per square mile while Thomas County has 1,075 square miles and only 7.6 people per square mile. Total 2009 employment in Brown, Pratt, and Thomas counties was 7,422, 6,860, and 4,961, respectively. Local government was the largest employer in all three counties. In 2008, per capita income in Pratt and Thomas County was about the same as the Kansas average, but nearly 10% less than the Kansas average in Brown County. All three counties have large agricultural production. The average 2007–2009 total production of corn, wheat, sorghum, and soybeans was 21.5 million bushels in Brown County, 18.7 million bushels in Pratt County, and 30.8 million bushels in Thomas County.

5.2 Procedure

Benefit–cost analysis was used to examine the question of road closure in the three counties. The cost of road closure is the additional travel cost of rural residents due to more circuitous routing to their destinations. The benefit is the avoided maintenance costs of roads removed from the county network. Total annual costs are measured by the following equation:

Total Cost = ADT (on road segments considered for simulated closure) x Vehicle Operating Cost Per Mile x 365 days x Average Extra Miles Traveled / 100

Equation 5. 1

Total benefit is calculated by multiplying the number of miles assumed to be closed by the avoided maintenance cost per mile.

In each county, 10 road segments were selected as potential candidates for simulated closure. This was done to analyze the traffic impacts on alternative roads near the road segments being considered for simulated closure. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads. TransCAD maps and KDOT traffic counts were used to identify candidate roads for simulated closure.

It was assumed that rural residents would use cars and pickup trucks for grocery and pleasure trips, while five-axle semis and tandem-axle trucks are used for grain hauling. In the rural resident survey, respondents were asked to indicate their destinations for each type of vehicle. However, to simplify computation, all truck types (other than pickup) were combined into one category. Thus there are three vehicle types in the analysis: cars, pickups, and trucks. The maintenance cost per mile was obtained from previous studies and is assumed to be the same in all three counties.

5.3 Conclusions of the Benefit–Cost Analysis

Table 5.1 contains the benefit–cost ratios for simulated closure of roads in the three counties. One set of ratios is calculated assuming annual maintenance cost per mile of $3,000, and the other set assumes $4,000 per mile. The benefit–cost ratios for Brown County are 0.30 and 0.41. Thus, none of the 10 road segments evaluated in Brown County should be closed. For

Pratt County, the benefits of simulated road closure are approximately equal to the costs if maintenance cost of $3,000 per mile is assumed, but if maintenance cost per mile is assumed to be $4,000, the benefit–cost ratio is 1.33. The latter ratio indicates that Pratt County would save money by closing the evaluated road segments. The benefit–cost ratios for Thomas County are 1.82 and 2.42 indicating that the evaluated road segments should be closed.

TABLE 5.1
Benefit–Cost Ratios of the Three Counties

Benefit–Cost Ratios Assuming Annual Maintenance Cost of $3,000 Per Mile			
County	**Benefits ($)**	**Costs ($)**	**Benefit–Cost Ratio**
Brown	68,760	226,147	0.30
Pratt	93,810	94,236	1.00
Thomas	84,300	46,385	1.82

Benefit–Cost Ratios Assuming Annual Maintenance Cost of $4,000 Per Mile			
County	**Benefits ($)**	**Costs ($)**	**Benefit–Cost Ratio**
Brown	91,680	226,147	0.41
Pratt	125,080	94,236	1.33
Thomas	112,400	46,385	2.42

Possible reasons for the contrasting results are differences in the ADT of the evaluated links (road segments) and the vehicle composition of the ADT.

TABLE 5.2
ADT, Vehicle Operating Cost Per Mile, and Total Annual Cost of Simulated Road Closure by Vehicle Type

Brown County				
Vehicle Type	**ADT***	**Vehicle Operating Cost Per Mile (¢)**	**Total Cost ($)**	**% of Total Cost**
Cars	100	76.5	56,543	25.0
Pickup Trucks	105	92.3	71,632	31.7
Trucks	83	159.7	97,972	43.3
Pratt County				
Vehicle Type	**ADT***	**Vehicle Operating Cost Per Mile (¢)**	**Total Cost ($)**	**% Total Cost**
Cars	120	76.5	63,663	67.6
Pickup Trucks	27	92.3	17,283	18.3
Trucks	12	159.7	13,290	14.1
Thomas County				
Vehicle Type	**ADT***	**Vehicle Operating Cost Per Mile (¢)**	**Total Cost ($)**	**% of Total Cost**
Cars	37	76.5	20,353	43.9
Pickup Trucks	15	92.3	9,955	21.5
Trucks	14	159.7	16,077	34.6

*ADT is the traffic on the links selected for simulated closure.

Examination of Table 5.2 indicates that ADT on road segments evaluated for closure in Brown County is 288 compared to 159 for Pratt County and 66 for Thomas County. Trucks have the highest vehicle operating cost per mile (159.7¢). In Brown County trucks account for 43.3% of the total cost of simulated road closure while cars (the lowest vehicle operating cost per mile) only account for 25%. The other two counties have a higher percent of cars and lower percent of trucks compared to Brown County. Thus Brown County has higher traffic on the road segments considered for simulated closure and relatively high truck traffic.

5.4 Overall Conclusions

The main conclusion is that rural counties will be able to save money by closing some relatively low-volume roads and redirecting the saving toward increasing the quality of other county roads. Counties with relatively extensive road systems (miles of road per square mile) and relatively high population density (i.e., Brown County) are less likely to realize savings from road closure. In contrast, counties with less extensive road systems and relatively low population density (i.e., Thomas County) are more likely to realize significant savings from closure of relatively low-volume roads.

This study did not consider the benefits and costs of bridges on the road segments considered for closure because it was beyond the scope of the study. The benefits of including bridges include the avoided cost of maintaining and reconstructing bridges. The costs would be unaffected since the additional travel costs would be the same. Rural residents would simultaneously lose access to the road and any bridges on the road. Thus, the inclusion of bridges in the analysis would increase the benefits relative to the costs, increasing the benefit–cost ratio.

Road supervisors should consider some demonstration projects where the roads with the least ADT are closed, but no single-access roads should be considered for closure so rural residents continue to have access to the county road system.

References

Anderson, J. & Sessions, J. (1991). Fifth International Conference on Low-Volume Roads, May "Managing Low Volume Road Systems for Intermittent Use." *Transportation Research Record 1291*, Transportation Research Board, 1991.

Applied Pavement Technology Inc. (2004). *Local road surfacing criteria*. South Dakota: South Dakota Department of Transportation Office of Research.

Baumel, C. P., Hamlett, C. A., & Pautsch, G. (1986). *The economics of reducing the county road system*. Iowa: U.S. Department of Transportation University Research Program, Iowa State University.

Brown County Engineers/Road Supervisors Annual Report, 2006-2009 issues.

Christensen P., Nolan, J., & Sparks, G. Modeling the rationalization of rural road networks: the case of Saskatchewan. *Proceedings of the 36th Canadian Transportation Research Forum*. (2001): 797–810. University of Saskatchewan Press, 2001.

Dissanayake, S. & Liu, L. *Speed limit-related issues on gravel roads*. (2009). Report K-TRAN: KSU-06-5. Kansas: Kansas Department of Transportation.

Epodunk, *Population Overview*, http://www.epodunk.com.

2009-2010 Governor's Economic and Demographic Report, Appendix F.

Hanson, S. D., Hamlett, C. A., Pautsch, G., & Baumel, C. P. (1985). Vehicle travel costs on paved, granular, and earth surfaced county roads. *Journal of the Transportation Research Forum*, *26*(1), 401–406.

Helmberger, P. J., Fruin, J., & Halbach, D. (1990). *Net benefits of rural road management strategies*. Unpublished manuscript.

Jahren, C. T., Smith, D., Thorius, J., Rukashaza-Mukome, M., White, D., & Johnson, G. (2005). *Economics of upgrading an aggregate road*. Minnesota: Minnesota Department of Transportation Research Services Division.

Kansas Department of Agriculture. *Kansas Farm Facts 2008 and 2009*, Topeka, Kansas.

Kansas Department of Agriculture. *Kansas Farm Facts 2010*, Topeka, Kansas, 2010.

Kansas Grain and Feed Association. *2010 Official Kansas Directory*, Topeka, Kansas, 2010.

Kentucky Transportation Center. (1988). *When to pave a gravel road: Helping hand guide*. Kentucky: Kentucky Transportation Center.

Pratt County Engineers/Road Supervisors Annual Report, 2006-2009 issues.

Sebaaly, P. E., Siddharthan, R., & David Huft. (2003). Impact of heavy vehicles on low volume roads. *Transportation Research Record 1819*. Transportation Research Board.

U.S. Bureau of the Census, Housing and Household Economic Statistics Division. *Small Area Income and Poverty Estimates*, http://www.census.gov.hhes/www/saipe/county.html.

U.S. Bureau of the Census, *State and County Quick Facts*, http:quickfacts.census.gov.

U.S.D.A., Economic Research Service, *County-Level Unemployment and Median Household Income for Kansas*, http://www.ers.usda.gov.

U.S. Department of Commerce, Bureau of Economic Analysis. *CA25N - Total Full-Time and Part-Time Employment by NAICS Industry*. (http://www.bea.gov/regional/reis).

Appendix A: Rural Resident Transportation Survey

RURAL RESIDENT TRANSPORTATION SURVEY

Part A: TRANSPORTATION EQUIPMENT

1. My location is in section ________ of ___________ township, and range ___________.

2. Which of the following types of farm equipment do you and members of your household own? Check all that apply.

Equipment Type	Own	Number Owned
(a) Tractor	________	________
(b) Combine	________	________
(c) Grain Wagons	________	________
(d) Other (please specify)	________	________

3. Which of the following types of trucks do you and members of your household own? Check all that apply

Equipment Type	Own	Number Owned	Model Year
(a) Pickup truck	________	________	________
(b) Single axle truck	________	________	________
(c) Tandem axle truck	________	________	________
(d) Semi-tractor trailer	________	________	________
(e) Other (please specify)	________	________	________

4. What is the gross vehicle weight (GVW) of each of the truck types you checked in question 3?

Equipment Type	GVW
(a) Pickup truck	________
(b) Single axle truck	________
(c) Tandem axle truck	________
(d) Semi-tractor trailer	________
(e) Other (please specify)	________

5. How many automobiles do you and members of your household own or lease?

Number owned __________

Number leased __________

6. How many licensed drivers are in your household?

One ___________
Two ___________
Three ___________
Four ___________
Other (please specify) ___________

Part B: OUTBOUND TRIPS

7. In a typical month how many times do you use the county roads to make tractor, combine trips, and grain wagon trips?

Season	Tractor Trips	Combine Trips	Grain Wagon Trips
Winter months	_________	_________	_________
Spring months	_________	_________	_________
Summer months	_________	_________	_________
Fall months	_________	_________	_________

8. What is the typical number of miles of county roads used per trip to make tractor and combine trips?

Number of Miles of County Road per Trip
(a) Tractor ____________________
(b) Combine ____________________
(c) Other (please specify) ____________________

9. In a typical month how many times do you use the county roads to make truck and auto trips?

Season	Auto Trips	Pickup Trips	Single-Axle Truck Trips	Tandem-Axel Truck Trips	Semi-Truck Trips	Grain Wagon Trips
Winter months	_________	_________	_________	_________	_________	_________
Spring months	_________	_________	_________	_________	_________	_________
Summer months	_________	_________	_________	_________	_________	_________
Fall months	_________	_________	_________	_________	_________	_________

10. In a typical month what are the primary destinations of the auto trips you make on the county roads?

Destination (city or other)	Number of Trips	Trip Purpose (i.e. shopping, school, medical, church, social functions)

11. In a typical month what are the primary destinations of the pickup trips you make on the county roads?

Destination (city or other)	Number of Trips	Trip Purpose

12. In a typical month what are primary destinations of the single axle and tandem axle truck trips you make on the country roads?

Destination (city or other)	Number of Trips	Trip Purpose

13. In a typical month what are the primary destinations of the semi truck trips you make on the county roads?

Destination (city or other)	Number of Trips	Trip Purpose (i.e. deliver grain, pick up supplies and fertilizer)

Part C: INBOUND TRIPS

14. In a typical month, how many trips to your location are made in the following types of vehicles?

Vehicle Type	Number of Trips
(a) Auto	_________
(b) Pickup	_________
(c) Delivery Van	_________
(d) Single Axle Truck	_________
(e) Tandem Axle Truck	_________
(f) Semi Truck	_________
(g) Postal Vehicle	_________
(h) School Bus	_________

15. In a typical month, what are the primary origins of auto, pickup, and delivery trips to your location?

Auto Trip Origins	Pickup Trip Origins	Delivery Van Trip Origins
_____________	______________	_________________
_____________	______________	_________________
_____________	______________	_________________
_____________	______________	_________________

16. In a typical month, what are the primary origins of single axle, tandem axle, and semi truck trips to your location?

Origins of Single Axle Truck Trips	Origins of Tandem Axle Truck Trips	Origins of Semi Truck Trips
_____________	___________	___________
_____________	___________	___________
_____________	___________	___________
_____________	___________	___________

17. In a typical month what are the primary origins of postal vehicle and school bus trips to your location?

Origins of Postal Vehicle Trips	Origins of School Bus Trips
_____________	___________
_____________	___________
_____________	___________
_____________	___________

Appendix B: Kansas Rural Road Survey, Grain Elevators

KANSAS RURAL ROAD SURVEY, GRAIN ELEVATORS

Company Name: ______________________________

Respondent Name: _____________________________

Part A: GRAIN RECEIPTS

1. Please provide wheat, corn, and sorghum receipts for the 2007–2009 period. If there is more than one elevator station in the company, simply provide grain receipts for all the elevators in the company as a single total. If possible provide grain receipts on a calendar year basis. If not possible, please specify your fiscal year.

Grain Receipts (bushels)

Year	Corn	Wheat	Sorghum	Soybeans
2007	________	________	________	________
2008	________	________	________	________
2009	________	________	________	________

2. In the past 12 months, what percent of your total grain receipts were delivered to your elevators in the following types of trucking equipment? Sum of percents must add to 100.

Equipment Type	Percent
(a) Single axle truck	________
(b) Tandem axle truck	________
(c) Semi-tractor trailer	________
(d) Pickup truck/grain wagon	________
(e) Farm tractor/grain wagon	________
(f) Other (please specify)	________

3. For the vehicles listed in question 2, what is the gross vehicle weight (GVW) of the trucks that delivered grain to your location in the past 12 months?

Equipment Type	Typical Gross Vehicle Weight
(a) Single axle truck	________
(b) Tandem axle truck	________
(c) Semi-tractor trailer	________
(d) Pickup truck/grain wagon	________
(e) Farm tractor/grain wagon	________
(f) Other (please specify)	________

4. What is the maximum number of bushels that each of the following types of trucking equipment can haul to your elevators?

Equipment Type	Maximum Bushels	Empty Weight of Truck (tons)
(a) Single axle truck	________	________
(b) Tandem axle truck	________	________
(c) Semi-tractor trailer	________	________
(d) Pickup truck/grain wagon	________	________
(e) Farm tractor/grain wagon	________	________
(f) Other (please specify)	________	________

Part B: MARKET AREA

5. What is the average distance from which farmers deliver their grain to your elevators?

Direction	Number of Miles
North	_____________
South	_____________
East	_____________
West	_____________

6. If possible, please estimate number of miles by road type that farmers use to deliver grain to your elevators.

Direction	Dirt Road Miles	Gravel Road Miles	Paved Road Miles
North	_____________	_______________	___________
South	_____________	_______________	___________
East	_____________	_______________	___________
West	_____________	_______________	___________

7. Please estimate the number of trips that farmers in your market area make to your elevator during harvest and non-harvest periods.

	Average Number of Trips per Farmer
(a) Wheat harvest	_____________
(b) Fall crop harvest	_____________
(c) Non-harvest per month	_____________

Part C: FERTILIZER DELIVERY TO FARMS

8. In the past 12 months what percent of the fertilizer deliveries were made in the following equipment types? Percents must add to 100.

Equipment Type	Percent
(a) Single axle truck	________
(b) Tandem axle truck	________
(c) Semi-tractor trailer	________
(d) Anhydrous nurse wagon	________
(e) 28% nitrogen nurse wagon	________
(f)Other (please specify)	________

9. If possible please estimate the number of miles by road type that were used to deliver fertilizer to farms from your elevators.

Direction	Dirt Road Miles	Gravel Road Miles	Paved Road Miles
North	____________	______________	__________
South	____________	______________	__________
East	____________	______________	__________
West	____________	______________	__________

10. What is the average distance that fertilizer is delivered to farms?

Direction	Number of Miles
North	____________
South	____________
East	____________
West	____________

11. Please estimate the number of trips that are made to deliver fertilizer to farms during the following seasons.

Season	Number of Trips
Spring	________
Summer	________
Fall	________

Appendix C: Kansas Rural Road Study, County Road Supervisors Survey

KANSAS RURAL ROAD STUDY

COUNTY ROAD SUPERVISORY'S SURVEY

County____________________

Respondent Name__________________________

PART A: CURRENT CONDITION OF COUNTY ROADS

1. How many miles of road and how many bridges is the county responsible for?
   (a) Miles of road _______________
   (b) Number of bridges _______________

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. For the county's unpaved 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 _______________

6. Has the number of paved miles of the county's roads declined in the last five years?
   (a) Paved miles in 2004 _______________
   (b) Paved miles in 2009 _______________

7. 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: REVENUE AND EXPENSE

8. What was the county's annual expenditure for road and bridge maintenance in the following years?
   (a) 2009 _____________
   (b) 2008 _____________
   (c) 2007 _____________

9. 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 _____________

10. 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 or more ________________

11. What are the sources of revenue for the county's road and bridge maintenance budget? Please specify dollar amounts for the most recent year available.
    (a) Local property tax _________________
    (b) Motor vehicle tax _________________
    (c) Grants from the state _________________
    (d) Special City/County Highway Fund _________________
    (e) Other _________________

Appendix D: County Maintenance, Construction, and Reconstruction Costs

COUNTY MAINTENANCE, CONSTRUCTION, AND RECONSTRUCTION COSTS

PART A: MAINTENANCE

1. Please give a general description (three or four sentences) of the following maintenance activities in the county.

Chip Seals

Overlays

Recycle

Other Types of County Maintenance

2. Since no miles were listed as overlays or recycle in the county between 2006 and 2009, what is the current cost per mile of chip seal maintenance?

_________ dollars per mile

PART B: CONSTRUCTION/RECONSTRUCTION COSTS

3. Please give a general description (three or four sentences) of the following types of construction/reconstruction activities in the county.

Paved Roads

Gravel Roads

Bridges

4. How often are the paved roads constructed/reconstructed in the manner described in question 3?

Every ______ years for construction.

Every ______ years for reconstruction.

5. How often are the gravel roads constructed/reconstructed in the manner described in question 3?

Every ______ years for construction.

Every ______ years for reconstruction.

6. How often are the bridges constructed/reconstructed in the manner described in question 3?

Every ______ years for construction.

Every ______ years for reconstruction.

7. What is the current cost per mile for paved and gravel road construction/reconstruction activities described in question 3?

Paved Roads ____________ per mile

Gravel Roads ____________ per mile

8. What is the current cost of the bridge construction/reconstruction activities described in question 3?

Cost per Average County Bridge __________

9. What is the number of miles of paved roads, gravel roads, and bridges in the county?

Paved Road Miles ____________

Gravel Road Miles ____________

Number of Bridges ____________

PART C: TYPES OF PAVED ROAD TREATMENTS (NOT NECESSARILY THE COUNTY)

10. Please give a general description (three or four sentences) of each of the following paved road treatments.

Crack Seal

Seal Coat

Overlay

Striping, Marking

Mill and Overlay

Patching

PART D: TYPES OF GRAVEL ROAD TREATMENTS (NOT NECESSARILY THE COUNTY)

11. Please give a general description (three or four sentences) of each of the following gravel road treatments.

Blading

Re-Gravel

Reclaiming

Reshape Cross Section

Annual Maintenance (stuff you have to do every year)

Appendix E: Pratt County Rural Roads Study, Pratt County Feeders, LLC

PRATT COUNTY RURAL ROADS STUDY
Pratt County Feeders, LLC

Respondent Name: ___________________________

PART A: CAPACITY AND PRODUCTION

1. What is the average number of cattle on feed at your company in the previous three years?

   2009 head _________
   2008 head _________
   2007 head _________

2. In the past 12 months, how many bushels of the following feed grains were delivered to the feed yard?

   Dry Corn _________ bushels
   Wet Corn _________ bushels
   Sorghum _________ bushels

3. In the past 12 months, how many tons of distillers grain were delivered to the feed yard?

   Wet distillers grain _________ tons
   Dry distillers grain _________ tons

4. In the past 12 months how many head of feeder cattle were delivered to the feed yard?

   _________ head

PART B: INBOUND TRUCK SHIPMENTS

5. In the past 12 months, what percentage of the total dry corn shipments were delivered to the feed yard in the following types of trucks?

   a. single axle truck _________ %
   b. tandem axle truck _________ %
   c. semi-tractor trailer _________ %
   d. other (please specify) _________ %

6. In the past 12 months, what percentage of the total <u>wet corn</u> shipments were delivered to the feed yard in the following types of trucks?

    a. single axle truck __________ %
    b. tandem axle truck __________ %
    c. semi-tractor trailer __________ %
    d. other (please specify) __________ %

7. In the past 12 months, what percentage of the total <u>sorghum</u> shipments were delivered to the feed yard in the following types of trucks?

    a. single axle truck __________ %
    b. tandem axle truck __________ %
    c. semi-tractor trailer __________ %
    d. other (please specify) __________ %

8. In the past 12 months, what percentage of the total <u>feeder cattle</u> were delivered to the feed yard in the following types of trucks?

    a. tandem axle truck __________ %
    b. semi-tractor trailer __________ %
    c. other (please specify) __________ %

9. In the past 12 months, what percentage of the total <u>wet and dry distillers grain</u> was delivered to the feed yard in the following types of trucks?

    a. tandem axle truck __________ %
    b. semi-tractor trailer __________ %
    c. other (please specify) __________ %

PART C: OUTBOUND TRUCK SHIPMENTS

10. In the past 12 months, what percentage of the total <u>finished cattle</u> were shipped from the feed yard in the following types of trucks?

    a. tandem axle truck __________ %
    b. semi-tractor trailer __________ %
    c. other (please specify) __________ %

11. In the past 12 months, what percentage of the total <u>manure</u> was shipped from the feed yard in the following types of trucks?

    a. tandem axle truck __________ %
    b. semi-tractor trailer __________ %
    c. other (please specify) __________ %

PART D: ORIGINS OF INBOUND TRUCK SHIPMENTS

12. In the past 12 months, what percent of your total inbound <u>dry corn</u> originated in the following miles from the feed yard?

    a. 1 to 25 miles from the feed yard __________ %
    b. 26 to 50 miles from the feed yard __________ %
    c. 51 to 100 miles from the feed yard __________ %
    d. over 100 miles from the feed yard __________ %

13. In the past 12 months, what percent of your total inbound <u>wet corn</u> originated in the following miles from the feed yard?

    a. 1 to 10 miles from the feed yard __________ %
    b. 11 to 25 miles from the feed yard __________ %
    c. 26 to 50 miles from the feed yard __________ %
    d. over 50 miles from the feed yard __________ %

14. In the past 12 months, what percent of your total inbound <u>sorghum</u> originated in the following miles from the feed yard?

    a. 1 to 25 miles from the feed yard __________ %
    b. 26 to 50 miles from the feed yard __________ %
    c. 51 to 100 miles from the feed yard __________ %
    d. over 100 miles from the feed yard __________ %

15. In the past 12 months, what percent of your <u>wet and dry distillers grain</u> originated within the following miles from the feed yard?

    a. 1 to 25 miles from the feed yard __________ %
    b. 26 to50 miles from the feed yard __________ %
    c. 51 to 100 miles from the feed yard __________ %
    d. over 100 miles from the feed yard __________ %

16. In the past 12 months, what percent of your <u>feeder cattle</u> originated in the following states?

    a. Kansas __________ %
    b. Nebraska __________ %
    c. Colorado __________ %
    d. Oklahoma __________ %
    e. Missouri __________ %
    f. Other (please specify) __________ %

PART E: TRUCK SHIPMENTS ON THE PRATT COUNTY ROAD SYSTEM

17. Assuming a typical truck shipment of dry corn to the feed yard, what is your best estimate of the number of miles the shipment travels on Pratt County roads?

    a. Paved miles __________
    b. Gravel miles __________

18. Assuming a typical truck shipment of wet corn to the feed yard, what is your best estimate of the number of miles the shipment travels on Pratt County roads?

    a. Paved miles __________
    b. Gravel miles __________

19. Assuming a typical truck shipment of sorghum to the feed yard, what is your best estimate of the number of miles the shipment travels on Pratt County roads?

    a. Paved miles __________
    b. Gravel miles __________

20. Assuming a typical truck shipment of distillers grain to the feed yard, what is your best estimate of the number of miles the shipment travels on Pratt County roads?

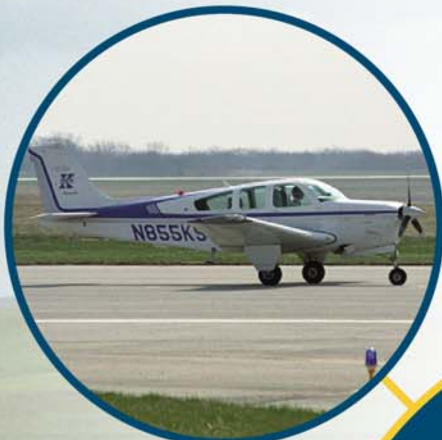
    a. Paved miles __________
    b. Gravel miles __________

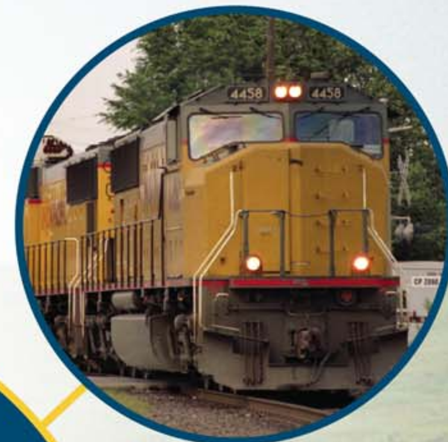
21. Assuming a typical truck shipment of feeder cattle to the feed yard, what is your best estimate of the number of miles the shipment travels on Pratt County roads?

    a. Paved miles __________
    b. Gravel miles __________

K-TRAN

KANSAS TRANSPORTATION RESEARCH AND NEW-DEVELOPMENT PROGRAM





Kansas Department of Transportation

AD ASTRA PER ASPERA