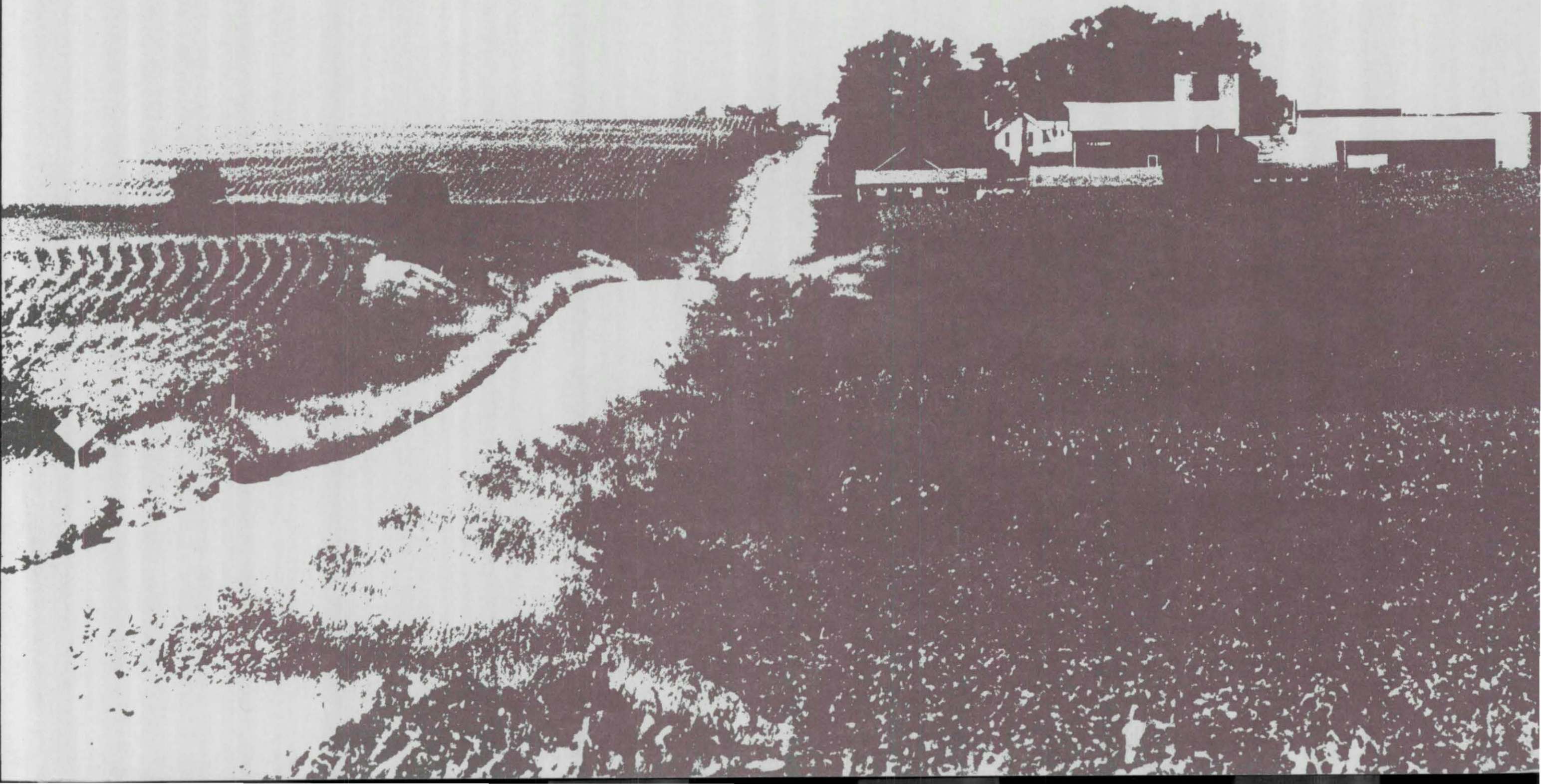
The Local Rural Road System

Alternative Investment Strategies

CARD Technical Report 89-TR6

Iowa State University
Ames, Iowa

Iowa DOT Project HR 242
Sponsored by the Highway Division of the
Iowa Department of Transportation and
the Iowa Highway Research Board.



The Local Rural Road System

The Local Rural Road System:

Alternative Investment Strategies

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In Cooperation With
The Highway Division and Planning and Research Division
Iowa Department of Transportation
and the Iowa Highway Research Board
Iowa Department of Transportation Project HR242
and the University Research Program
Office of the Secretary
U.S. Department of Transportation

Published by the Center for Agricultural and Rural Development (CARD), Iowa State University.

Composed and printed by Iowa State University
Ames, Iowa 50011

First edition, 1989

Library of Congress Catalogue Card
Number 88-063307

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Acknowledgments

A large number of people contributed to the completion of this study. First, the advisory committee, chaired by Wesley Smith, County Engineer, Hamilton County, Iowa, generously helped the researchers understand the county road and bridge problem and provided guidance throughout this long and difficult study. Other members of the advisory committee are:

Eldo Schornhorst, County Engineer, Shelby County, Iowa
Jerry Nelson, County Engineer, Linn County, Iowa
Don Linnan, County Engineer, Buena Vista County, Iowa
Jack Fischer, County Supervisor, Pocahontas County, Iowa
Rex Wiant, Iowa Department of Transportation, Ames, Iowa
Steve Belzung, Iowa Department of Transportation, Ames, Iowa
Jerry Shepler, Iowa Farm Bureau Federation, West Des Moines, Iowa
Carl Swerdloff, U.S. Department of Transportation, Washington, D.C.

Special acknowledgment is due, however, to Wesley Smith, Eldo Schornhorst, Jerry Nelson, James Cable (formerly with the Iowa Department of Transportation and now Associate Professor, Department of Civil Engineering, Iowa State University), and Steve Gannon (Assistant Linn County Engineer) for the enormous amount of time and effort they gave to providing information on the study area road systems and road and bridge costs and for helping the researchers think through and resolve the many problems that arose in this study.

The staff of the Iowa State University Statistical Laboratory collected and coded the questionnaire data. Mary A. (Toni) Genalo assisted in developing the questionnaire and supervised all the data collection and coding. She was ably assisted by Esther Harmison. Professors Roy Hickman and Harold Baker designed the data collection process. Harold Baker drew the area samples. The interviewers who collected the data are:

Kathryn Bottorff	Bonnie Lou Kardell
Kenneth Bottorff	Wilma Jean Klindt
Barbara Bourquin	Rose Laugerman
Dorothy Bousfield	Yolanda (Lonnie) Lauridsen
Norma Jean Carey	Eleanor Lee
Dorothy Carroll	Marcia Luze
Toni Genalo	Mary Rathbone
Jane Goeken	Jeannie Schneider
Helen Groenewold	Karen Trimble
Esther Harmison	Miriam Troyer

Kathryn Bottorff also helped pretest the questionnaire and gathered information on the questionnaire refusals.

Several undergraduate and graduate students assisted in the data processing and analysis. Shawn Dunn, Pamela Hartin, Dana Kunz, Ritchie Chin, Susie Dunn, and Tae Kyun Kim helped with the computer programs and in the data analysis. Steve Hanson developed the vehicle travel costs. Kent Hanson and Mark Baumel assisted in data coding and analysis. Debra Ferry developed part of the maintenance cost computer program.

Leroy Hamilton of the Iowa Department of Transportation supervised the origin and destination survey in Linn County. Mike Keefer and Bill Snow of the U.S. Post Office provided invaluable technical assistance in estimating the postal routes and costs. Roxanne Clemens cheerfully typed several versions of the final report manuscript.

Finally, this study could not have been completed without the funding from the Iowa Highway Research Board and the U.S. Department of Transportation and the willingness of the many farm and non-farm residents of the study areas in Hamilton, Shelby, and Linn counties who provided the information on their 1982 travel patterns.

We extend our thanks to each of you!

Synopsis

Many of today's local rural roads and bridges were built in the late 1800s and early 1900s when farms were small, and farmers needed road access to homes, schools, churches, and markets. During the 1920s and 1930s, these roads were surfaced, mainly with gravel, and bridges were reinforced to carry six-ton loads. Since then, farm size has increased and the number of heavy vehicles traveling on rural roads has also increased—to the detriment of the road system. Farmers are using large tandem-axle and semitrailer trucks, long farm tractor-wagon combinations, and wide combines to travel from farms to fields and vice versa. Farm-supply and marketing firms are using similar heavy trucks for pickups and deliveries. At the same time, revenues to maintain the present system and to reconstruct it to accommodate the changing needs of rural America are declining in real terms. Unless revenues increase or the investment needs decline, the local rural road system will continue to deteriorate.

A benefit-cost analysis was used to examine the effects of alternative investment strategies on the local rural road system. The study first estimated the change in costs to the traveling public of various investment strategies. The change in travel cost of each investment strategy was then compared to the cost of implementing that strategy on the county rural road system. The basic purpose of this study was to develop guidelines for local supervisors and engineers in evaluating investment or disinvestment proposals, and to provide information to state legislatures in developing local rural road and bridge policies.

For this analysis, three case study areas of 100 square miles each were selected in Iowa. One study area, located in Hamilton County, has a relatively high agricultural tax base, a high percentage of paved roads, and relatively few bridges. The second study area, located in Shelby County, has a relatively low agricultural tax base, hilly terrain, a low percentage of paved roads, a large number of oil- and earth-surface roads, and many bridges. The third study area, located in Linn County, has a relatively high agricultural tax base, a high percentage of paved roads, and numerous non-farm households with commuters to Cedar Rapids and Waterloo.

A questionnaire was used to collect data from farm and non-farm residents in the three study areas. Data were obtained on the number of 1982 trips by origin, destination, and type of vehicle.

Several investment strategies were analyzed in this study:

1. Reducing the size of the county road system by abandoning sets of low volume roads that serve no property accesses
2. Reducing the number of miles of public roads by converting continuous roads to private drives
3. Paving selected gravel roads and then abandoning low volume roads that serve no property accesses
4. Converting selected low-volume roads that serve no households or farmsteads to low-maintenance roads
5. Reducing the number of miles of public roads by converting sets of dead-end roads to private drives
6. Converting all existing paved roads to gravel roads
7. Upgrading selected bridges to legal load limits

Conclusions

- The major sources of vehicle miles on county roads are automobiles used for household purposes and pickup truck travel for farm purposes.
- Farm-related travel represents a relatively small percentage of total travel miles but a relatively high percentage of total travel costs.
- A relatively small number of low volume abandoned roads produced greater cost savings to the counties and abutting landowners than the additional travel costs to the traveling public.

The sets of roads abandoned in this study that resulted in positive net savings were:

1. Almost four percent of the non-paved county roads in the Linn study; however, the net savings were very small. This area had a large number of non-farm households on the county roads.
2. Slightly over 5 percent of the non-paved county roads in the Shelby study. This area had a very small number of paved county roads.
3. Over 12 percent of the non-paved county roads in the Hamilton study. This area had a relatively large number of paved county and state roads.

- Paving additional county roads increased the net savings from the abandonment of low volume, no-property-access roads. However, the net costs of paving these roads exceeded the gain in net savings from abandonment.
- Converting low volume roads to low maintenance area service B roads produced the largest net savings of all strategies evaluated in this study. However, bridge deterioration and county liability on area service B roads are potential problems.
- Converting low volume roads to private drives also produced positive net savings. Dead-end roads produced greater net savings than non-dead-end roads. However, this strategy shifts part of the public maintenance burden to abutting landowners.
- Reconstructing selected bridges to legal load limits reduced large truck and tractor-wagon travel costs. However, the additional bridge reconstruction costs exceeded the reduction in travel costs.
- The benefits in reduced travel costs from the existing paved county roads in the Hamilton study area substantially exceeded the costs of providing those county roads.

Public Policy Implications

- There are permanent net cost savings from abandonment of a limited number of low-traffic county roads that serve no property accesses. However, there could be substantial legal costs and damage awards associated with road abandonment. Moreover, a major effort to reduce the size of the county road system is unlikely until programs are designed to relieve local officials of the considerable political liability associated with road abandonment. Proposals to reduce the local government financial liability from abandonment include: (1) denying claims to an individual if the proposed road abandonment is a second access; (2) placing a cap on damage claims; (3) permitting local governments to withdraw or revise an abandonment plan if an appeal to a district court may result in an excessive damage award. One proposal to relieve elected officials of the political liability is to authorize appointed committees to develop and implement road abandonment proposals.
- There are substantial potential net cost savings from converting low volume roads—especially dead-end roads—to private drives. This is a viable option on roads that serve households; it reduces maintenance costs and shifts the remaining costs to the abutting landowners. One possible method of reducing the impact of this shift in cost is to legislate a property tax exemption on land in roads that are converted to private drives.
- There are substantial net cost savings from converting low-volume roads to area service B roads. This is a viable option for low volume roads that serve as the only access to farm fields. However these roads, which remain in the public domain, may incur major costs if bridges deteriorate to a level which requires reconstruction. Moreover, depending on court decisions, counties may or may not be free of liability on area service B roads.
- The travel cost savings from reconstructing selected posted bridges to legal load limits are less than the cost of reconstructing all the bridges.
- The reduction in travel costs from the existing paved core of county roads greatly exceeds the cost of paving those roads.
- The 1986-2001 Quadrennial Need Study (Iowa Department of Transportation 1982) indicates that the needs of the county road system in Iowa continue to increase, which suggests that the system continues to deteriorate. If this is correct, the cost savings from road abandonment and converting roads to private drives and area service B roads may be needed to rebuild the remaining county road system.

It is possible that present laws in some states may preclude any possibility of road abandonment or conversion of roads to private drives and area service B roads. In fact, changes in public attitudes, public policy, and state laws may be needed before any of these changes and the resulting net savings can be realized. Some of the areas which need to be addressed are:

1. A reasonable method of compensating abutting landowners for change from public to private access
2. A method of arbitration of disputes between adjoining landowners affected by the change and/or the local government authority
3. Exemption of the local government authority from legal action upon completion of established guidelines
4. Legislation to strengthen existing laws regarding road abandonment and shifting public roads to private roads
5. A method of educating the public of the benefits and costs of alternative road system changes to enable the public to improve the quality of its input into the policy-making process

Chapter 1

Introduction: The Problem and Some Alternative Solutions

The local rural road system—maintained and controlled by counties or townships—consists of 2.2 million miles and represents 71 percent of the 3.2 million miles of rural roads in the United States. The system is generally laid out in rectangular grids, particularly in the Midwest where the regularity of the county roads dates back to the Ordinance of 1785 that established the one-mile survey grids to open the land for settlement.

Many of today's local rural roads and bridges were built in the late 1800s and early 1900s when overland transportation was limited to horse and wagon or the recently built railroad lines. The discovery of large petroleum reserves in Texas and Oklahoma spurred the development of the automobile and truck industries during the 1920s and 1930s and created a need to get rural America "out of the mud." Roads were surfaced, and some bridges were replaced to accommodate trucks with gross weights of six to seven tons. About 70 percent of today's rural bridges were built before 1935, but even those constructed in the 1940s were designed only for 15-ton loads.

By 1950 about 50 percent of the local rural roads were improved with all-weather gravel or paved surfaces. Thus the widths, grades, bases, surface designs, and capacities of many local rural roads and bridges are based on the traffic needs of the 1940s and 1950s.

The declining number of farms and the increasing size of farm trucks and implements are changing the traffic on the local rural road system. There are no weight limits on "implements of husbandry" (farm equipment). Today some farmers use a tractor and two wagons to haul 600 to 900 bushels of grain with a gross weight of 28 to 36 tons. Many bridges are over 55 feet long, so that the entire load is on the bridge at one time. Some single-axle wagons hold over 800 bushels of grain; after deducting about 6,000 pounds of hitch weight, the loaded weight ranges up to 50,000 pounds per axle.

As farm size has increased, so have the trucks serving agriculture. Tandem-axle trucks with gross weights of 27 tons are common on rural roads and bridges. In 1975, the U.S. Congress permitted states to set higher weight limits for trucks on the interstate highway system. Most states adopted the federal limits and raised the weight limits to the federal standard of 20,000 pounds per axle, 34,000 pounds per two-axle tandem, and 80,000-pound maximum overall weight.

The introduction of low-cost unit grain trains in the corn and wheat states has encouraged the use of larger farm vehicles to haul grain longer distances. Some farmers are buying tandem-axle and semi-trailer trucks to move their grain out of the field quickly, to increase their marketing options, to reduce hauling costs, and to eliminate the safety hazards of farm tractor-wagon combinations. These heavy vehicles place additional stress on the local road and bridge system.

In most instances, a farmer increases his farm size by buying or leasing land from neighboring farms, thereby reducing the total number of farms. This reduction in the number of farms means that some rural roads may no longer be needed for access to homes, schools, and markets. Some observers believe that the miles of rural roads might be reduced without denying access to the remaining farms and residences.

And finally, the declining rural population has resulted in a reduction in the number of rural schools. To help minimize the cost of transporting

Table 1.1. Net annual savings from reducing the size of the county road system by abandoning low-volume roads that serve no property accesses, 1982

	Computer solution					
	Linn study area		Shelby study area			Hamilton study area
Type of savings	L_1 (5.25 miles)	L_2 (3.75 miles)	S_1 (9.25 miles)	S_2 (6.75 miles)	S_3 (5.25 miles)	H_1 (17.75 miles)
Savings to the traveling public	$ −29,014	$ −28,138	$ −39,276	$ −78,436	$ −77,052	$ −68,521
Savings to the county	24,353	15,942	49,367	31,146	14,611	65,689
Net value of land to abutting landowners	5,029	3,592	2,663	1,943	1,512	19,313
Total net savings	$ 368	$ −8,604	$ 12,754	$ −45,347	$ −60,929	$ 16,481
Net savings per mile abandoned	$ 70	$ −2,294	$ 1,379	$ −6,718	$ −11,605	$ 929

schoolchildren farther to fewer schools, school boards are purchasing 72- to 89-passenger school buses. These school buses weigh up to 15 tons when loaded and cannot cross bridges that are posted at less than their gross weights.

Condition of the Local Rural Road and Bridge System

Precise data on the current condition of the local rural road system are not available since no ongoing coordinated data collection exists for local rural roads. However, there is ample evidence that the system is deteriorating rapidly. In a recent Illinois survey, farmers and agribusiness representatives rated about half of the Illinois local rural roads as needing more than regular maintenance; over 20 percent of these roads were rated as needing major repair.

Common complaints about the local rural roads include:

1. Overweight vehicles breaking up road surfaces
2. Lack of hard surfaces creating dust and rideability problems
3. Road widths and other design characteristics inadequate for today's large farm equipment and heavy trucks
4. Narrow lanes creating safety problems

While the local road deficiencies are significant, the condition of local bridges is also of great concern. Deficient bridges on local rural roads create serious safety and traffic constraints. On 1 January 1986, 167,985 bridges or 55 percent of all off-federal-aid bridges that had been inventoried were deficient. In addition, 121,507 or 40 percent of the 304,948 off-federal-aid bridges were posted, or should have been posted, at less than legal weight limits. The estimated replacement and rehabilitation costs of these deficient off-system bridges is $20.4 billion. However, even this understates the magnitude of the problem. Bridges under 20 feet long were not included in the inventory, and thousands of such bridges need replacement or rehabilitation.

Table 1.2. Net annual savings from converting two sets of roads to area service B roads, Shelby County study area, 1982

	Computer solution	
Type of savings	B_1 (9.25 miles)	B_2 (20.25 miles)
Savings to the traveling public	$ −5,731	$ −14,401
Savings to the county	37,482	73,093
Total net savings	$ 31,751	$ 58,692
Net savings per mile converted	$ 3,433	$ 2,898

The distribution of deficient bridges indicates that the local bridge problem is national in scope. States with the largest number of deficient bridges are Texas, Iowa, Missouri, Nebraska, Oklahoma, North Carolina, Kansas, Indiana, New York, Tennessee, Mississippi, and Illinois. States in the Northeast, Midwest, Southeast, and Southwest are included in the groups with a high percentage or a large total number of deficient bridges. Western states have the least problem with bridges. The paucity of county road and bridge condition data suggests the need for statewide road data banks or inventory systems.

Table 1.3. Net annual savings from converting low-volume roads to private drives, Hamilton and Shelby study areas, 1982

	Hamilton study area		Shelby study area
Type of savings	Continuous roads (8.75 miles)	Dead-end roads (31.75 miles)	Dead-end roads (14.0 miles)
Savings to the traveling public	$ −31,878	$ 0	$ 0
Savings to the county	57,419	129,423	56,744
Private drive maintenance costs	$ −16,679	$ −65,967	$ −33,571
Net rental value of 3.15 acres of land freed per mile of private drive	3,662	14,093	4,211
Total net savings	$ 12,524	$ 77,549	$ 27,384
Net savings per mile privatized	$ 1,518	$ 2,442	$ 1,956

Funding for the Local Rural Road and Bridge System

Local rural road and bridge construction and maintenance funds are typically derived from highway user taxes and local property taxes. Highway user tax collections have increased recently because of large increases in fuel and truck road use taxes. But many counties are already at the maximum level of the local tax levy. For example, many counties in Iowa are at the maximum levy and cannot raise property taxes for rural roads without changes in state legislation. Several counties are between 95 and 99 percent of the maximum local levy. Only a small number of Iowa counties could raise the local levy by 20 percent or more. This means that there are major constraints on additional revenues for rebuilding the local rural road system.

There are major needs for increased local rural road and bridge funding. For example, the 1986 "Iowa Highway Needs Study" (Iowa Department of Transportation, 1987) indicates that the projected 1986-2005 county road revenue buying power would cover only 46 percent of the projected county road and bridge needs. The 1982 "Iowa Highway Needs Study" had indicated that the projected 1982-2001 county road revenue buying power would cover 51 percent of the projected needs. Thus, the deficit in county road revenues relative to needs continues to grow. Counties and townships in other states, as well as state departments of transportation, face similar budget problems.

Alternative Solutions

The local rural road and bridge problem is basically a shortage of funds to maintain and reconstruct the present system to accommodate the changing transportation needs of rural America. A number of alternative solutions to increase revenues or to reduce costs exist, including the following.

1. Continue the Present Sources of Funding and Tax Levels and Maintain the Current Size of the Local Rural Road and Bridge System.

This alternative would mean that there would be no large increases in property or road use taxes to finance the reconstruction of the local rural road system. There have been motor fuel tax increases in many states in recent years. However, these per gallon fuel tax increases have been offset by more fuel-efficient vehicles. In addition, the share of the road use tax funds going to the local rural road system will likely be offset by declining property tax collections as the decline in property tax valuations works its way through the tax system. Thus, this alternative would likely result in continued deterioration of the local rural road system. Counties and townships would continue to face increasing maintenance costs to repair existing surfaces and bridges. Some bridges would need to be closed without additional replacement funds. More importantly, county and township governments could face increased exposure to large tort liability claims for damages resulting from deteriorating roads and bridges. Courts historically have been generous to these claims.

2. Legislate Large Increases in State and Federal Funding.

Potential sources of state funds include increased state or federal fuel taxes, increased state vehicle registration fees, funding from state and federal general funds, or a larger share of the road use tax fund. It is unlikely that the present political climate would permit raising the fuel and registration fees enough or shifting additional funds from state general funds to meet the increasing needs of the rural road system. At the present time, the federal government is attempting to reduce its role in financing local roads and bridges. Some state governments are attempting to reduce the share of total road use taxes allocated to local roads. However, the magnitude of the local rural road and bridge problem, as well as the state and municipal road and street system problems, suggests that state governments may be forced to increase fuel taxes and to assume part of the costs of rebuilding the local rural bridges.

3. Impose Local Option Taxes Alone or With Bonding Authority for Local Rural Road and Bridge Funding.
The local option taxes could be in the form of property, sales, fuel, excise, or other taxes. When levied alone, they would approximate user taxes because a significant portion of the traffic on local roads is local traffic. When these taxes are used to support bonding programs for capital improvements, the program becomes even more of a user tax. However, interest on the bonds increases the cost of rebuilding the system unless the inflation rate is greater than the interest rate.

4. Reduce the Minimum Reconstruction and Maintenance Standards on all Local Rural Roads and Bridges.
The minimum standards for local rural roads and bridges are generally based on design guides published by the American Association of State Highway and Transportation Officials. In some cases, road plans must be approved by state and federal agencies. Future reconstruction costs could be reduced by lowering the minimum design standards on low-volume, off-system rural roads. Costs could be cut by reducing the widths of rights-of-way, shoulders, and bridges, and by reducing the thickness of the pavement and the maximum grades. Lower minimum standards, on the other hand, could result in increased maintenance costs through greater erosion from steeper and narrower ditches, faster deterioration of pavements and bridges, and reduced snow-storage capacities. This option would also increase vehicle operating costs to the traveling public.

5. Reduce the Size of the Local Rural Road System by Abandoning Some Road Segments That Serve No Property Accesses.
The rectangular grid of many local rural roads provides many property owners with up to four-way access to their homes, farmsteads, and other property. This suggests that some local rural roads could be eliminated from the system and still provide one-way access to all homes, farms, fields, and local businesses. However, reducing the number of rural roads will result in higher travel costs to the public through longer travel distances. Thus, decisions to reduce the size of the rural road system must be evaluated in terms of the additional costs to the traveling public relative to the cost savings to the local governments providing the public road system. Any proposal to reduce the size of the local road system must be researched with care. There will likely be little effort to reduce the size of the local road system until programs are designed to relieve local government officials of the considerable political liability associated with road abandonment.

6. Establish a Reduced Maintenance Classification on Selected Area Service Roads.
Many low-volume road segments provide access only to farm fields. It is possible to reduce maintenance significantly on these area service roads and still provide access to farm fields. Area service B road maintenance generally includes no gravel resurfacing or snow removal. Eventually the B roads would revert to dirt roads and would not be opened in the winter. Therefore, these roads could not service households, farmsteads, or any other property that must have winter access by registered vehicles.

There are potential problems with this reduced maintenance option. First, while the road surfaces would be downgraded over time, substantial local government investments would eventually be required on bridge maintenance, reconstruction, or replacement with low-water crossings if the roads are to remain open. Second, while Iowa law exempts the county governments from liability for personal injury or property damage caused by the lower level of maintenance, the exemption has not been tested in the courts. Third, county boards of supervisors are reluctant to place many roads in the area service B category because of political implications.

7. Establish a Land Access System.
Another alternative to reducing local rural road costs is to establish a system of land access roads, which would remain under public jurisdiction but would not be open to public traffic. These roads, which would serve no residences, would provide access only for farming operations. All maintenance would be the responsibility of adjoining landowners. The level of maintenance would depend on the type of activity on the roads. For example, a road providing access only to fields could be allowed to revert to earth surface, while a road serving a livestock operation would need a gravel surface. All liability would be transferred to the adjoining landowners. However, the exclusion of public traffic should reduce liability from animal escape and vehicle accidents. Elected local government officials would act as a review board to settle disputes among abutting owners over the level of maintenance and the distribution of the maintenance costs.

Most public roads have a 66-foot right-of-way. Land access roads may need only a 40 feet right-of-way. Thus, each abutting landowner would receive an additional 13 feet of land along the land access roads.

8. Return Some Roads to Private Ownership.
A 1976 editorial in the *Des Moines Register* states:

> County roads that served dozens of farms forty years ago may be serving only two or three farms today. Many roads that were once vital to a county's well-being have become, in effect, private roads although the county is responsible for their upkeep. Such roads no longer belong in the county road system.

Some observers believe that road abandonment is the fundamental answer to the lack of funds for rural road and bridge construction and maintenance. However, it often costs more to vacate a road than to keep it because district courts have tended to make large awards to landowners for the loss of public access. Many county engineers believe that only a very small number of local rural roads will be abandoned unless laws are changed to reduce damage claims for the action and to transfer the responsibility for maintenance and liability for publicly-owned field access roads to the benefited property.

Dead-end roads are prime candidates for conversion to private drives because these roads carry only traffic originally from or destined for residences, farms, and fields located on these roads. Thus, conversion of dead-end roads to private drives would result in no additional travel costs. Furthermore, private maintenance costs on these roads would likely be substantially lower than public maintenance costs. However, damage claims permitted by some state laws are so large that the private drive option will likely be exercised only if these maximum damage claims are lowered.

9. Reduce and Enforce Weight Limits on Local Rural Roads and Place Weight and Width Limits on Implements of Husbandry.
This alternative undoubtedly would reduce maintenance costs of existing roads and bridges. However, a reduction of current weight limits and placing weight and width limits on implements of husbandry would increase the costs of agricultural production and marketing. It would also create enforcement problems. There is a need to study the reconstruction and maintenance costs of higher weight limits versus the increased costs of agricultural production if lower weight limits were imposed.

Objectives
The basic purpose of this study was to develop guidelines for local supervisors and engineers in evaluating local rural road and bridge investment or disinvestment proposals, and to provide information to state legislatures developing local road and bridge policy proposals. The general objective of the study was to evaluate the cost savings of selected local rural road and bridge investment strategies. Specifically, the objectives were to:

1. Describe the county road system traffic flows in three study areas in Iowa in terms of
   A. The number, origin, and destination of trips by households by vehicle type
   B. The number, origin, and destination of farm-related trips by vehicle type

2. Estimate the vehicle travel cost per mile by vehicle type and road surface.

3. Determine the costs of maintaining county bridges and county roads by surface type and traffic levels.

4. Develop a computer program to estimate the change in travel costs and the change in road and bridge maintenance costs under alternative road investment strategies.

5. Identify, analyze, and evaluate the cost savings of alternative county road and bridge investment strategies.

6. Describe the impacts of the alternative investment strategies on farm, household, local school system, and postal service travel costs and on county road and bridge maintenance, resurfacing, and reconstruction costs.

Literature Review

Numerous writers have discussed the deteriorating conditions of the local rural road and bridge system. However, only a small number of studies, (Fruin 1977; Baumel and Schornhorst 1983; Chicoine and Walzer 1984) have attempted to identify alternative solutions. Fewer yet have attempted to quantify the impacts of the deteriorating roads and bridges on travel costs or the impacts of alternative solutions on travel costs and local government costs.

The Pennsylvania Department of Transportation (1983) identified an "Agricultural Access Network" in two Pennsylvania counties. These agricultural access networks included those roads that were judged to be most important to the rural areas for the transport of agricultural products to markets and supplies to the farms. In addition, the study identified the key transportation obstructions that inhibit agricultural movements.

Tucker and Thompson (1981) examined the impact of alternative rural road development and maintenance policies on grain marketing costs in southeastern Michigan. The results indicate that grain marketing costs decrease as the road system is improved, but the savings in grain transport costs are far less than the costs of the road improvements.

Nyamaah and Hitzhusen (1985) used a circuitry model to estimate the rerouting costs to road users when 15 rural bridges in Ohio were posted or closed. The model indicated substantially greater benefits from bridge repair or replacement than the county engineers estimated.

Chicoine and Walzer (1984) surveyed farmers, township officials, and agricultural and rural business officials in four Midwestern states to identify their opinions and attitudes on a wide range of rural road and bridge questions and issues. In addition, they identified the preferred alternative sources of rural road and bridge financing, as well as alternative investment strategies and management practices.

Smith, Wilkinson, and Anschel (1973) examined the impact of unimproved roads in the eastern Kentucky coal fields on resident participation in social recreation, education, and medical activities. They found that lack of access to all-weather roads had no measurable adverse effect on human resource development and cultural integration.

The Midwest Research Institute (1969) developed criteria for evaluating low volume rural roads for potential abandonment. These criteria were to be used to calculate a benefit-cost ratio for each road. The benefits were based on traffic levels, number and type of users, type of road, and access requirements. Each factor was assigned an arbitrary weight and aggregated into an index. The costs of retaining a road included the 20-year routine maintenance and capital costs, liability risks, and vacating costs. The benefit index does not include any monetary measures of the value of an individual road to the traveling public. This procedure does not measure the change in cost to the traveling public from eliminating a road or set of roads from the network, nor does it measure the maintenance and resurfacing costs transferred to roads that inherit additional traffic.

Johnson (1977) developed models that could be used to estimate the benefits of road improvements, including building a new road, replacing and upgrading bridges, and widening or resurfacing a road. The analysis was conceptual rather than empirical, and no measured benefits were presented.

Several studies, including those by Hartwig and the Iowa Department of Transportation (1982), have suggested a potential cost savings from the abandonment of local rural roads. Baumel, Hamlett, and Pautsch (1986) were the first to quantitatively evaluate the impact of local road abandonment on all traffic types using the rural road and bridge system. They estimated benefits and costs of abandoning selected roads in three study areas in Iowa. This current analysis is an update and an extension of the earlier study.

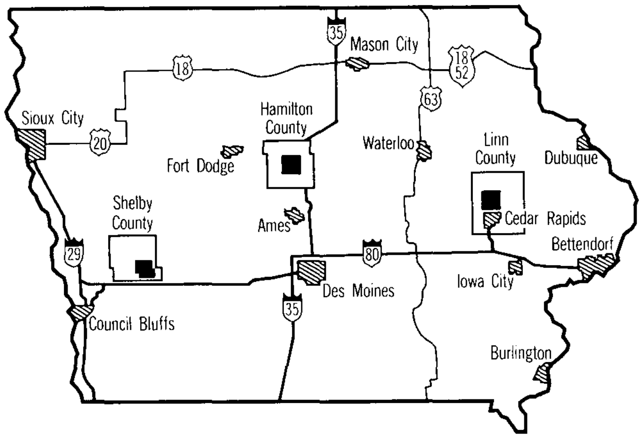
Chapter 2

Method of Analysis

A benefit-cost analysis was used to evaluate the impacts of alternative county road investment strategies on the traveling public and on investment costs in the county road system on three areas of approximately one hundred square miles each in Iowa. The study areas, (outlined in Fig. 2.1) are located in Hamilton, Shelby, and Linn counties in Iowa. The three counties were selected for their differences in terrain, quality of roads, and economic activities.

- Hamilton County, located in north central Iowa, has a relatively high agricultural tax base, relatively level terrain, a high percentage of paved roads, and relatively few bridges.
- Shelby County, located in southwest Iowa, has a relatively low agricultural tax base, hilly terrain, a small percentage of paved roads, and many bridges.
- Linn County, located in east central Iowa, has a relatively high agricultural tax base, a high percentage of paved roads, and a large number of non-farm households with commuters to Cedar Rapids and Waterloo.

Figure 2.1. Location of study areas



Impact of Alternative Investment Strategies on Travel Costs

Most changes in road systems affect travel costs. For example, if a section of road is removed from the road network, some vehicles must travel further to reach their destinations. This additional distance increases travel costs. Paving a gravel road reduces travel costs, which decline on paved roads relative to gravel or earth roads.

Except for school bus and postal service travel costs, the impacts of the alternative investment strategies on travel costs were estimated in two steps. First, a network model was used to estimate the minimum-cost traffic flows for all 1982 traffic within each study area. These traffic flows were then used to estimate the minimum total cost of all 1982 travel in each study area. Travel costs were defined as the variable vehicle cost per mile times the number of miles traveled by each vehicle type.

A network model, utilizing Dijkstra's algorithm, was used to estimate the minimum-cost routing from each origin to each destination for each vehicle type. The advantages of Dijkstra's algorithm are that it preserves the origin-destination relationship and it requires relatively few operations to find an optimal solution. A network consists of a set of nodes connected by arcs. A node represents a point where a trip originates, is relayed, or terminates. Arcs represent the road distance between two nodes and allow the traffic to flow between two nodes. The roads in each study area were coded into a computer network; roads became arcs, and nodes were located at intersections and at half-mile intervals.

Types of Arcs in the Complete Road Network Model

Study Area Arcs

The roads within each study area were divided into approximately half-mile segments. A node representing each household, farm, and field access point on the half-mile arc was placed at the end of that arc. Each bridge in the study area was also represented as an arc. The actual square footage of each bridge was coded with its arc so that maintenance, repair, and replacement costs could be based on the size of the bridge. The physical characteristics of each half-mile section—pavement surface, distance, and weight constraints—were coded into a computer data set.

Border Area Arcs

A large number of trips from inside to outside the study areas are trips to destinations within three miles of the areas' borders. Many farmers living inside a study area farm tracts of land within the three-mile border. Border area arcs were created to allow the computer to accurately route trips to destinations within the three-mile area surrounding the study boundaries. Border arcs were formed by placing a node at each road intersection in the three-mile wide outside border. The distance and pavement surface of these arcs were coded into the computer data set.

Outside Arcs

Outside arcs were created to allow the algorithm to route farmers through the study area when traveling to land outside the three-mile border area. Outside arcs were formed by placing four nodes, one each to the north, south, east, and west of the study area, and connecting these nodes to the nodes on the respective edge of the study area. For example, if a farmer had a tract of land located outside the three-mile border and south of the study area, the tract would be given the south border node as a destination. Any trips to that outside tract would be routed from the origin node within the study area to the outside node. This allowed the calculation of within-study-area cost of travel to tracts of land further than three miles outside the study area.

Highway Arcs

Many trips are to distant locations, frequently to large cities and out-of-state locations. The method used to incorporate these trips into the analysis is based on the assumption that travel routes to or from distant locations will maximize the use of state or interstate highways. One node was assigned to each state or interstate highway within the study and boundary areas. The highway nodes were connected to nodes serving as access points to the highway with a zero distance for all vehicles. The computer routed the trip to the closest access to a state or federal highway lying in the direction of the true destination or origin.

Tract Arcs

The origin or destination of many farmer trips is a tract of land. Tracts of farmland often have multiple access points. In most cases, the access used depended on the direction of the trip origin. Each tract of land was assigned a node number. When a farmer traveled from tract to tract, the origin and destination were coded as the tract's node number. The computer then found the cost-minimizing route between the two tracts by finding the optimal access points for each trip. Tract arcs were given a distance of 100 miles so that only trips that had that tract node as an origin or destination would be routed over the arc. This prevents road traffic from "driving through the field." When calculating the actual cost of a given trip, the 100 miles to travel on a tract arc was set equal to zero.

Network Constraints

A separate computer program was developed to check the weight limit of each study area bridge with the weights of the vehicles in the study area. If the weight of the vehicle exceeded the weight constraint of the bridge, the arc distance or cost was set equal to a large number before the routing began. For example, if a bridge had a posted load limit of 10 tons and the vehicle type had a weight exceeding 10 tons, then the bridge arc was assigned a large distance for all trips involving that vehicle type.

The first step in estimating the impact of alternative investment strategies on travel costs was to code into the computer network the 1982 travel data taken from the questionnaires obtained from the study area residents and farmers. The computer then optimized the routes for all 1982 trips to obtain the least-cost routes for all 1982 travel in the study areas. This optimization is hereafter called the base solution.

The basic assumptions behind the network model used in this analysis are:

1. Travel costs are a linear function of distance traveled for each vehicle type.
2. The number of trips from each origin to each destination in each time period by each vehicle type is independent of changes in the road system.
3. Vehicle-purchase decisions are not affected by the changes in the distance between an origin and a destination resulting from a change in the road system. The changes in distance are generally small.
4. Vehicle trips leaving a specific origin for a specific destination must leave that origin and arrive at that destination.
5. Vehicle drivers select travel routes to minimize travel costs.
6. Vehicles with gross weights greater than the posted carrying capacity of a bridge cannot cross that bridge.

Detailed specifications of the network model are presented in Appendix A.

The second step was to reoptimize the traffic flow under the alternative investment strategy to obtain the minimum total cost of all 1982 travel. The difference between the total cost of travel under the base solution obtained in step one and the cost under the alternative investment obtained in step two is defined as the change in cost to the traveling public.

School bus and post office travel costs could not be estimated by the network model because much of the routing of these vehicles depends on how the routes were structured outside the study areas. Alternative methods were used to estimate the change in travel costs of these vehicles from the alternative investment strategy. Existing school bus routes were rerouted visually to estimate the change in travel costs. Postal service travel costs before and after the investment strategies were implemented were estimated by officials from the U.S. Post Office in Des Moines based on actual postal routes inside and outside each study area.

Changes in Road Costs

Alternative road investment strategies affect the cost of providing these roads through changes in:

1. Fixed maintenance costs that are associated with time and weather
2. Variable maintenance costs caused by vehicle traffic
3. The annualized cost of periodic resurfacing and reconstruction
4. The net opportunity cost of having the land in roads rather than in agricultural production

Annual fixed maintenance costs on paved roads include drainage, signing, and major maintenance ditching; these costs are independent of traffic volume. Variable maintenance costs on paved roads include snow removal, resurfacing, painting lane stripes, patching, and shoulder resurfacing. Variable maintenance costs on paved roads vary by surface type and thickness, subbase thickness, number and weight of vehicle axles, and number of vehicle axle passes.

Fixed costs on granular roads include signing, drainage, snow removal, and weed control. Variable maintenance costs on granular surface roads include gravel resurfacing and blading. No estimates of the impact of vehicle axle weight are available on granular and earth-surface roads. Major reconstruction and resurfacing costs vary by type of road and traffic volume. The procedure for estimating maintenance, resurfacing, and reconstruction costs is presented in Appendix B.

The Data

The data required to evaluate the several road and bridge investment strategies in this study include the following:

1. The quantity, origins, and destinations by vehicle type of all household and farm travel that originates or terminates within the study areas
2. The quantity and types of overhead traffic that moves through but does not originate or terminate in the study areas
3. The travel costs of each type of vehicle traveling in the study areas
4. The miles and types of roads and the number and sizes of bridges within the study areas
5. The cost of maintaining and rebuilding the roads and bridges in the study areas
6. The value of land in road rights-of-way

Quantity and Types of Travel in the Study Areas

Data on personal and farm travel were obtained by a survey of households and farms in the three study areas. The survey was conducted by the Iowa State University Statistical Laboratory. All interviews were conducted by professional interviewers.

The goal of the survey was to obtain data on all 1982 travel from farm and non-farm residents in the three study areas. The first round of farm interviewing accounted for about 75 percent of the farmland within the study area borders. By mapping out the land covered by the completed questionnaires, examining plat books, and questioning neighbors, the majority of the land not listed in the questionnaires was found to be farmed by operators who lived outside the ten-mile by ten-mile study areas. Farmers who operated the farmland not covered in the initial round of interviews were located and interviewed. These farmers, who lived outside the study areas but farmed land within them, are referred to as nonresident farmers in the remainder of this paper.

Only 5 out of 231 farmers operating in the Hamilton County study area, 11 out of 274 farmers in the Shelby area, and 10 out of 248 farmers in the Linn area refused to be interviewed. Thus, the farm interview rate was 97.8 percent in Hamilton County and 96 percent in Shelby and Linn counties. Neighbors were questioned about the farming characteristics of the refusing farmers. Information gathered from neighbors, along with questionnaire responses from nearby farmers with similar size farms, were used to construct questionnaires for the refusing farmers. Residents who had died or moved out of the area since 1982 were also accounted for by interviewing neighbors and friends. Questionnaires from respondents with similar characteristics were then substituted for those residents.

All non-farm rural households in the Hamilton and Shelby study areas were targeted to be interviewed. Only 8 out of 125 non-farm households in the Hamilton area and 10 out of 170 non-farm households in the Shelby area refused to be interviewed. Thus, the non-farm household interview rate was 93.6 percent in Hamilton County and 94.1 percent in Shelby county. Neighbors were questioned about the characteristics of households that refused to be interviewed or residents who had died or moved out of the study area since 1982. Responses from questionnaires obtained from nearby households of similar size and type were used for the missing households.

Time and money constraints prohibited interviewing the many non-farm rural households in the Linn County study area. Therefore, a sampling procedure was devised to obtain data from these households. First, a "windshield" survey of the entire study area was made to identify farm and non-farm households. Of the 445 identified farm households, 245 turned out to be non-farm households. All of these households were asked for an interview. A total of

Table 2.1. Summary of farm and non-farm interviews and sample expansion in the Hamilton, Shelby, and Linn County study areas

	Hamilton		Shelby		Linn	
Description	**Households**	**Farms**	**Households**	**Farms**	**Households**	**Farms**
Study area farm interviews	170	170	196	196	195	195
Nonresident farm interviews	*	56	*	67	*	43
Farm refusals[a]	4	5	6	11	5	10
Rural non-farm interviews	110	—	160	—	231	—
Rural non-farm refusals	8	—	10	—	14	—
Town household sample interviews	7	—	—	—	18	—
Small town household expansion	80	—	—	—	198	—
Linn County non-farm sample interviews	—	—	—	—	59	—
Linn County sample refusals	—	—	—	—	12	—
Linn County non-farm sample expansion	—	—	—	—	781	—
Total	379	231	372	274	1,513	248

*Household travel information was not taken for nonresident farmers.

[a]Includes nonresident farm refusals.

14 households refused to be interviewed, resulting in a 94 percent response rate. A random area sample of the remaining non-farm households was drawn at a sampling rate of one out of 12. Only 12 sampled non-farm households refused to be interviewed for an 83 percent response rate. The 59 non-farm interviews were then expanded 11 times at the location of each of the 59 interviewed locations; that is, the responses on each questionnaire were assigned to 11 additional households located at the same node as each interviewed household.

The Hamilton and Linn study areas each contained one incorporated town. Data on travel patterns of residents of these towns were obtained by an area sample of households. For every 11 households, one was sampled. Data for the remaining households were obtained by expanding the sampled questionnaires.

Table 2.1 presents a summary of the number and type of interviews by study area. The total number of farms was nearly identical in each of the three study areas. The total number of households—farm and non-farm—was almost exactly the same in the Hamilton and Shelby study areas. However, the Linn County study area had about four times as many households as the other two.

A major effort was made to validate the questionnaire response and interviewer quality. Telephone calls were made to 10 percent of the households and farms interviewed by each interviewer to validate the initial questionnaires. The answers obtained through the validation calls were essentially the same as the initial answers. In addition, all discrepancies between answers within questionnaires or unclear responses were resolved by telephone calls to the initial respondents.

Separate questionnaires were developed for farm and non-farm respondents. A summary of the main information requested in the questionnaires is presented in Table 2.2. The farm questionnaire asked for all the information contained in Table 2.2. The non-farm questionnaire asked for information on items 1 and 14-17. Copies of the farm and non-farm questionnaires are presented in Appendix E.

Partial Survey Results

Responses to the questionnaires provided a large amount of information on farm and non-farm travel patterns. Tables 2.3, 2.4, and 2.5 summarize selected sets of the questionnaire data.

Table 2.2. Summary of information requested on the questionnaires

1. Exact location of respondent's home and land tracts
2. Number of acres in each tract
3. Access points for each land tract
4. Location of land tracts outside study area
5. Information about a farming partner, if applicable
6. Deliveries made to each tract
  a. Number of deliveries
  b. Name and location of dealer making the delivery
  c. Type of vehicle used for deliveries
7. Alternate routes (those different from the shortest route)
8. Origin, destination, and number of pickup truck trips by farmers
  a. Tract-to-tract travel
  b. Off-farm travel
9. Origin and destination of farm equipment travel from one tract to another
  a. Type of vehicle
  b. Number of times vehicle entered each tract
10. Number and size of combines used
11. Number and size of tractors used
12. Total number and size of trucks
13. Intra-farm and off-farm product hauling
  a. Products hauled
  b. Number of trips
  c. Destination
  d. Type of vehicle
14. Demographic information
15. Detailed information on personal travel
16. Deliveries made to the house
  a. Number of trips
  b. Origin of trips
  c. Type of vehicle
17. Traffic coming onto homestead
  a. Number of visitors
  b. Origin of the traffic
  c. Type of vehicle

Table 2.3 presents the distribution of the number of spatially separated tracts of land operated by individual farmers. The distance separating multiple-tract farms is a major determinant of the amount of road travel by farmers to plant, cultivate, harvest, and haul the crops to market or to on-farm storage. Single-tract farms require little, if any, road travel to reach the fields.

The percentage of farmers operating single-tract farms was 23.0 percent in Hamilton County, 25.7

percent in Shelby County, and 35.0 percent in Linn County. These single-tract farmers, with an average of 137 and 142 acres per farm in the Hamilton and Shelby study areas, respectively, and 86 acres per farm in the Linn area, operated a disproportionately small percentage of the total farm acres in the three study areas. Only 8.0, 11.0, and 10.5 percent of the land farmed by study area residents were operated as single-tract farms in the Hamilton, Shelby, and Linn study areas, respectively.

Two-tract farms made up 23.6, 25.7, and 21.0 percent of the resident-farmed land in the Hamilton, Shelby, and Linn study areas, respectively. The average size of the two-tract farm was over 200 acres. The largest percentage of farmers—40.8 percent in Hamilton and 42 percent in Shelby—operated three to five tracts of land. Farms of six or more tracts of land contained 30, 15, and 48 percent of the land farmed by resident farmers in the Hamilton, Shelby, and Linn study areas, respectively. The Linn County study area had the largest percentage of single-tract farms as well as the largest percentage of very large farms.

Table 2.4 presents the total and average number of vehicles used on resident farms in the three study areas. As expected, the most numerous vehicle was the farm tractor. There were 924 tractors in the Hamilton County study area, nearly 1,200 tractors in the Shelby area, and 841 tractors in the Linn area for an average of 4.1, 4.5, and 3.2 tractors per farm, respectively. The second most numerous vehicle was the pickup truck, averaging between 1.2 and 1.5 pickup trucks per farm. The large truck used most frequently was the single-axle truck; one out of three Hamilton area farmers, one out of two Shelby area farmers, and two out of five Linn area farmers had a single-axle truck.

Shelby and Linn study area farmers owned more trucks of all sizes than the Hamilton area farmers. The absence of any operating railroad lines in Shelby County in 1982 could be the reason for the large number of trucks in that area. However, the Linn County study area had more large trucks than the other two areas, and Linn County has more railroad lines than Hamilton County and, indeed, more railroad lines than most Iowa counties. A more reasonable explanation for the large number of trucks in the Linn and Shelby study areas is the location of major grain markets at Cedar Rapids and Clinton for the Linn County farmers and at Council Bluffs and Omaha for Shelby County farmers. Grain

Table 2.3. Distribution of number of tracts per farm and average acres per farm in each tract group by county study area[a]

County study area	Number of tracts	Average acres per farm	Percent of total acres	Number of farmers	Percent of total farmers
Hamilton	1	137	8.0	40	23.0
	2	225	13.5	41	23.6
	3-5	465	48.1	71	40.8
	6-8	791	18.4	16	9.2
	9-11	1,229	5.4	3	1.7
	12-14	1,500	6.6	3	1.7
Shelby	1	142	11.0	52	25.7
	2	243	18.9	52	25.7
	3-5	435	55.3	85	42.1
	6-8	772	13.9	12	6.0
	9-11	611	0.9	1	0.5
Linn	1	86	10.5	70	35.0
	2	144	10.6	42	21.0
	3-5	293	30.8	60	30.0
	6-8	719	21.4	17	8.5
	9-11	1,000	8.8	5	2.5
	12-14	1,233	10.8	5	2.5
	32	4,044	7.1	1	0.5

[a]Excludes nonresident farmers

farmers in Hamilton County sell most of their grain through grain elevators with unit-train facilities, which are typically located within 10 miles of most farms in the Hamilton study area.

Table 2.5 presents the average number of personal trips per household per day in the three study areas. The percentage of households with less than one personal trip per day ranged from 21 percent in the Linn study area to 40 percent in the Shelby study area. About one-third the households in all three areas made 1.0 to 1.9 personal trips per day. The percentage of households with two or more trips per day was 28 percent in the Shelby area, 38 percent in the Hamilton area, and 46 percent in the Linn area. Thus, the Linn area had the largest number of trips per day, followed by the Hamilton, and then the Shelby study area.

Table 2.4. Total, average, and maximum number of vehicles per farm by type of vehicle and study area[a]

County study area	Type of vehicle	Total number of vehicles	Average vehicles per farm	Maximum number of vehicles per farm
Hamilton	Tractor	924	4.1	10
	Pickup	336	1.5	9
	Single-axle truck	68	0.3	4
	Tandem-axle truck	32	0.2	3
	Semitrailer truck	3	0.01	1
Shelby	Tractor	1,194	4.5	9
	Pickup	475	1.4	9
	Single-axle truck	120	0.5	3
	Tandem-axle truck	47	0.2	4
	Semitrailer truck	14	0.05	4
Linn	Tractor	841	3.2	15
	Pickup	320	1.2	8
	Single-axle truck	101	0.4	6
	Tandem-axle truck	50	0.2	6
	Semitrailer truck	17	0.07	5

[a]Excludes nonresident farmers.

Table 2.5. Number of personal trips per household per day by county study area

	Study area					
	Hamilton		Shelby		Linn	
Average number of trips per day	Number of households	Percent of households	Number of households	Percent of households	Number of households	Percent of households
0-0.9	98	25.8	150	40.4	324	21.4
1-1.9	139	36.6	118	31.7	496	32.7
2-2.9	60	15.9	55	14.8	345	22.8
3-3.9	35	9.2	29	7.8	153	10.1
4-4.9	21	5.5	10	2.7	109	7.2
5-5.9	16	4.3	2	0.5	30	2.0
6-6.9	3	0.8	2	0.5	16	1.1
7-7.9	3	0.8	3	0.8	11	0.7
8-8.9	3	0.8	0	0.0	1	0.1
9-9.9	1	0.3	0	0.0	13	0.9
10+	0	0.0	3	0.8	15	1.0
Total	379	100.0	372	100.0	1,513	100.0

Table 2.6 presents the total number and age distribution of the residents in the three study areas. The Linn County area has about eight times as many non-farm residents as the Hamilton and Shelby areas. Moreover, a much higher percentage of the Linn non-farm residents are less than 50 years old.

The total number of farm residents ranged from 533 in the Hamilton study area to 639 in the Shelby area. With the exception of the Linn study area residents, the farm groups had a lower share of their population over 59 years of age. The age distribution data suggest that farm personal travel as a percentage of total travel should be higher than non-farm personal travel. However, the data on number of trips per day indicate that the non-farm population use the county roads for personal travel more often than the farm population.

Table 2.6. Percent age distribution and total number of residents in the three study areas

	Percent of residents					
	Farm			Non-farm		
Age in years	**Hamilton**	**Shelby**	**Linn**	**Hamilton**	**Shelby**	**Linn**
0-5	6.9	7.2	8.1	5.3	10.3	9.7
6-15	13.1	16.6	16.0	13.8	13.6	17.2
16-19	9.9	9.2	9.2	6.7	6.0	9.2
20-29	17.5	13.8	12.6	11.4	20.3	15.2
30-39	9.4	11.9	14.2	14.4	11.2	17.2
40-49	15.4	13.5	11.0	5.3	8.6	14.5
50-59	18.8	14.4	12.9	18.2	6.9	5.8
60+	9.0	13.4	16.0	24.9	23.1	11.2
Total	100.0	100.0	100.0	100.0	100.0	100.0
Total number of residents	533	639	619	507	464	3,913

Table 2.7. Miles of road in each study and border area by type of surface

	Study area					
	Hamilton		Shelby		Linn	
Type of road	**Miles**	**Percent**	**Miles**	**Percent**	**Miles**	**Percent**
Study area						
Paved						
State	20.2	10.2	11.0	5.4	9.7	4.5
County	36.0	18.1	12.2	6.0	46.5	21.5
Gravel	140.2	70.7	75.0	36.7	151.3	70.0
Earth	2.0	1.0	31.8	15.5	8.7	4.0
Oiled	0.0	0.0	74.3	36.4	0.0	0.0
Total	198.4	100.0	204.3	100.0	216.2	100.0
Border area						
Paved						
State	53.0	18.5	52.5	18.2	30.5	13.0
County	65.3	22.7	46.7	16.1	51.8	22.1
Gravel	168.2	58.6	116.0	40.2	148.5	63.2
Earth	0.5	0.2	28.0	9.7	4.0	1.7
Oiled	0.0	0.0	45.5	15.8	0.0	0.0
Total	287.0	100.0	288.7	100.0	234.8	100.0

Other Travel Data

The farm and household survey data and the postal service and school bus data provided information on all traffic originating and/or terminating within each study area. However, these data did not include information on overhead traffic which travels through but does not originate or terminate in the areas.

Omission of overhead traffic was thought to be most serious in Linn County because of traffic that might be commuting through the study area to and from Cedar Rapids. Therefore, an agreement was reached with the Iowa Department of Transportation and the Linn County engineers' office to conduct an overhead traffic survey in the Linn study area. Two locations on paved roads and one location on a gravel road were selected to conduct a "stop and go" survey.

All vehicles passing the survey location were stopped and asked their entry and exit points in the study areas. In addition, the type of vehicle was recorded. The drivers were also asked if they lived in the Linn County study area; if they did, their traffic was not counted. The vehicles were stopped and the drivers were asked these questions from 7:00 A.M. until 1:00 P.M. on one day and from 1:00 P.M. until 7:00 P.M. on the following day. Automatic counters were placed at these locations from 7:00 P.M. until 7:00 A.M. the next day. The collected data were expanded to annual traffic estimates by multiplying by a conversion factor of 1.017 times 365 days. The conversion factor was obtained from the Iowa Department of Transportation and was an average for the state.

Study Area Road Systems

The three study areas chosen in Hamilton, Shelby, and Linn counties each measured ten miles by ten miles. In addition, a border area of three miles on all sides of each study area was included in the model. However, the only traffic counted in the three-mile border area was traffic originating or terminating in the study area that originated or terminated in the border areas. Table 2.7 presents the number of miles of road by type of surface in each study and border area.

The quality of the county road systems is higher in the Hamilton and Linn study areas than in the Shelby area (Table 2.7). The Linn study area has the most paved county roads—21.5 percent—followed by the Hamilton area with 18.1 percent, and the Shelby study area with 6.0 percent. About 20 percent of the border area roads are paved county roads. Over one-half of the Shelby County study area roads have oil or earth-surfaces, whereas the Hamilton study area has no oil-surface roads and only one percent earth-surface roads. The Linn study area had no oiled roads and only four percent earth-surface roads.

Road Maintenance Costs

Unpaved Roads

No published or unpublished research was found on unpaved road maintenance costs. Therefore, the unpaved road maintenance cost estimates used in this analysis were developed from data provided by the county engineers in the three study areas. Table 2.8 presents the cost per unit used to develop the annual maintenance cost per year. Gravel and

Table 2.8. Estimated maintenance costs per ton or per mile on gravel roads by study areas, 1982

	Study area		
Type of cost	**Hamilton**	**Shelby**	**Linn**
Gravel per ton	$ 3.67	$ 8.00	$ 7.00
Blading per mile per pass	21.00	21.00	21.00
Snow removal per mile	475.70	475.70	475.70
Signing per mile	100.00	100.00	100.00
Culvert repairs, weed control, and minor ditching per mile	300.00	300.00	300.00
Culvert replacement per mile	200.00	200.00	200.00
Major ditching—removal of 400 cubic yards of dirt per mile	800.00	800.00	800.00

blading costs are assumed to vary with traffic levels. All other costs are assumed to be independent of traffic levels. The major difference in the costs is gravel cost per ton, which is the result of the differences in distance that the gravel must be hauled (Table 2.8).

The county engineer in each study area used the cost data in Table 2.8 to estimate the following maintenance cost equations for gravel roads in each of the three study areas:

$$C_H = \$2{,}370 + \$4.70X \quad (2.1)$$
$$C_S = 2{,}765 + 8.75X \quad (2.2)$$
$$C_L = 2{,}525 + 6.25X \quad (2.3)$$

where

C_H = annual maintenance cost on gravel roads in Hamilton County,
C_S = annual maintenance cost on gravel roads in Shelby County,
C_L = Annual maintenance cost on gravel roads in Linn County,
X = average number of vehicles per day.

The maintenance cost equation for earth-surface roads was estimated by eliminating gravel costs from the Hamilton study area estimates (Table 2.8). The resulting cost equation for earth surfaces is:

$$C_D = \$2{,}026 + \$1.52X \quad (2.4)$$

where

C_D = average earth- and oil-surface road maintenance cost in each of the three study areas.

No data were available on oil-surface road maintenance costs. Therefore, the earth-surface maintenance cost function was used for oil-surface roads.

Paved Road

The annual fixed maintenance costs for paved roads included shoulder maintenance, striping and painting, patching and crack filling, signing, drainage, and weed control. The paved road fixed maintenance costs for each county, estimated by the county engineer in each study area, are Hamilton, \$1,160; Shelby, \$1,083; Linn, \$1,400.

The Iowa Department of Transportation (DOT) reports average total annual maintenance costs by county and surface type. The annual paved road fixed costs per mile were subtracted from the Iowa DOT 1982 average total paved road maintenance costs; the remainder was defined as the average annual paved road variable maintenance cost. The average variable maintenance costs were then assigned to the paved roads in the study in proportion to the vehicle miles by type of vehicle traveling on that road in the following manner:

1. Data were collected on the design term, structural number, slab thickness, and type of pavement for all paved roads in the three study areas. The design term is an indicator of the effective thickness of the surface, base, and subbase of the road. It was used to calculate the remaining 18-kip (one 18,000-pound weight pass over the road surface) applications to the road before resurfacing is required. The total lifetime 18-kip applications were divided by the expected life of the road to obtain a yearly 18-kip load application for the road. The structural number was used to determine the 18-kip equivalence of all single and tandem-axle loadings on flexible pavements, and the slab thickness was used to estimate the 18-kip equivalence of all single- and tandem-axle loadings on rigid pavements.
2. Data on the type of axle and weight on each axle were collected for all vehicles traveling in the three study areas. The axle type and weight, along with the structural number and slab thickness, were used to calculate the number of 18-kip loads each vehicle applies to a road with each pass.
3. The number of trips each type of vehicle makes on each road was obtained from the traffic flow estimates from the network model. This number was multiplied by the appropriate 18-kip equivalence to estimate the number of 18-kip applications to each road in 1982. The number of 18-kip applications was summed over all vehicles to obtain the total number of 18-kips applied to each road in 1982.
4. The total number of 18-kip applications in 1982 was divided by the average annual 18-kip application remaining in the road and then multiplied by the average variable maintenance costs of that road to estimate the variable maintenance costs for that road.

This procedure accounted for the weight application of different vehicle types on different road surfaces. It also provided estimates of the change in variable maintenance costs on roads that have increased or decreased traffic resulting from different county road investment strategies.

Area Service B Roads

Area service B roads are defined as public roads that access only farm fields and have significantly reduced maintenance. Area service maintenance generally includes no gravel resurfacing or snow removal and reduced levels of drainage. These roads eventually revert to earth surface and are not open to registered vehicles (those that must be licensed by the state) in the winter.

Bridge maintenance is assumed to be 80 cents per square foot per year. No area service B roads or bridges are reconstructed. Table 2.9 presents the estimated area service B road maintenance costs.

Private Drives

Maintenance cost data for private roads were obtained on six drives that the Iowa DOT had converted from public roads to private drives. Two private drives serve non-farm households, two serve small- to medium-size farms, one serves a large farm, and one serves a field access drive only. The maintenance costs obtained from the owners or residents of these properties are presented in Table 2.10. The average annual maintenance costs were: $1,437 per mile for private drives serving households only; $1,509 per mile for drives serving small- to medium-size farms; $2,382 per mile for a private drive serving a large farm; and $460 per mile for a drive serving fields only. In addition to

Table 2.9. Estimated maintenance costs per mile of area service B roads

Type of yearly service	Cost per mile
Blading, five times	$ 105
Signing	100
Culvert repairs and minor ditching	150
Culvert replacement	100
Major ditching	150
Snow removal	0
Surfacing	0
Total	$ 505

Table 2.10. Estimated annual maintenance cost on private roads by type of access, 1982

Type of access	Length of private road in feet	Annual maintenance costs: Rock	Grading	Snow removal	Weed control	Drainage	Total per year	Per mile annual conversion factor	Estimated annual cost per mile per year	Average annual cost by type of access
Residences only										
Residence I	250	$ 66	—	$ 5	—	—	$ 71	0.04735	$ 1,500	$ 1,431
Residence II	450	106	$ 10	—	—	—	116	0.08523	1,361	
Small to medium-size farms with households										
Farm I 350 acres—crops and pasture	300	87	—	—	$ 5	—	92	0.05682	1,619	1,509
Farm II 130 acres—crops	1,320	60	120	80	60	30	350	0.25	1,400	
Large farms with households 1,300 acres, 3,500 hogs	2,120	428	375	75	50	25[a]	953	0.4	2,382	2,382
Field access only 360 acres	2,640	20	150	25[a]	25[a]	10[a]	230	0.5	460	460

[a]Added to costs reported by farmer.

annual maintenance costs, the private drives in the Hamilton County study area were charged a reconstruction cost of $7,824 per mile annualized over 60 years.

A large share of the annual private drive maintenance costs was for resurfacing and grading. The relatively small difference in cost between maintaining a residence driveway compared to drives serving small- to medium-size farms is probably due to the cost efficiencies of having a tractor front-end loader, sprayer, and mower on the farms. Thus, even though the traffic is heavier on the farm drives, the annual maintenance cost is only slightly higher.

Resurfacing and Reconstruction Costs

In addition to annual maintenance costs, roads must be periodically resurfaced and roads and bridges must be periodically reconstructed. Table 2.11 shows the frequency with which resurfacing and reconstruction costs were charged to different types of roads and bridges. Gravel roads are not resurfaced because gravel is applied annually and the roads are bladed several times each year. Thus, the gravel road resurfacing costs are included in the annual maintenance costs.

The resurfacing and reconstruction costs for each type of road were obtained from the Iowa DOT and were converted to annual costs by a capital-recovery formula using a 1982 real interest rate of 5.6 percent per year. The detailed procedures for estimating maintenance, reconstruction, and resurfacing costs are presented in Appendix B.

Bridges

Table 2.12 presents data on bridge numbers, size, and conditions in the three study areas. The Shelby and Linn study areas have the largest number of bridges, the largest average size of bridges, and the most bridges having load ratings below the legal limit of 40 tons. Bridge maintenance costs in the three study areas were estimated by the county engineers to be 80 cents per square foot annually to keep the bridges in an "as is" condition. This maintenance cost includes painting, signing, major and minor deck repair, major and minor substructure repair, and erosion control.

Vehicle Travel Costs

Over a hundred different types of vehicles traveled the county roads in the three study areas. Farm tractors alone were reported to pull 25 types of trailing equipment or wagons. In addition, there were many sizes of combines and tractors. The number and variety of vehicles made it necessary to group several different types together and to estimate costs for a typical vehicle in the group.

Travel costs per mile were estimated for all major groups of vehicles traveling on the county roads in the three study areas. The major vehicle groups are: automobiles; pickup trucks; school buses; commercially-owned vans and trucks; garbage trucks; farmer-owned single-axle; tandem-axle, and semitrailer trucks; farm combines; and farm tractors pulling grain wagons or tillage equipment.

Variable operating costs per mile were estimated for each of these vehicle groups operating on paved, gravel, and earth-surface roads. These costs include fuel, oil, tires, maintenance, and travel time. They

Table 2.11. Frequency of road resurfacing and road and bridge reconstruction by road surface in years

	Frequency in years		
		Reconstruction	
Surface type	Resurfacing	Roads	Bridges
Paved	15	45	45
Gravel	—	60	60
Earth	—	60	60

Table 2.12. Total number, size, and condition of the bridges in the Hamilton, Shelby, and Linn study areas

	Hamilton	Shelby	Linn
Number of bridges	31	58	59
Average bridge size in square feet	785	1,830	1,537
Smallest bridge in square feet	288	390	174
Largest bridge in square feet	2,000	7,025	6,419
Number of bridges with less than 40-ton load rating	3	46	36

reflect the marginal cost of driving an additional mile on each type of road surfaces. Fixed costs, including time-related depreciation, insurance, and licenses, were not included in the operating costs because they are largely independent of vehicle miles. A small component of insurance premiums is mileage-related, but this cost also varies by driver age and sex and by purpose and distance of the trip. The large number of variables affecting the small amount of mileage-related insurance costs made it impossible to build these costs into the analysis.

Variable costs are assumed to be a linear function of the number of miles traveled on each surface type; therefore, all costs are estimated in cents per mile. The costs are based on 1982 prices and representative vehicles. In cases where 1982 prices were not available, other prices were adjusted to 1982 levels.

The data used to develop the variable cost functions were gathered from three general sources. First, published and unpublished research was used whenever possible. Second, industry sources such as automotive, truck, and farm equipment manufacturers and dealers; tire manufacturers and dealers; automotive parts and petroleum dealers; and truck and farm equipment owners were asked to provide necessary data. Third, experts including agricultural engineers, industry executives, and researchers were asked to provide data unavailable elsewhere. In some cases, one of these general sources provided all the necessary data. In other instances, a combination of the three sources was used to provide the appropriate information.

The vehicle cost data were not collected from random samples because random sample data were not available. Consequently, no variances or other statistical measures relating to the distribution of the cost estimates are provided. The details of the estimation procedure are presented in Appendix C.

The data were generally gathered for a representative vehicle traveling on rural roads and not for the spectrum of vehicle types. For example, the data used to develop the automobile variable cost per mile reflect operating characteristics of a 1978 3,500 lb. automobile, such as a Chevrolet Caprice Classic; the pickup truck data reflect operating characteristics of a 1978 3,500 lb. pickup truck, such as a 360 cubic inch V-8 Dodge. The selection of the representative vehicles used to develop the variable cost estimates was based upon frequency distributions of vehicle types obtained from the county vehicle registration files along with personal communications from public and private sector sources.

Table 2.13. Estimated 1982 road vehicle variable cost in cents per mile by vehicle and surface type

	Cost per mile by surface type			
Vehicle type	**Paved**	**Gravel**	**Earth**	**Area service B**
Automobile	20.2	28.3	36.4	40.5
Pickup truck	24.4	33.8	43.2	48.1
Pickup truck pulling a trailer	35.3	48.9	62.6	69.6
Commercial van	40.2	55.8	71.3	79.4
Commercial semitrailer truck[a]	53.5	80.3	107.1	117.7
Garbage truck	77.2	112.4	147.7	1.63
School bus	31.2	45.6	59.7	*
Farmer-owned single-axle truck[a]				
Truck alone	32.3	45.9	59.6	66.0
Pulling pup trailer	38.4	54.6	70.8	74.6
Pulling grain wagon	35.9	51.1	66.2	73.3
Farmer-owned tandem-axle truck[a]				
Truck alone	38.4	56.0	73.6	84.0
Pulling pup trailer	47.5	69.2	90.9	99.2
Pulling grain wagon	45.0	65.6	86.2	98.0
Farmer-owned semitrailer truck[a]	39.8	59.7	71.0	78.0

[a]Assumes 50 percent of travel is loaded and 50 percent of travel is unloaded.

*School buses were not permitted on area service B roads.

Variable costs per mile were estimated for empty and loaded trucks and farm tractor wagons. The cost estimates for these vehicles, presented in Tables 2.13 and 2.14 are averages of loaded and empty variable cost per mile. Table 2.13 presents the estimated total variable cost in cents per mile for road vehicles on paved, gravel, earth, and area service B road surfaces. The automobile and the pickup truck, chosen to represent the 1982 fleet of cars, had variable costs of 20 and 24 cents per mile on paved surfaces, respectively. Vehicles with variable costs between 31.2 to 39.8 cents per mile on paved surfaces include school buses, pickup trucks pulling a trailer, farmer-owned single-axle trucks, tandem-axle trucks, and semi-trailers. Commercial vans and semi-trailer truck variable costs were 40.2 and 53.5 cents per mile, respectively. The primary reason that commercial trucks had higher costs per mile than farmer-owned trucks was the wage rate charged for trucks. The wage rates used were $3.60 per hour for farmer-owned trucks and $8.60 per hour for commercial trucks. These are the typical non-union wage rates paid in 1982 in rural areas and they are significantly lower than union wage rates.

Virtually all variable cost components were higher for garbage trucks than for all other road vehicles, primarily because of the "stop and go" travel pattern of garbage trucks.

The cost per mile was lowest for all vehicles on paved surfaces. Costs per mile for automobiles, pickup trucks, and commercial vans increased 38 to 40 percent on gravel surfaces, 77 to 80 percent on earth surfaces, and approximately 100 percent on area service B roads. The costs per mile for the garbage truck and single- and tandem-axle trucks increased 42 to 45 percent on gravel and 84 to 91 percent on earth surfaces. Semi-trailer costs increased 50 percent on gravel, 100 percent on earth surfaces and 120 percent on area service B roads.

Table 2.14 presents the estimated total variable costs in cents per mile for paved and gravel surfaces by size of farm tractor and type of vehicle pulled. Farm tractor and combine variable costs were assumed to be constant over gravel, oil, and earth surfaces, including area service B roads. The cost on paved surfaces for a tractor with no trailing vehicle ranged from 100 cents per mile for a 60 H/P tractor to 184 cents per mile for a 185 H/P tractor.

The type of equipment pulled by the tractor on paved surfaces had little impact on the variable cost per mile. Variable costs increased only two percent for a small tractor pulling a 350-bushel wagon compared to driving the tractor alone. For the large 185 H/P tractor, variable costs increased only 8.7 percent when pulling two 450-bushel wagons. The impact of the type of equipment pulled on variable cost per mile was slightly higher on gravel surfaces than on paved surfaces. Variable cost per mile for the smallest tractor and for the largest tractor when pulling two large wagons increased 3.3 and 15 percent, respectively, over the cost of driving the tractor alone.

Table 2.14. Estimated 1982 variable farm tractor travel costs in cents per mile by tractor size, type of trailing equipment, and road surface

Equipment or wagon being pulled	Tractor size							
	60 HP		100 HP		140 HP		185 HP	
	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel
Tractor alone	100.1	112.6	123.5	139.7	138.2	157.1	184.4	207.4
Farm machinery	100.8	113.9	124.6	141.7	139.7	160.1	186.6	211.7
Grain wagons								
125-bushel[a]	100.9	114.1	124.7	142.0	139.9	160.4	186.8	212.3
250-bushel[a]	101.5	115.3	125.6	143.8	141.2	163.1	188.8	216.1
350-bushel[a]	102.0	116.4	126.4	145.5	142.4	165.5	190.5	219.6
450-bushel[a]	—	—	127.3	147.3	143.7	168.2	192.4	223.4
550-bushel[a]	—	—	128.7	149.9	145.6	172.0	195.2	228.9
2 350-bushel[a]	—	—	129.4	151.4	146.7	174.0	196.6	231.9
2 450-bushel[a]	—	—	—	—	149.3	179.3	200.4	239.5

[a]Assumes 50 percent of travel is loaded and 50 percent of travel is unloaded.

Variable cost increases on gravel surfaces over paved surfaces were smaller for tractors than for road vehicles. Variable cost increases for tractors on gravel surfaces ranged from 12 to 14 percent for the 60 H/P tractor, 13 to 17 percent for the 100 H/P tractor, 14 to 20 percent for the 140 H/P tractor, and 12 to 20 percent for the 185 H/P tractor. The smaller increases for travel on gravel surfaces were a result of tractors being designed to operate on low quality surfaces. For example, tractor tires have less wear on gravel roads than on paved roads.

Table 2.15 presents the estimated variable running costs in cents per mile for farm combines. The variable cost of operating a small two-row combine on a paved road was 101.7 cents per mile; this cost increased 12 percent on a gravel road. The cost per mile increased sharply with larger combines. On paved surfaces, the cost per mile of a six- or eight-row combine was 59 percent higher than for a two-row combine; on gravel surfaces, the six- or eight-row combine cost 60 percent more per mile than a two-row combine.

Post Office Travel Costs

All postal travel costs were provided by the U.S. Postal Service. Postal travel cost per mile for 1982 included a 30-cent per mile vehicle allowance. Carrier salary costs, including fringe benefits, were estimated to be $17.30 per hour. The average speed for postal carriers was estimated to be 12 miles per hour.

Travel-Time Penalty

For the time-critical farm operations, an extra cost was added to the increased travel cost due to changes in the road system. A travel-time penalty is incurred if the increased travel prohibits a farmer from completing time-critical operations, such as planting or harvesting, in the same amount of time as before the change in the road system. In this study, the travel-time penalty was charged only to the increase in time-critical farm operations resulting from reductions in the miles of road. The method used to estimate this cost was to calculate the cost of increasing machine capacity to allow the farmer to drive the additional distance and complete the time-critical operations on the same number of acres in the same amount of time required before the change in the road system. Appendix D presents a detailed explanation of the travel-time penalty and the estimation procedure.

Table 2.15. Estimated 1982 farm combine variable cost in cents per mile on paved and gravel surfaces by size of combine

Engine horsepower	Size of corn head	Cost per mile	
		Paved	Gravel
70	2-row	101.69	114.70
120	4-row	146.13	164.85
145	6-8-row	161.70	183.22

Table 2.16. Travel-time penalty vehicle costs applied to the increased travel due to a change in the road system, by type of vehicle in cents per mile

Machine	Road surface	
	Paved	Gravel
Planter/tillage	372	413
Combines		
2-row	83	99
4-row	229	247
6-8-row	436	479

Table 2.17. Estimated rental values of farmland per acre in the three study areas, 1982

Study area	1982 land rental value per acre
Hamilton	$140.91
Shelby	95.49
Linn	126.74

The estimated travel-time penalty costs, presented in Table 2.16, were applied only to the increased planter, combine, and part of the tillage road travel miles resulting from changes in the road system.

Opportunity Cost of Using Land for Roads

Land used for roads incurs an opportunity cost because there are other productive uses of that land, and that opportunity cost must be considered in the benefit-cost analysis. Agricultural production is the most likely alternative use for the land in the three study areas, and so farmland rental values were used as the measure of the opportunity cost of keeping the land in roads.

Farmland rental values in 1982 for Hamilton, Shelby, and Linn counties were estimated in two steps. First, the crop-reporting district average rental rate per acre was calculated as a percentage of the average land value in that district. Next, the estimated 1982 county land rental was obtained by multiplying the 1982 average county farmland value by the percentage from step one. Table 2.17 presents the estimated 1982 rental values for the three study areas.

Chapter 3

Results

The alternative investment strategies evaluated in this study are:

1. Reducing the size of the public county road system by abandoning selected low-volume roads that serve no property or residence accesses
2. Reducing the miles of public county roads by converting dead-end and continuous roads to private drives
3. Paving selected county roads to estimate the impact of additional paved roads on the net savings from road abandonment
4. Converting low-volume roads that serve no household accesses to area service B roads
5. Converting all county roads to gravel surfaces to estimate the impact of paving the existing core of paved roads
6. Reconstructing selected bridges to legal load limits

Reducing the Size of the County Road System

The savings from abandoning low-volume roads serving no property or residence accesses were estimated by removing selected roads from the computerized road network and then rerunning the computer program that simulates the effects of the smaller road system on travel miles and costs. The travel costs from the solution with abandoned roads were compared to the travel costs in the base solution to obtain the change in travel, maintenance, and reconstruction costs. The only roads eliminated from the Linn and Shelby County study areas were those roads that serve no property or residence accesses. In the first Hamilton study area solution, roads with no property or residence accesses were eliminated from the computerized county road system. In the second Hamilton solution, 8.25 miles were converted from public roads to private drives in the computerized county road network. Only traffic originating or terminating on the private drives was permitted to travel over them.

The criteria for selecting roads to be eliminated from the computerized road networks were as follows:

I. Roads that did not landlock property or houses were eliminated from the system. The eliminated roads in this category had three common characteristics: gravel or earth surfaces, low traffic levels, and small importance as links in the network.

II. Only low-traffic roads that landlock property or houses were converted to private drives.

The following assumptions were made in this analysis:

- The traveling public attempts to minimize the travel costs from an origin to a destination.
- The number of trips from an origin to a destination does not change as a result of changes in the road system.
- The routes used to travel from an origin to a destination can change if the road system changes.
- The variable vehicle travel costs are a linear function of distance.
- The U.S. Postal Service must serve all residences that have a passable road access.
- School buses must provide school transportation to all residences with school-age children.
- If the variable maintenance cost on the existing surface of a paved road exceeds the annualized cost of resurfacing to a higher quality pavement, the road will be resurfaced to a higher quality surface.
- A portion of the road maintenance costs are independent of traffic levels. The remaining maintenance costs vary with traffic levels.

A network algorithm was used to determine the cost-minimizing routes for all 1982 trips from each origin to each destination for each farm and household in each study area, with all 1982 county roads in the model. This computer run was called the base solution. After specific road segments were removed from the computerized road network, the computer model was rerun to route the same trips for each vehicle type. With a smaller number of road miles, the total travel miles increased because of longer distances between some origins and destinations. The difference between the total travel cost in the base computer solution and the cost in the solution with a smaller road system is the estimated change in travel cost to the traveling public if a set of roads are abandoned.

The cost savings to the counties or the public from abandonment of a set of roads include the differences between the two solutions in:

1. Variable road maintenance costs
2. Fixed road maintenance costs
3. Road resurfacing costs
4. Road reconstruction costs
5. Bridge maintenance costs
6. Bridge reconstruction costs

In addition, the rental value of right-of-way in agricultural production was included in the savings from road abandonment. The following are the results of the abandonment analysis in each of the three study areas.

Linn County Study Area

Table 3.1 presents the estimated miles of travel in the Linn County study area under three solutions. The base solution had all the study area roads in the computerized road network. The second solution, called L_1, had 5.25 miles of study area roads removed from the computerized road network. These 5.25 miles of road, consisting of 3.25 miles of gravel road and 2 miles of earth-surface road, served no household, farm, or field accesses. In addition, two bridges were eliminated in L_1.

The third solution, called L_2, had an additional 3.75 miles of road removed from the computerized road network. These 3.75 miles included 1.75 miles of gravel, 2 miles of earth surface roads and one

Table 3.1. Estimated total miles driven in the Linn County study area under the base solution and change in miles driven in the L_1 and L_2 solutions by vehicle groups, 1982

			Change in miles driven from previous solution			
	Base solution		L_1 (5.25 miles)		L_2 (3.75 miles)	
Type of travel	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total
Household						
Auto	18,070,652	64.2	38,337	50.9	80,448	65.6
Pickup	1,046,123	3.7	2,131	2.8	1,894	1.5
Truck	499,378	1.8	0	0.0	832	0.7
Subtotal	19,616,153	69.7	40,408	53.7	83,174	67.8
Overhead traffic	7,044,416	25.0	0	0.0	1,095	0.9
Farm						
Auto	33,217	0.1	708	0.9	486	0.4
Pickup	969,429	3.4	10,193	13.5	31,290	25.5
Truck	203,644	0.7	934	1.2	691	0.6
Tractor-wagon	21,146	0.1	805	1.1	721	0.6
Tractor pulling equipment or alone	98,876	0.4	3,908	5.2	4,254	3.4
Combine	8,672	0.0	329	0.4	170	0.1
Subtotal	1,334,984	4.7	16,877	22.4	37,612	30.6
Other						
School bus	88,110	0.3	15,480	20.5	0	0.0
Post office	71,100	0.3	2,533	3.4	815	0.7
Subtotal	159,210	0.6	18,013	23.9	815	0.7
Grand Total	28,154,763	100.0	75,298	100.0	122,696	100.0

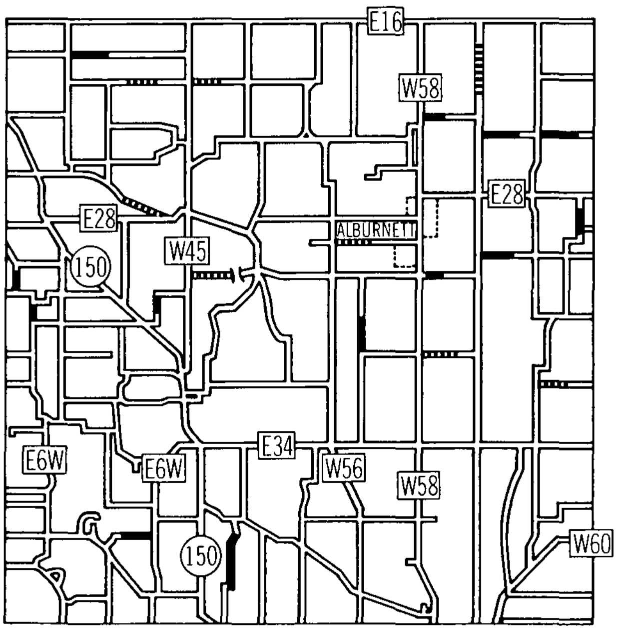
bridge. Figure 3.1 shows the Linn study area road system in the base solution and the abandoned roads in the L_1 and L_2 solutions.

The estimated vehicle miles driven in the study area in the 1982 base solution totaled 28.2 million miles. Of this total, 19.6 million or 69.7 percent of total miles were driven for household purposes; most of this travel was in automobiles.

Over seven million miles or one-fourth of all travel was overhead traffic. Overhead traffic is defined as that traffic traveling through but not originating or terminating in the study area.

The third important category of traffic was farm travel. Farm travel included automobile and pickup truck miles driven for farm purposes as well as larger farmer-owned trucks, commercial trucks serving the farm operation, and all farm implement miles. Farm travel totaled 1.3 million miles or 4.7 percent of all traffic in the Linn County study area. Farm pickup truck travel was 3.4 percent of all travel and almost 73 percent of all farm travel. The next largest type of farm travel was truck miles.

Figure 3.1. Linn County study area: Roads abandoned in the L_1 and L_2 solutions



L_1 - Roads examined for abandonment 5.25 miles; 2 bridges

L_2 - Roads examined for abandonment 3.75 miles; 1 bridge

Truck miles include farmer-owned trucks and trucks serving farms but owned by farm-supply and marketing firms.

The fourth category of travel in the study area was school bus and postal service miles. These two types of travel each represented 0.3 percent of total 1982 travel in the study area.

After removing the 5.25 miles of road serving no households, farms, or field accesses in the L_1 solution, total travel miles increased by about 0.3 percent over the base solution miles. Household traffic increased by 0.2 percent or just under the average percentage increase in traffic; most of the increase in household travel miles was by automobiles.

None of the overhead traffic traveled on the 5.25 miles of road removed from the base solution road network. Therefore, eliminating the 5.25 miles of road resulted in no change in overhead traffic miles. Farm vehicle traffic increased about 1.3 percent from the abandonment of the 5.25 miles of road. Pickup trucks accounted for 60 percent of the increase in farm vehicle traffic. Tractors accounted for 28 percent of the increased farm miles, and larger trucks accounted for only 6 percent of the increased farm traffic.

School bus and postal vehicle miles increased 11.3 percent; this was the largest percentage increase in travel of all the vehicle groups. This is reasonable because these vehicles must provide service to the same households under both road systems.

There was a larger increase in total miles driven in the L_2 solution than in the L_1 solution, even though fewer miles were abandoned in the L_2 solution. Overall, total miles driven increased 4.3 percent over the combined base and L_1 solutions. Over two-thirds of the L_2 increase in travel miles was in household vehicles, primarily in automobiles. There was a very small—less than one percent—increase in overhead traffic as a result of the abandonment of the 3.75 miles in the L_2 solution. Almost all of the remaining increase in miles was in farm vehicles, primarily in pickup trucks.

Table 3.2 presents the estimated total variable cost of travel in the base, L_1, and L_2 solutions. Under the base solution with all study area roads in the computerized network, the estimated total variable cost of all travel in the study area was $6.9 million. About two-thirds of the total was for household travel, mostly by automobile. Overhead travel cost was about one-fourth of the total. Farm vehicle travel costs were eight percent of all vehicle travel costs even though the farm vehicles had only four percent of total miles. Combined school bus and postal service travel costs were 1.4 percent of total cost, but only one-half of one percent of the total miles of travel. The reasons for the high farm vehicle, school bus, and postal vehicle shares of total cost relative to total miles driven are the high cost per mile of driving these vehicles and the relatively high portion of these miles driven on low-quality road surfaces.

After the 5.25 miles of road were eliminated from the computerized road network in the L_1 solution, total travel cost increased $29,014—an increase of 0.4 percent over the base solution cost. Almost half of the increased cost was for farm travel, even though farm travel miles represented only 22.4 percent of the change in miles driven. The $12,373 of increased farm travel costs is the gross value of the 5.25 miles of road to agriculture. The relatively large farm share of total cost is caused by the high travel cost per mile of farm vehicles. In addition, a travel-time penalty of $1,947 was charged for the planter, tillage, and combine field time lost because of the longer travel distances. The travel-time penalty charge is equivalent to the additional investment in farm equipment required to enable the farmer to plant and harvest crops in the same total time, including travel time, as required in the base solution. Household travel accounted for 29.9 percent of the change in total cost, but this group had 53.7 percent of the change in miles driven. School buses and post office vehicles had 19.5

Table 3.2. Estimated total variable cost of all travel in the Linn County study area under the base solution and change in travel cost in the L_1 and L_2 solutions by vehicle groups, 1982

			Change in total variable cost from previous solution			
	Base solution		L_1 (5.25 miles)		L_2 (3.75 miles)	
Type of travel	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total
Household						
Auto	$ 3,901,648	56.9	$ 8,175	28.2	$ 11,023	39.2
Pickup	277,969	4.1	445	1.5	408	1.5
Truck	342,118	5.0	67	0.2	36	0.1
Subtotal	$ 4,521,735	66.0	$ 8,687	29.9	$ 11,467	40.8
Overhead traffic	1,683,887	24.6	0	0.0	376	1.3
Farm						
Auto	$ 7,847	0.1	$ 104	0.4	$ 70	0.3
Pickup	281,916	4.1	3,674	12.7	7,203	25.6
Truck	83,655	1.2	268	0.9	407	1.4
Tractor-wagon	29,787	0.5	1,008	3.5	944	3.3
Tractor pulling equipment or alone	128,327	1.9	4,924	17.0	5,411	19.2
Combine	13,856	0.2	448	1.5	245	0.9
Timeliness	0	0.0	1,947	6.7	1,284	4.6
Subtotal	545,388	8.0	12,373	42.7	15,564	55.3
Other						
School bus	$ 35,583	0.5	$ 5,649	19.5	$ 0	0.0
Post office	63,707	0.9	2,305	7.9	731	2.6
Subtotal	99,290	1.4	7,954	27.4	731	2.6
Grand Total	$ 6,850,300	100.0	$ 29,014	100.0	$ 28,138	100.0

percent and 7.9 percent of the change in total travel costs, respectively.

After the 3.75 miles of L_2 roads were eliminated from the computerized road network in the L_2 solution, total travel costs increased $28,138. Over 55 percent of this increase was for farm travel, even though farm travel had only 30.6 percent of the change in miles driven. Household travel had only 40.8 percent of the change in travel costs compared to 67.8 percent of the change in travel costs compared to 67.8 percent of the change in miles driven.

Table 3.3 presents the annual cost to the county of maintaining the L_1 and L_2 miles of road. Only a small part of the total cost to the county varies with traffic levels, the remainder is independent of traffic levels. In most cases if a county road is abandoned, the land reverts to the abutting landowners, who can return the land to agriculture or to other productive uses. Using 1982 land-rental values for agricultural purposes, the estimated rental value for the land in the 5.25 miles of L_1 roads was $5,323. However, a cost of $1,000 per mile was charged to obliterate the road and convert the roadbed to agricultural production. The annualized cost of obliterating the 9 miles of road was $294, resulting in a net rental value of $5,029. The gross rental value would accrue to the abutting landowners. In most cases, the county would incur the obliteration costs. The net rental value of the 3.75 miles of L_2 roads was $3,592.

Table 3.4 summarizes the results of the analysis of the L_1 and L_2 Linn County roads. The L_1 analysis shows an annual net savings of $368 from abandonment of the first 5.25 miles, or a net

Table 3.3. Estimated total annual cost savings to the county and abutting landowners from abandoning the L_1 and L_2 roads, Linn County study area, 1982

	Annual cost savings	
Source of cost savings	**L_1 (5.25 miles)**	**L_2 (3.75 miles)**
Cost savings to the county		
Variable road maintenance	$ 116	$ 1,232
Fixed road maintenance	12,258	8,471
Road resurfacing	89	−239
Road reconstruction	8,411	4,799
Bridge maintenance	1,284	583
Bridge reconstruction	2,195	1,096
Total county cost savings	$ 24,353	$ 15,359
Plus		
Rental value of land	5,323	3,802
Less		
Road obliteration costs	294	210
Total cost savings	$ 29,382	$ 18,951

Table 3.4. Net savings from road abandonment by computer solution, Linn County study area, 1982

	Computer solution	
Type of savings	**L_1 (5.25 miles)**	**L_2 (3.75 miles)**
Savings to the traveling public	$ −29,014	$ −28,138
Savings to the county	24,353	15,942
Net value of land to abutting landowners	5,029	3,592
Total net savings	$ 368	$ −8,604
Net savings per year per mile of road abandoned	$ 70	$ −2,294

savings of $70 per year per mile of abandoned road. Thus, the savings to the county and abutting landowners barely exceed the additional travel cost resulting from the abandonment of the L_1 roads. The 5.25 miles are 2.5 percent of all county roads in the Linn County study area.

The L_2 analysis shows a negative net savings of $8,604 from abandonment of the 3.75 miles of L_2 roads. Thus, the costs to the traveling public exceed the savings to the county and the abutting landowners from the abandonment of the L_2 roads. The conclusion from the Linn area analysis is that there is very limited potential cost savings from reducing the size of the county road system in urbanized areas like the study area in Linn County.

The estimated net benefits of local rural road abandonment are lower than those initially reported in this study (Baumel, Hamlett, and Pautsch, 1986). The reasons for the lower net benefits are:

1. Road and bridge reconstruction and paved road resurfacing costs are estimated on a 45-year life cycle. In the earlier report, road reconstruction and resurfacing costs were estimated on a one-time basis. No bridge reconstruction costs were included in that report.
2. No resurfacing costs are charged to gravel roads. Annual maintenance costs include sufficient gravel to maintain an adequate surface. In the earlier analysis, gravel roads were resurfaced every 20 years in addition to the resurfacing contained in the annual maintenance cost.

Shelby County Study Area

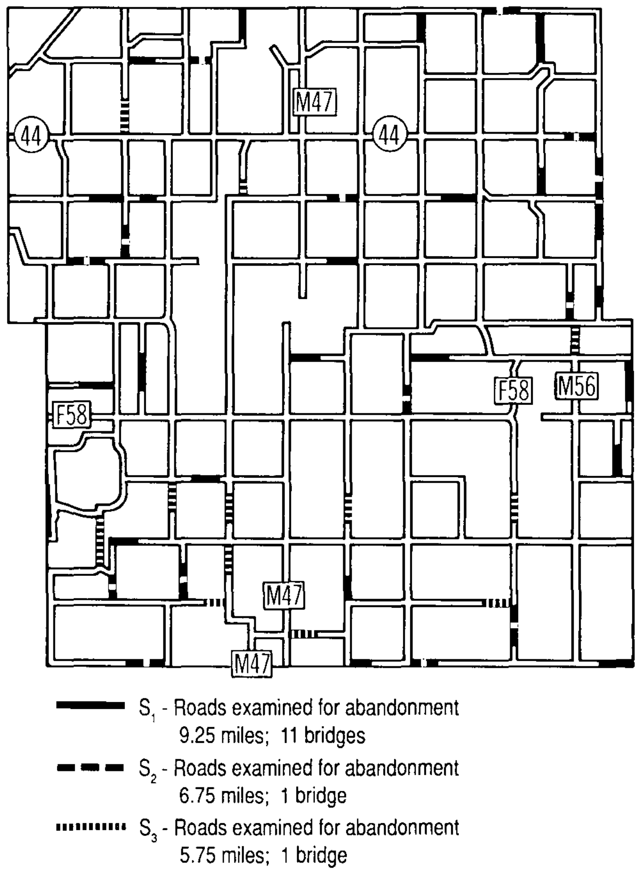
Table 3.5 presents the estimated miles of travel in the Shelby County study area under four solutions. The base solution included all the study area roads in the computerized network. The second solution, S_1 had 9.25 miles of study area roads removed from the computerized network. The third solution, S_2, had 6.75 miles of road removed from the network. The fourth solution, S_3, had 5.25 miles of road removed from the network. In addition, 11 bridges with a total of 12,699 square feet of deck space were eliminated in S_1, and one bridge each was eliminated in the S_2 and S_3 solutions. Figure 3.2 shows the roads in the base solution and the roads abandoned in the S_1, S_2, and S_3 solutions. Table 3.6 shows the number of miles of road abandoned in each of the Shelby study area solutions by type of road surface.

The estimated vehicle miles driven in the Shelby study area in 1982 totaled 6.2 million miles (Table 3.5). The Shelby area had only 22 percent as many traffic miles as the Linn study area. Of this total, 4.2 million or 68.4 percent of total miles were driven for household purposes; most of this travel was in automobiles.

Farm travel totaled 1.8 million miles or 29.7 percent of all traffic in the Shelby County study area. Farm pickup truck travel was 23.4 percent of all travel and almost 55 percent of all farm travel. The next largest type of farm travel was large truck miles which totaled 38 percent of total miles. The third category of travel in the study area was school bus and postal service miles. These two types of travel each represented 1.9 percent of total 1982 travel in the study area.

After removing the 9.25 miles of road, total travel miles in the S_1 solution increased by about 1.2 percent over the base solution miles. Household

Figure 3.2. Shelby County study area: Roads abandoned in the S_1, S_2, and S^3 solutions



traffic increased by only 0.7 percent or just slightly more than half the total traffic miles. Most of the increased household traffic was by automobiles.

Farm vehicle traffic increased about 2.2 percent due to the abandonment of the 9.25 miles of road. Pickup trucks accounted for over 55 percent of this increased farm vehicle traffic. Tractors accounted for 39 percent, and large trucks accounted for only 2.7 percent of the increased farm traffic.

School bus miles increased 4.3 percent. Postal service miles increased 2.3 percent, which is almost double the percent increase in total miles driven.

There was a larger increase in total miles driven in the S_2 solution than in S_1, even though fewer miles of road were abandoned in S_2. Overall, total miles driven increased 2.5 percent in the S_2 solution over the combined S_1 and base solutions. Almost half of

Table 3.5. Estimated total miles driven in the Shelby County study area under the base solution and change in miles driven in the S_1, S_2, and S_3 solutions, by vehicle groups, 1982

			Change in miles driven from previous solution					
	Base solution		S_1 (9.25 miles)		S_2 (6.75 miles)		S_3 (5.25 miles)	
Type of travel	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total
Household								
Auto	3,657,386	58.9	27,218	36.9	38,767	25.1	103,134	47.0
Pickup	464,614	7.5	1,117	1.5	2,549	1.6	6,944	3.1
Truck	123,192	2.0	762	1.0	405	0.3	3,232	1.5
Subtotal	4,245,192	68.4	29,097	39.4	41,721	27.0	113,310	51.6
Farm								
Auto	34,369	0.6	630	0.9	3,123	2.0	996	0.4
Pickup	1,449,380	23.4	22,519	30.5	70,612	45.8	78,751	35.9
Truck	179,620	2.9	1,114	1.5	2,283	1.5	3,510	1.6
Tractor-wagon	42,353	0.7	479	0.6	2,398	1.6	2,370	1.1
Tractor pulling equipment or alone	126,652	2.0	15,564	21.1	19,953	12.9	7,692	3.5
Combine	8,491	0.1	700	0.9	881	0.6	704	0.3
Subtotal	1,840,865	29.7	41,006	55.5	99,250	64.4	94,023	42.8
Other								
School bus	52,024	0.8	2,250	3.1	8,640	5.6	6,930	3.2
Post office	65,383	1.1	1,495	2.0	4,636	3.0	5,194	2.4
Subtotal	117,407	1.9	3,745	5.1	13,276	8.6	12,124	5.6
Grand Total	6,203,464	100.0	73,848	100.0	154,247	100.0	219,457	100.0

Table 3.6. Miles of county road in the base solution and miles abandoned in the Shelby County study area, by surface type and computer solution, 1982

		Miles of county road abandoned in		
Surface type	Miles of county road in base solution	S_1	S_2	S_3
Paved	12.2	0.00	0.00	0.00
Gravel	75.0	1.50	3.50	4.00
Oiled	74.3	1.50	1.00	1.25
Earth	31.8	6.25	2.25	0.00
Total	193.3	9.25	6.75	5.25

the S_2 increase in miles was by farm pickups and 25 percent was by household automobiles.

The S_3 solution created a larger increase in total miles driven than the S_1 or S_2 solutions, even though S_3 had only 5.25 miles of road abandoned. Total miles driven in S_3 increased 3.4 percent over the combined base, S_1, and S_2 solutions. Almost half of the S_3 increase in miles was by automobiles driven for household purposes, while pickup trucks had a 35.9 percent increase in miles driven. The major reason for the large increase in automobile and pickup miles in S_3 was that most of the roads abandoned had relatively high traffic levels and were relatively close together, which reduced the rerouting options. The geographic concentration of the abandoned roads in S_3, combined with nearby roads which were abandoned in the S_2 and S_1 solutions, resulted in longer distances for automobile and pickup traffic to get into and out of the area.

Table 3.7 presents the estimated total variable cost of travel in the Shelby base solution and the change in the total cost of travel for the S_1, S_2, and S_3 solutions. Under the base solution with all study area roads in the computerized network, the estimated total variable cost of all travel in the study area was $1.85 million. Fifty-five percent of the total variable cost was for household travel, mostly by automobile. Farm vehicle travel costs were 40.6 percent of all vehicle travel costs, even though these vehicles had only 29.7 percent of total miles. The combined school bus and postal service travel cost was 4.4 percent of total cost, but these two types of vehicles had only 1.9 percent of the total miles of travel. The reason for the high farm, school bus, and postal service shares of total cost relative to the percentage of miles driven is the high cost per mile of driving these vehicles combined with the low-quality road surfaces on which much of this travel occurs.

Table 3.7. Estimated total variable cost of all travel in the Shelby County study area under the base solution and change in travel cost in the S_1, S_2, and S_3 solutions, by vehicle group, 1982

			Change in total variable cost from the previous solution					
	Base solution		S_1 (9.25 miles)		S_2 (6.75 miles)		S_3 (5.25 miles)	
Type of travel	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total
Household								
Auto	$ 832,791	44.9	$ 5,219	13.3	$ 10,976	14.0	$ 27,136	35.2
Pickup	127,411	6.9	224	0.6	951	1.2	2,018	2.6
Truck	59,246	3.2	222	0.5	343	0.4	1,612	2.1
Subtotal	$ 1,019,448	55.0	$ 5,665	14.4	$ 12,270	15.6	$ 30,766	39.9
Farm								
Auto	$ 9,024	0.5	$ 185	0.5	$ 886	1.1	$ 276	0.4
Pickup	433,302	23.4	6,940	17.7	22,234	28.4	25,133	32.6
Truck	72,185	3.9	298	0.7	853	1.1	1,647	2.1
Tractor-wagon	56,691	3.0	617	1.6	3,217	4.1	3,258	4.2
Tractor pulling equipment or alone	168,495	9.1	19,888	50.6	26,079	33.3	3,562	4.6
Combine	13,590	0.7	1,099	2.8	1,415	1.8	1,154	1.5
Timeliness	0	0.0	2,192	5.6	3,379	4.3	3,598	4.7
Subtotal	753,287	40.6	31,219	79.5	58,063	74.1	38,628	50.1
Other								
School bus	$ 22,537	1.2	$ 1,052	2.7	$ 3,949	5.1	$ 3,004	3.9
Post office	58,584	3.2	1,340	3.4	4,154	5.3	4,654	6.1
Subtotal	81,121	4.4	2,392	6.1	8,103	10.3	7,658	10.0
Grand Total	$ 1,853,856	100.0	$ 39,275	100.0	$ 78,436	100.0	$ 77,052	100.0

Abandonment of the 9.25 miles of road in the S_1 solution increased the total travel cost $39,275, or 2.1 percent over the base solution cost. Almost 80 percent of the increase was for farm travel even though farm travel miles accounted for only 55.5 percent of the change in miles driven. The $31,219 increase in farm travel costs is the annual value of the 9.25 miles of S_1 roads to agriculture.

In the S_2 solution, total travel cost increased $78,436, or 4.1 percent over the combined base and S_1 solutions. Almost 75 percent of the increased travel cost was for farm travel.

In the S_3 solution, total travel costs increased $77,052, or 3.9 percent over the combined base, S_1, and S_2 solution costs. About 40 percent of that increase was for household travel, 50 percent was for farm travel, and 10 percent was for school bus and post office travel.

Table 3.8 presents the annual cost of maintaining the roads eliminated from the S_1, S_2, and S_3 solutions. Total variable maintenance costs increased when the S_1, S_2, and S_3 roads were removed from the system because the traffic traveling on these roads was rerouted to other roads in the three solutions. Most of the roads in the Shelby study area are unpaved, and most of the rerouted traffic continued to travel over unpaved roads. Unpaved roads have higher variable maintenance costs than paved roads. Thus, when the S_1, S_2, and S_3 roads were removed from the computerized road networks, the higher traffic levels over the remaining unpaved roads resulted in higher total variable maintenance costs than if all the roads had remained in the system. Fixed road maintenance costs declined sharply in the S_1, S_2, and S_3 solutions because of the reduced miles of road.

There were no direct resurfacing cost savings from the abandonment of gravel and earth-surface roads because only paved roads are resurfaced. Reconstruction costs declined as the number of miles of road declined in the S_1 and S_2 solutions. However, increased resurfacing costs on the remaining roads in each solution resulted in increased resurfacing costs from the S_1, S_2, and S_3 abandonments.

The largest savings came from eliminating the fixed road maintenance and reconstruction costs and the bridge maintenance and reconstruction costs on the abandoned roads. Bridge maintenance cost savings varied with the number of square feet of deck space of bridges in the S_1, S_2, and S_3 solutions. The S_1 solution eliminated 12,699 square feet of bridge deck space, S_2 eliminated 3,428 square feet of deck space, and S_3 eliminated 1,960 square feet.

Each mile of road contains eight acres of land. Thus, the abandoned S_1 roads contain 78 acres of land, the abandoned S_2 roads contain 54 acres, and the abandoned S_3 roads contain 42 acres. The 1982

Table 3.8. Estimated total annual cost savings from abandoning the S_1, S_2, and S_3 roads in the Shelby County study area, 1982

	Annual cost savings		
Source of cost savings	**S_1 (9.25 miles)**	**S_2 (6.75 miles)**	**S_3 (5.25 miles)**
Cost savings to the county			
Variable road maintenance	$ −1,041	$ −2,749	$ −5,077
Fixed road maintenance	20,957	17,001	14,517
Road resurfacing	−41	−50	29
Road reconstruction	10,194	5,248	709
Bridge maintenance	10,159	1,780	2,529
Bridge reconstruction	9,138	9,915	1,905
Total county cost savings	$ 49,366	$ 31,145	$ 14,612
Plus			
Rental value of land	7,066	5,156	4,011
Less			
Road obliteration costs	4,403	3,213	2,499
Total cost savings	$ 52,029	$ 33,088	$ 16,124

rental value of land in Shelby County was estimated to be $95.49 per acre. However, the estimated cost of obliterating the roads and returning the land to agricultural production was estimated to be $8,500 per mile. Thus, abutting landowners would receive a net land rental value of $288 per year per mile of road abandonment. The net result of all the savings from abandoning these roads was $52,029 for the S_1 roads, $33,088 for the S_2 roads, and $16,124 for the S_3 roads.

Table 3.9 summarizes the results of the analysis of the S_1, S_2, and S_3 solutions. The abandonment of the S_1 roads would return a net savings of $1,378 per mile per year, while the abandonment of the S_2 and S_3 roads would cause the change in travel costs to substantially exceed the cost savings to the county and abutting landowners. As shown in Table 3.10, there was a wide range in the average number of vehicles per day on these road segments. In the S_1 solution, 78 percent of the road segments had 10 or fewer vehicles per day. In S_2, 43 percent of the roads had 21 to 30 vehicles per day. In the S_3 solution, 54 percent of the roads had 31 to 40 vehicles per day. Benefits to the traveling public for keeping individual roads in the network depend on the number, type, and cost of the vehicles traveling over the roads, as well as the additional travel distance required if the roads, are removed from the network. Obviously, a very small number of vehicles per day means low travel savings from keeping the roads in the network. Thus, the conclusion from the Shelby County study area analysis is that, on the average, abandoning the low traffic S_1 roads would return savings to the county and abutting landowners that are substantially higher than the costs to the traveling public. Abandoning the higher traffic S_2 and S_3 roads would cost the traveling public substantially more than the savings to the county and abutting landowners.

The estimated net benefits in this analysis of local rural road abandonment are lower than those given in the initial report (Baumel, Hamlett, and Pautsch 1986) for the reasons stated at the conclusion of the Linn County study.

Table 3.9. Net savings from road abandonment by computer solution, Shelby County study area, 1982

Type of savings	Computer solution S_1 (9.25 miles)	S_2 (6.75 miles)	S_3 (5.25 miles)
Savings to the traveling public	$ −39,276	$ −78,436	$ −77,052
Savings to the county	49,367	31,146	14,611
Net value of land to abutting landowners	2,663	1,943	1,512
Total net savings	$ 12,754	$ −45,347	$ −60,929
Net savings per year per mile of road abandoned	$ 1,378	$ −6,718	$ −11,605

Table 3.10. Average number of base solution vehicles per day traveling over the Shelby study area roads abandoned in the S_1, S_2, and S_3 solutions, 1982.

Average number of vehicles per day	Number of roads abandoned S_1 (9.25 miles)	S_2 (6.75 miles)	S_3 (5.25 miles)
0-10	21	3	0
11-20	6	5	0
21-30	0	6	2
31-40	0	0	7
41-50	0	0	4
Over 50	0	0	0

Hamilton County Study Area

Three computer solutions were run for the Hamilton area. The base solution included all roads in the study area in 1982. The second solution, called H_1, estimated total miles driven and travel costs after 17.75 miles of gravel road were removed from the Hamilton area network. None of the roads removed for the H_1 solution served field, farm, or residence accesses.

In the third solution, called the H_2 solution, 8.25 additional miles of gravel road were removed from the computerized road network and converted to private drives. The transfer of these public roads to private roads was based on the assumptions that only originating or terminating traffic could travel over the private drives, and that the maintenance costs of the H_2 roads would shift from the county to the abutting landowners. Figure 3.3 shows the roads in the base solution, the roads abandoned in the H_1 solution, and the roads converted to private drives in the H_2 solution.

Figure 3.3. Hamilton County study area: Roads abandoned in the H_1 solution and continuous roads converted to private drives in the H_2 solution

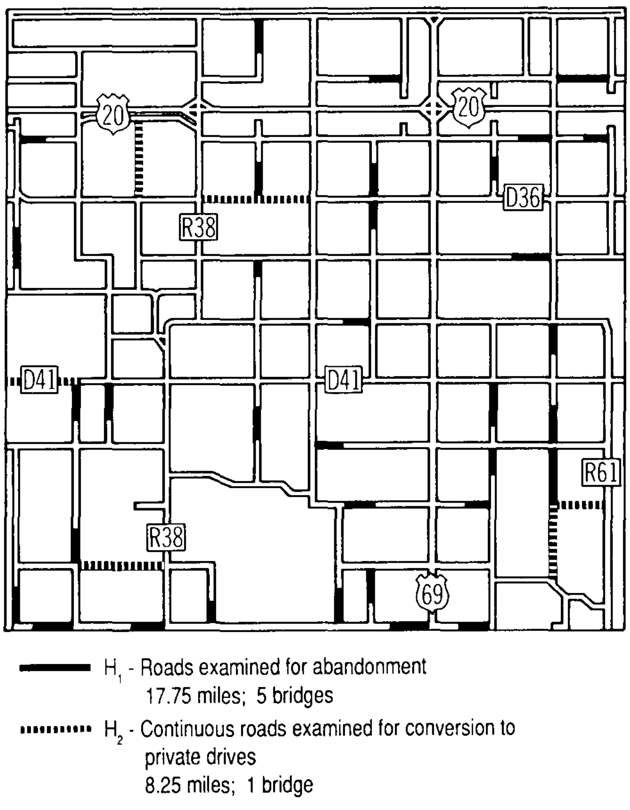


Table 3.11 presents the estimated total miles driven in the Hamilton base solution and the additional miles driven by rerouted traffic in the H_1 and H_2 solutions. Vehicle miles driven in the Hamilton study area base solution totaled just over 6 million. Over two-thirds of these miles were driven for household purposes, mostly in automobiles. Of the 1.7 million miles driven for farm purposes, over 77 percent was by pickup trucks. Only 1.7 percent of all traffic was school bus or postal service miles.

After the 17.75 miles of gravel road were removed in the H_1 solution, total distance traveled increased 167,898 miles, an increase of 2.7 percent over the base solution miles. Almost half of the increased miles were for farm purposes, largely by pickup trucks, while only 28.6 percent of the base solution miles were for farm purposes. Post office and school bus miles had only 1.7 percent of the base solution miles but had almost 12 percent of the additional miles in the H_1 solution. Household travel had 70 percent of the base solution miles but just over 40 percent of the additional miles resulting from the abandonment of the 17.75 miles of H_1 roads.

In the H_2 solution, total traffic increased 74,138 miles, an increase of 1.2 percent over the combined base and H_1 solution miles. All of this increase in miles driven came from the conversion of the 8.25 miles of non-dead-end road in H_2 solution. Almost 60 percent of the increased traffic was for farm purposes, mostly by pickup trucks. The remaining increase in miles was split nearly evenly between household purposes, school buses, and postal service vehicles.

Table 3.12 shows the estimated travel cost of all base solution traffic and the additional travel cost resulting from removing 17.75 miles of road in the H_1 solution and converting 8.25 miles of H_2 roads to private drives. The cost of all Hamilton study area travel in the base solution was \$1.8 million. About 55 percent of the total cost was for household travel even though it represented 70 percent of the total miles driven. Almost 41 percent of the cost was for farm travel; yet only 28.6 percent of total miles was farm travel. Only 3.9 percent of the total cost was for school bus and post office travel.

In the H_1 solution, total cost increased $68,521, an increase of 3.9 percent over the base solution cost. Almost 60 percent of the increased travel cost was for farm travel. The largest increase in farm travel cost was for pickup trucks, followed by tractors pulling equipment, and timeliness cost. Household travel costs were only 21 percent of the increased costs, and school bus and post office travel were almost 19.5 percent of the increased costs.

In the H_2 solution, travel costs increased $31,880 over the combined base and H_1 solution costs. Most of the additional travel cost was for farm traffic, mostly by pickup trucks. School bus and post office travel had 26.1 percent of the additional costs, but household travel had only 13.2 percent.

Table 3.13 presents the annual cost savings from abandoning the roads in the H_1 and H_2 solutions. The annual net cost savings to Hamilton County from abandoning the 17.75 miles of H_1 roads were $65,689. In addition, the net opportunity cost of keeping the land in roads was $19,313, which includes $20,009 in rental income forgone, minus the $696 per mile annualized cost of obliterating the road and returning the land to agricultural production. The net result was an annual cost savings of $85,002 from abandoning the 17.75 miles of H_1 roads in the county system.

The total cost savings to the county from converting the 8.25 miles of H_2 roads to private drives was $57,419. The private drive road and bridge mainte-

Table 3.11. Estimated total miles driven in the Hamilton County study area under the base solution and change in miles driven in the H_1 and H_2 solutions, by vehicle groups, 1982

	Base solution		H_1 (17.75 miles)		H_2 (8.25 miles)	
Type of travel	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total
Household						
Auto	3,889,368	63.6	50,352	30.0	15,082	20.3
Pickup	297,207	4.9	15,448	9.2	1,509	2.0
Truck	75,723	1.2	2,210	1.3	1,091	1.5
Subtotal	4,262,298	69.7	68,010	40.5	17,682	23.8
Farm						
Auto	52,731	0.9	5,116	3.0	1,956	2.6
Pickup	1,352,440	22.1	53,157	31.7	36,072	48.7
Truck	133,842	2.2	8,021	4.8	803	1.1
Tractor-wagon	50,665	0.8	3,505	2.0	1,145	1.5
Tractor pulling equipment or alone	143,458	2.4	9,166	5.5	3,020	4.1
Combine	13,965	0.2	1,100	0.7	503	0.7
Subtotal	1,747,101	28.6	80,065	47.7	43,499	58.7
Other						
School bus	46,800	0.8	9,450	5.6	6,570	8.9
Post office	55,387	0.9	10,373	6.2	6,387	8.6
Subtotal	102,187	1.7	19,823	11.8	12,957	17.5
Grand Total	6,111,586	100.0	167,898	100.0	74,138	100.0

Table 3.12. Estimated total variable cost of all travel in the Hamilton County study area under the base solution and change in travel cost in the H_1 and H_2 solutions, by vehicle group, 1982

	Base solution		H_1 (17.75 miles)		H_2 (8.25 miles)	
Type of travel	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total
Household						
Auto	$ 841,974	48.1	$ 9,987	14.5	$ 3,299	10.3
Pickup	81,110	4.6	3,397	5.0	317	1.0
Truck	34,917	2.0	1,026	1.5	602	1.9
Subtotal	$ 958,001	54.7	$ 14,410	21.0	$ 4,218	13.2
Farm						
Auto	$ 12,336	0.7	$ 1,124	1.6	$ 294	0.9
Pickup	383,625	21.9	14,064	20.5	9,359	29.4
Truck	53,134	3.0	3,319	4.8	324	1.0
Tractor-wagon	70,982	4.1	4,317	6.3	1,495	4.7
Tractor pulling equipment or alone	183,558	10.5	10,674	15.6	4,281	13.4
Combine	21,920	1.3	1,565	2.3	743	2.3
Timeliness	0	0.0	5,718	8.3	2,849	8.9
Subtotal	$ 725,555	41.4	$ 40,781	59.5	$ 19,345	60.7
Other						
School bus	$ 18,519	1.1	$ 4,025	5.9	$ 2,608	8.2
Post office	49,628	2.8	9,305	13.6	5,709	17.9
Subtotal	68,147	3.9	13,330	19.5	8,317	26.1
Grand Total	$ 1,751,703	100.0	$ 68,521	100.0	$ 31,880	100.0

Table 3.13. Estimated total annual cost savings from removing the H_1 and H_2 roads from the Hamilton County public road system, 1982

	Annual cost savings	
Source of cost savings	H_1 (17.75 miles)	H_2 (8.25 miles)
Cost savings to the county		
Variable road maintenance	$ −2,255	$ 16,027
Fixed road maintenance	42,174	19,602
Road resurfacing	0	64
Road reconstruction	14,068	15,761
Bridge maintenance	3,120	1,008
Bridge reconstruction	8,582	4,957
Total county cost savings	$ 65,689	$ 57,419
Less		
Private drive road maintenance	—	−11,913
Private drive bridge maintenance	—	−1,008
Private drive reconstruction	—	−3,758
Road obliteration costs	696	—
Plus		
Land rental value	20,009	3,662
Total cost savings	$ 85,002	$ 44,402

Table 3.14. Net cost savings from abandonment of the H_1 roads and conversion of the H_2 roads to private drives, Hamilton County study area, 1982

	Computer solution	
Type of savings	**H_1 (17.75 miles)**	**H_2 (8.25 miles)**
Savings to the traveling public	\$ −68,521	\$ −31,880
Savings to the county	65,689	57,419
Net value of land to abutting landowners	19,313	3,662
Less private drive maintenance costs	—	−16,679
Total net savings	\$ 16,481	\$ 12,522
Net savings per year per mile of road	\$ 929	\$ 1,518

nance and road reconstruction costs for the 8.25 miles of H_2 roads were estimated to be \$16,679. This was an average maintenance and reconstruction cost of \$2,022 per mile of private road.

Private drive width is assumed to be 40 feet. The 26-foot width reduction from public roads to private drives provides 3.15 acres of land per mile of private drive for conversion to agricultural production at a rental value of \$3,662 per year.

Table 3.14 summarizes the results of the analysis of the H_1 and H_2 solutions. Abandonment of the 17.75 miles of H_1 road would return a net savings of \$16,481 per year or \$929 per mile per year. Converting the 8.25 miles of H_2 roads to private drives would return a net savings of \$12,522 per year or \$1,518 per mile per year.

Table 3.15 shows the base solution average number of vehicles per day traveling on the H_1 and H_2 roads. Over 72 percent of the roads abandoned in the H_1 solution had 10 or fewer vehicles per day, and 27 percent had between 11 and 20 vehicles per day. This suggests that roads with 20 or fewer vehicles per day serving no access points and located in areas with a core of properly spaced paved roads cost more to keep in the system than they are worth to the traveling public.

The major conclusions from the Hamilton County study area analysis are:

1. There are relatively large potential cost savings from reducing the number of miles of low-volume roads that serve no property accesses in areas where the remaining road system has a relatively large percentage of paved roads. Areas within a large number of counties in north central and northwest Iowa meet this paved road condition.

Table 3.15. Average number of vehicles per day traveling over the Hamilton study area H_1 roads in the base solution

Average number of vehicles per day	Number of sections of road H_1
0-10	29
11-20	11
21-30	1
31-40	0
Over 40	0

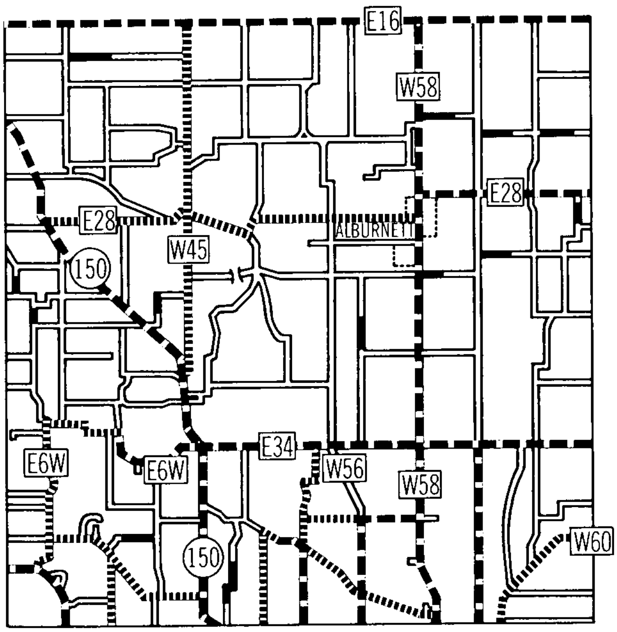
2. There is a large cost savings potential in converting dead-end roads to private drives. This cost savings potential exists in all counties. However, this option, while allowing the abutting landowners to use the private drives, also requires the landowners to maintain these roads. The net savings after deducting private maintenance costs are about 50 percent higher than from road abandonment.

The estimated net benefits in this analysis of local rural road abandonment are lower than those initially reported (Baumel, Hamlett, and Pautsch 1986). Two reasons for these lower net benefits have been stated already (in the conclusion to the Linn County Study). A third reason is that the private drive analysis of the Hamilton County study area in the earlier study included both continuous and dead-end roads (Baumel, Hamlett, and Pautsch 1986). This updated analysis separates the Hamilton County study area private drives into a continuous road and a dead-end road analysis.

Impact of Paving Additional Roads

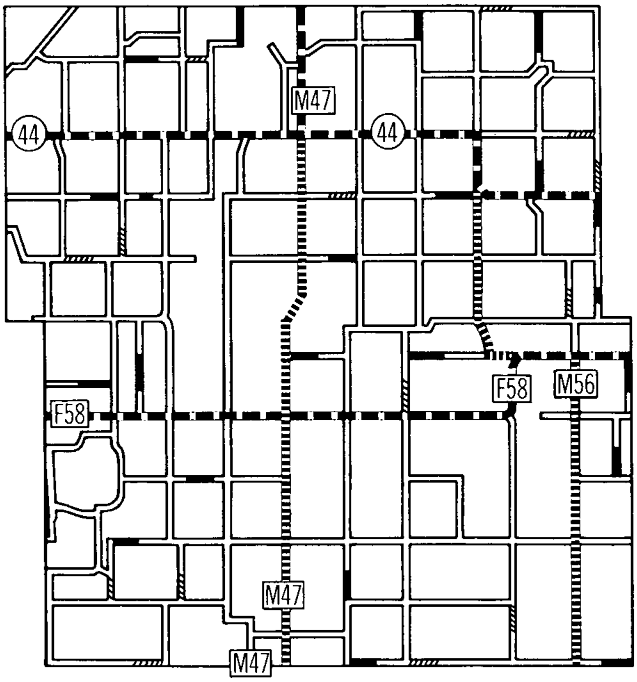
The abandonment analysis indicated that if a few road segments with no property access were abandoned in the three study areas, the additional travel costs from rerouting the traffic around the abandoned roads would be less than the maintenance and investment cost savings from the abandoned roads. However, as the number of abandoned roads increased, the travel costs for the rerouted traffic increased faster than the maintenance and investment cost savings from the abandoned roads. These results were particularly strong in the Shelby County study area where the percentage of paved roads is small. This suggested that increasing the number of miles of paved roads would increase the potential for road abandonment. The abandonment analysis was extended by examining the impact of paving additional local rural roads on the benefits and costs of road abandonment. Because vehicle travel costs are lower on paved roads than on gravel or earth-surface roads, total vehicle travel costs should decline with the paved core. In this analysis, a set of roads was paved in the computerized road network to provide a core of paved roads in each study area. Figures 3.4, 3.5, and 3.6 show the locations of the newly paved roads. The network model was rerun to estimate total miles and travel costs with the paved core. Then, the low-traffic volume road segments with no property access points in the L_1, S_1, S_2, and H_1 solutions were again

Figure 3.4. Linn County study area: Newly paved and abandoned roads



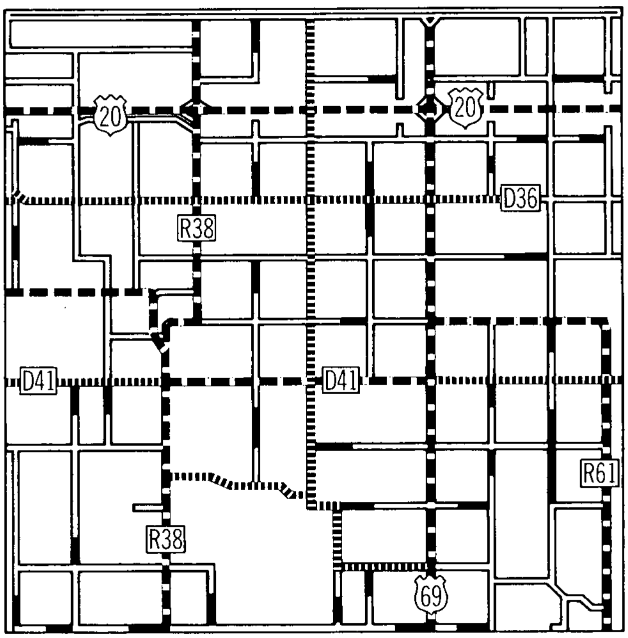
Existing paved roads
Newly paved roads (29.5 miles)
L_1 abandonment (9.25 miles)

Figure 3.5. Shelby County study area: Newly paved and abandoned roads



Existing paved roads
Newly paved roads (17.25 miles)
S_1 abandonment (9.25 miles)
S_2 abandonment (6.75 miles)

Figure 3.6. Hamilton County study area: Newly paved and abandoned roads



Existing paved roads
Newly paved roads (32.5 miles)
H_1 abandonment (17.75 miles)

removed from the computerized road network. The network model was rerun to estimate total miles and travel costs for the abandonment solution. Table 3.16 shows the miles of roads that were paved and then abandoned by study area solution.

Table 3.17 presents the change in travel costs from the base solution to the paved solution and from the paved solution to the abandonment solution, by type of travel. Total travel costs declined sharply in each paved core solution, with the largest portion of these savings accruing to household and farm travel.

In the abandonment solutions, travel costs increased for all types of travel except for overhead traffic; overhead traffic had no cost change because no overhead traffic traveled on the abandoned roads. The largest increases in travel costs were for farm traffic because farm trips are typically short distances to fields or to farmsteads; these trips generally have fewer rerouting options than the longer-distance household trips to schools, churches, shopping, and other destinations. A second reason for the large additional farm travel costs from abandonment is that farm vehicle travel costs per mile are sharply higher than for other types of vehicles, so that a relatively small change in distance has a large impact on farm travel costs.

Table 3.16. Number of additional miles of road paved and miles abandoned, by study area solution

Study area	Solution	Additional paved miles	Miles abandoned
Linn	1	29.5	0
Linn	2	29.5	5.25 (L_1)
Shelby	1	17.25	0
Shelby	2	17.25	9.25 (S_1)
Shelby	3	17.25	6.75 (S_2)
Hamilton	1	32.5	0
Hamilton	2	32.5	17.75 (H_1)

Table 3.18 presents the estimated change in annual road maintenance and investment costs for the three paved core and the three abandonment solutions. The average annual net increase in maintenance and investment costs for paving roads ranged from $8,542 per paved mile in the Hamilton County study area to $11,202 per paved mile in the Shelby area. These costs are net of the costs of maintaining and reconstructing the roads if they remained gravel.

The average annual maintenance and investment cost savings for abandonment after paving the additional roads ranged from $4,717 per mile in the S_2 solution to $5,999 in the H_1 solution. These cost savings are net of the maintenance and reconstruction costs transferred to roads that inherit the traffic from the abandoned roads.

Table 3.19 presents the savings for the paving and the abandonment solutions before and after paving. The travel cost savings resulting from the additional paved roads are all less than the net paving costs. However, the estimated travel cost savings are only from traffic originating in or destined for the study

Table 3.17. Estimated change in travel costs resulting from paving a core set of roads and then abandoning the L_1, S_1, S_2, and H_1 roads, by study area, 1982

	Change in travel costs						
	Linn County study area		Shelby County study area			Hamilton County study area	
Type of travel	Pave 29.5 miles of gravel road	Abandon L_1 roads (5.25 miles)	Pave 17.25 miles of gravel road	Abandon S_1 roads (9.25 miles)	Abandon S_2 roads (6.75 miles)	Pave 32.5 miles of gravel road	Abandon H_1 roads (17.75 miles)
Household	$ −153,451	$ 7,355	$ −25,326	$ 6,226	$ −11,777	$ −19,997	$ 8,992
Overhead	−11,703	0	—	—	—	—	—
Farm	−16,020	9,473	−14,250	28,768	−51,051	−25,346	33,165
Farm timeliness	−712	1,858	−321	2,182	−1,401	−1,359	5,365
School bus	−2,108	5,547	−672	1,051	0	−1,010	3,818
Post office	0	2,305	0	1,340	0	0	9,305
Total	$ −183,994	$ 26,538	$ −40,569	$ 39,567	$ 64,229	$ −47,712	$ 60,645

areas and do not include any cost savings due to overhead traffic that may travel over the newly paved roads. Changes in traffic origins and destinations resulting from the additional paved roads or benefits from economic development are not included, either. Therefore, no net benefits were calculated for the additional paved road solutions.

The net savings from abandonment, after adding the additional miles of paved roads, ranged from $ −4,798 per mile in the S_2 solution to $2,582 per mile in the H_1 solution. The net savings from abandonment in the L_1 and S_1 solutions are only slightly higher than the abandonment savings before the additional paving. The negative cost savings in the S_2 solution after paving are about two-thirds of the negative cost savings from abandonment before paving. The Hamilton County study area net savings per mile of abandoned roads after the additional paving were more than double the abandonment savings before the additional paving. However, in all three study areas the cost of the additional paving, net of travel cost savings, was substantially larger than the change in net abandonment savings as a result of the additional paving. The conclusion is that it would be uneconomical to pave additional miles of road to permit more road abandonment.

Table 3.18. Estimated change in annual maintenance and investment costs from paving a core system and then abandoning the L_1, S_1, S_2, and H_1 roads, by study area, 1982

	Change in costs						
	Linn County study area		Shelby County study area			Hamilton County study area	
Type of cost	Pave 29.5 miles of gravel road	Abandon L_1 roads (5.25 miles)	Pave 17.25 miles of gravel road	Abandon S_1 roads (9.25 miles)	Abandon S_2 roads (6.75 miles)	Pave 32.5 miles of gravel road	Abandon H_1 roads (17.75 miles)
Road costs							
Variable maintenance	$ −29,584	$ 501	$ −10,501	$ 675	$ 2,487	$ −10,936	$ −11,895
Fixed maintenance	−32,813	−12,258	−29,014	−20,957	−17,001	−40,232	−42,174
Resurfacing	−124,728	13	35,173	51	865	69,731	−2,386
Reconstruction	67,489	−7,604	−34,871	−11,116	−4,552	−36,922	−19,014
Paving	382,369	—	215,535	—	—	290,243	—
Bridge costs							
Maintenance	0	−1,284	0	−10,159	−1,780	0	−3,120
Reconstruction	27,563	−2,195	16,918	−9,138	−9,915	5,745	−8,582
Net land rental value less land reconstruction costs	0	−5,029	0	−2,663	−1,943	0	−19,313
Total	$ 290,295	$ −27,856	$ 193,240	$ −53,307	$ −31,840	$ 277,629	$ −106,484
Average net change in road costs per mile	$ 9,841	$ −5,306	$ 11,202	$ −5,763	$ −4,717	$ 8,542	$ −5,999

Table 3.19. Net savings from abandonment of the L_1, S_1, S_2, and H_1 roads before and after paving a core of additional roads, by study area, 1982

	Linn County study area		Shelby County study area			Hamilton County study area	
	Pave 29.5 miles of gravel road	Abandon L_1 roads (5.25 miles)	Pave 17.25 miles of gravel road	Abandon S_1 roads (9.25 miles)	Abandon S_2 roads (6.75 miles)	Pave 32.5 miles of gravel road	Abandon H_1 roads (17.75 miles)
Change in travel costs	$ −183,994	$ 26,538	$ −40,569	$ 39,567	$ 64,229	$ −47,712	$ 60,645
Change in annual maintenance and investment costs	290,295	−27,856	193,240	−53,308	−31,840	277,629	−106,484
Net savings from abandonment	—	1,318	—	13,741	−32,389	—	45,839
Net savings per mile abandoned after the additional paving	—	251	—	1,485	−4,798	—	2,582
Net savings per mile abandoned before the additional miles were paved	—	70	—	1,379	−6,718	—	928

Converting Low Volume Roads to Area Service B Roads

To compare the area service B low-maintenance road strategy with the abandonment strategy, the 9.25 miles of S_1 roads were converted to area service B roads in the computerized Shelby County road network. In addition, a second set of 20.25 low-volume roads was also converted to area service B roads. This set included 14 miles of gravel road, 6.25 miles of earth road, and five bridges. Figure 3.7 shows the location of the area service B roads.

The basic assumptions behind the area service computer solutions are that the B roads would

1. Receive no snow removal
2. Receive no gravel applications
3. Not be reconstructed
4. Receive only minimal grading of five times per year.

Bridge maintenance expenditures were assumed to be 80 cents per square foot per year, the same for area service B roads as for the regularly maintained county roads. No area service B road bridges would be reconstructed. Thus, the area service B roads would not be open to registered vehicles during the winter months and the quality of the roads, and eventually the bridges, would deteriorate over time.

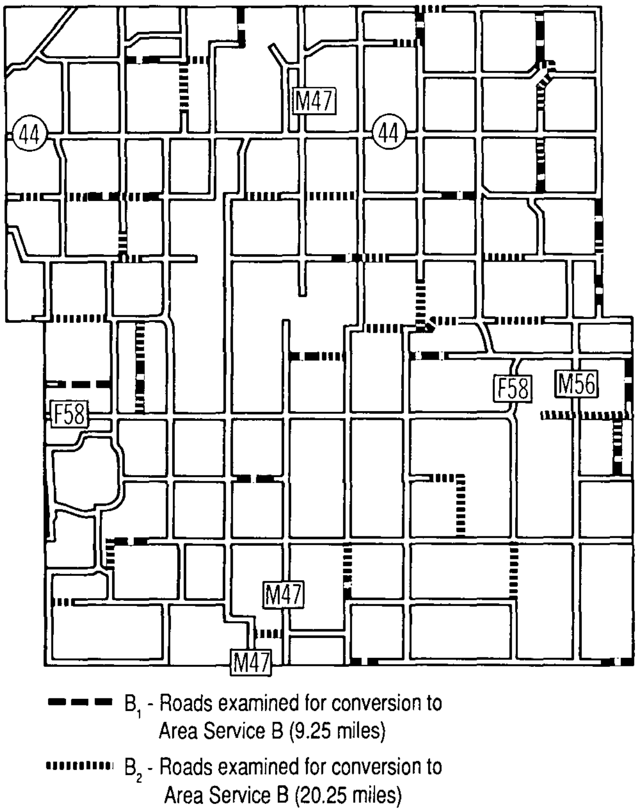
Table 3.20 shows the change in vehicle miles from the base solution as a result of converting the two sets of roads to area service B roads. The computer solution converting the S_1 roads to area service B roads is referred to as the B_1 solution. The second set of roads converted to area service B roads is referred to as the B_2 solution.

The increase in miles driven in the B_1 solution is only 20 percent of the S_1 abandonment solution. The

Table 3.20. Estimated total miles driven in the Shelby County study area under the base solution and change in miles driven in each of two solutions with roads converted to area service B roads, by vehicle group, 1982

			Change in miles driven from previous solution			
	Base solution		B_1 (9.25 miles converted to B roads)		B_2 (20.25 miles converted B roads)	
Type of travel	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total
Household						
Auto	3,657,386	58.9	7,668	53.2	13,010	35.8
Pickup	464,614	7.5	285	2.0	538	1.5
Truck	123,192	2.0	306	2.1	425	1.2
Subtotal	4,245,192	68.4	8,259	57.3	13,973	38.5
Farm						
Auto	34,369	0.6	63	0.4	315	0.9
Pickup	1,449,380	23.4	2,317	16.1	6,937	19.1
Truck	179,620	2.9	36	0.2	759	2.0
Tractor-wagon	42,353	0.7	0	0.0	0	0.0
Tractor pulling equipment or alone	126,652	2.0	0	0.0	0	0.0
Combine	8,491	0.1	0	0.0	0	0.0
Subtotal	1,840,865	29.7	2,416	16.7	8,011	22.1
Other						
School bus	52,024	0.8	2,250	15.6	5,670	15.6
Post office	65,383	1.1	1,495	10.4	8,622	23.8
Subtotal	117,407	1.9	3,745	26.0	14,292	39.4
Grand Total	6,203,464	100.0	14,420	100.0	36,276	100.0

Figure 3.7. Shelby County study area: Low maintenance area service B roads



major reasons for the relatively small increase in miles driven in the B_1 solution compared to the S_1 solution are:

1. Farm tractors and combines can use the area service B roads all year to travel from farm to fields and from field to field. All farm equipment travel using the S_1 roads must be rerouted after abandonment.
2. Registered non-farm vehicles can use the area service B roads during the nine non-winter months and registered farm vehicles can use the roads 90 percent of the time. All traffic using the S_1 roads must be rerouted after abandonment.

Thus, registered vehicles incurred relatively small increases in travel distance from converting the S_1 roads to area service B roads and most farm vehicles incurred no additional miles of travel.

On the average, conversion of the S_1 roads to area service B roads resulted in a total of 1,559 miles of additional travel for each road mile converted. The conversion of the second set of roads to area service B created 1,791 miles of additional travel per mile of road converted. Almost all of the increases in traffic from the conversion to B roads came from automobiles used for household travel, farm pickups and trucks, and school bus and post office travel.

Table 3.21 shows the increase in travel cost resulting from the B_1 and B_2 solutions. Total variable costs increased $5,731 in the B_1 solution over the base solution. These increased costs were only 14.5 percent of the increased costs when the S_1 roads were abandoned. The largest increases in costs were incurred by school buses and post office vehicles, which were prohibited from traveling over area service B roads in this analysis. On a per mile basis, travel costs increased $620 per mile of S_1 roads converted to area service B roads.

In the B_2 solution, conversion of the 20.25 miles to area service B roads increased travel costs by $14,401, or $711 per converted mile. Over half of this increased cost was by school buses and post office vehicles. Another 25 percent was by farm pickup trucks.

Table 3.22 shows the annualized cost savings to the counties from converting the S_1 and the second set of roads to area service B roads. The total cost savings to the county were $37,482 per year in the B_1 solution. On a per mile basis, converting the S_1 roads to area service B roads would save Shelby County $4,052 per mile per year. Converting the second set to area service B roads would save Shelby County $3,610 per mile of converted road per year. The principle reason why the B_1 roads had substantially larger savings than the B_2 roads is the large number of bridges on the B_1 roads.

Table 3.23 shows the annual net savings from converting the B_1 and B_2 roads to area service B roads. The net savings on the B_1 roads were $3,433 per mile per year. This compares with a net savings of $1,379 per mile per year in the S_1 abandonment solution. Thus, conversion to area service B roads results in:

1. Smaller increases in travel costs than road abandonment
2. Smaller cost savings to the county than road abandonment
3. Higher net savings to society than road abandonment

Table 3.21. Estimated total cost of all travel in the Shelby County study area under the base solution and change in total cost in each of two solutions with roads converted to area service B roads, by vehicle group, 1982

			Change in total variable cost from the previous solution			
	Base solution		B_1 (9.25 miles converted to B roads)		B_2 (20.25 miles converted B roads)	
Type of travel	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total
Household						
Auto	$ 832,791	44.9	$ 1,863	32.5	$ 2,414	16.8
Pickup	127,411	6.9	98	1.7	86	0.6
Truck	59,246	3.2	100	1.7	115	0.8
Subtotal	$ 1,019,448	55.0	$ 2,061	35.9	$ 2,615	18.2
Farm						
Auto	$ 9,024	0.5	$ 34	0.6	$ 149	1.0
Pickup	433,302	23.4	1,140	19.9	3,648	25.3
Truck	72,185	3.9	104	1.8	221	1.6
Tractor-wagon	56,691	3.0	0	0.0	0	0.0
Tractor pulling equipment or alone	168,495	9.1	0	0.0	0	0.0
Combine	13,590	0.7	0	0.0	0	0.0
Timeliness	0	0.0	0	0.0	0	0.0
Subtotal	753,287	40.6	1,278	22.3	4,018	27.9
Other						
School bus	$ 22,537	1.2	$ 1,052	18.4	$ 2,491	17.3
Post office	58,584	3.2	1,340	23.4	5,277	36.6
Subtotal	81,121	4.4	2,392	41.8	7,768	53.9
Grand Total	$ 1,853,856	100.0	$ 5,731	100.0	$ 14,401	100.0

Table 3.22. Estimated annual cost savings from converting two sets of roads to area service B roads, Shelby County study area, 1982

	Annual cost savings	
Source of cost savings	B_1 (9.25 miles)	B_2 (20.25 miles)
Cost savings to the county		
Variable road maintenance	$ −83	$ 638
Fixed road maintenance	16,286	35,293
Road resurfacing	−10	−13
Road reconstruction	12,151	27,261
Bridge maintenance	0	0
Bridge reconstruction	9,138	9,914
Total county cost savings	$ 37,482	$ 73,093
Cost savings to the county per mile of road converted to area service B maintenance	$ 4,052	$ 3,610

Table 3.23. Annual savings from converting two sets of roads to area service B roads, Shelby County study area, 1982

	Computer solution	
Type of savings	B_1 (9.25 miles)	B_2 (20.25 miles)
Savings to the traveling public	$ −5,731	$ −14,401
Savings to the county	37,482	73,093
Annual net savings	$ 31,751	$ 58,692
Annual net savings per mile of road converted	$ 3,433	$ 2,898

The net savings on the B_2 roads were $2,898 per mile of road. Several of the B_2 roads were also S_2 and S_3 roads. Thus, a rough comparison of S_2 and S_3 solutions suggests that the area service B option that allows farmers more direct access to their fields is, in some cases, a better solution than road abandonment. However, there are some potentially major problems with the area service B alternative.

1. Given no bridge reconstruction, the area service B alternative is a transition solution. As the bridges on these roads deteriorate structurally and become obsolete, the counties will eventually face the issue of bridge replacement or abandonment.
2. While Iowa law removes area service B road tort liability from the counties, this law has not been tested in court. If the courts rule this portion of the law unconstitutional, the legal costs and damage awards from area service B roads could be substantial.

Converting Dead-end Roads to Private Drives

Iowa law prohibits the abandonment of roads that serve as the sole access to property. Thus, many abandoned roads are less than one mile long and the remainder of the section road becomes a dead-end road. It is reasonable to assume that the only traffic on these dead-end roads is either originating or terminating traffic. In effect, dead-end roads become private drives. This suggests the possibility of shifting the dead-end road ownership and maintenance costs from the county to the abutting landowners.

Two computer solutions were obtained to estimate the net benefits from converting dead-end roads to private drives. In the first solution, all dead-end roads resulting from the abandonment of the S_1 roads in the Shelby County study area were converted to private drives. In the second solution, all dead-end roads resulting from the abandonment of the H_1 roads in the Hamilton area were converted to private drives. Figures 3.8 and 3.9 show the locations of these dead-end roads.

In each case, the conversion to private drives resulted in no additional travel miles or costs. Thus, the analysis of conversion of dead-end roads to private drives consists of comparing public and private maintenance and investment costs. In addition, conversion to private drives allows the abutting landowners to reduce the width of the right-of-way from 66 feet to approximately 40 feet. This permits the abutting landowner to have an additional 3.15 acres of land per mile converted to private drive.

Table 3.24 shows the public and private maintenance costs and the rental value of the right-of-way that can be used for agricultural purposes. Converting 13.75 miles of Shelby study area dead-end roads (SDE) created by the abandonment of the S_1 roads saved the county $56,743, mostly from reductions in fixed road maintenance and from road and bridge reconstruction costs. Net costs to the abutting landowners increased $29,361, mostly from road maintenance and reconstruction costs. Similar per mile results were obtained in converting the Hamilton study area dead-end roads (HDE) to private drives.

Table 3.25 summarizes the per mile impact of private drives on the county, abutting landowners, and society. The counties would save $4,076 and $4,053 per mile of road converted to private drives in the Hamilton and Shelby study areas, respectively. Abutting landowners would incur additional net costs of $1,634 to $2,097 per mile of road. The net savings would be about $2,442 and $1,956 per

Figure 3.8. Shelby County study area: Dead-end roads converted to private drives in SDE solution

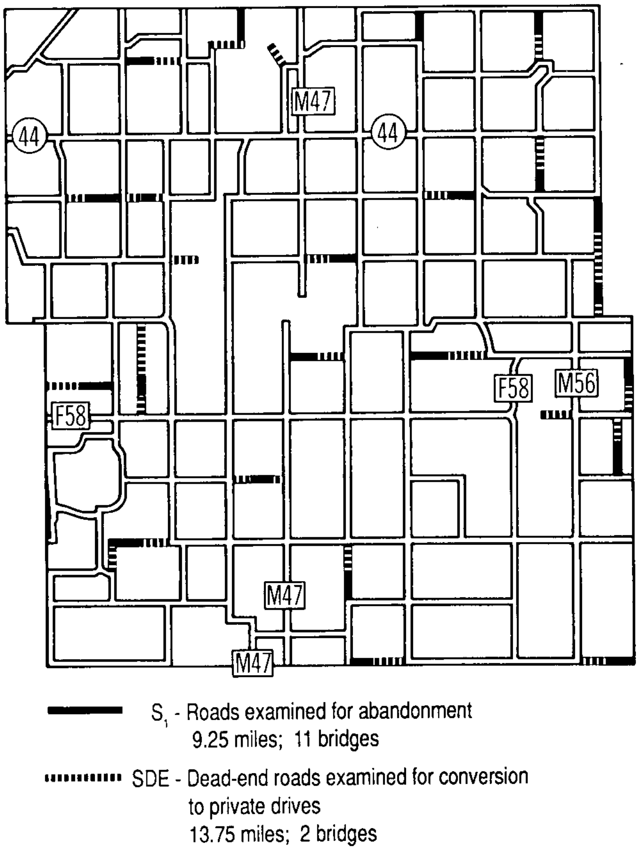


Figure 3.9. Dead-end roads converted to private drives in HDE solution

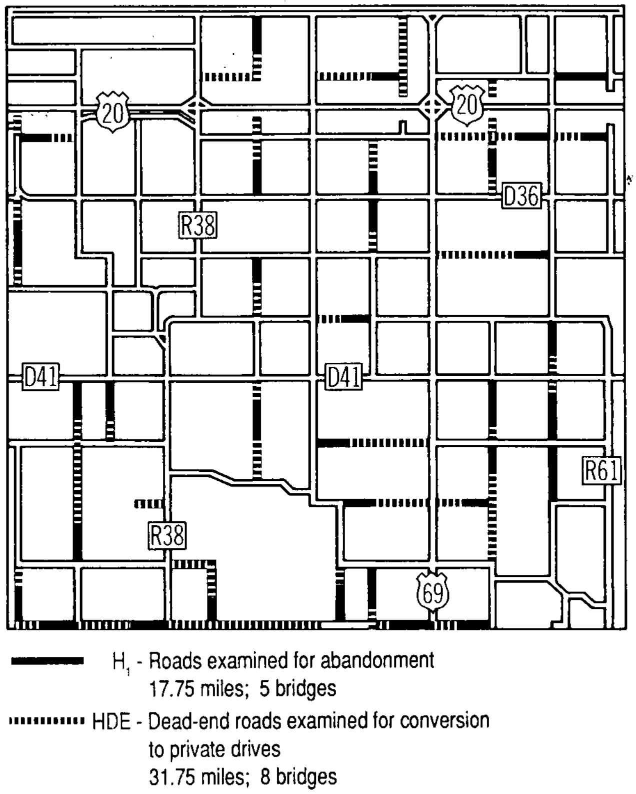


Table 3.24. Estimated annual net cost savings from converting selected public dead-end roads to private drives, Shelby and Hamilton County study area, 1982

	Annual cost savings	
Source of cost savings	SDE (13.75 miles)	HDE (31.75 miles)
Cost savings to the county		
Variable road maintenance	$ 459	$ 0
Fixed road maintenance	32,476	75,438
Road resurfacing	0	0
Road reconstruction	19,265	31,594
Bridge maintenance	1,404	5,426
Bridge reconstruction	3,139	16,965
Total county cost savings	$ 56,743	$ 129,423
Cost to abutting landowners		
Road maintenance	$ 22,581	$ 45,852
Road reconstruction	9,587	14,689
Bridge maintenance	1,404	5,426
Total	33,572	65,967
Less rental value of four acres per mile of dead-end road	4,211	14,093
Net cost savings	$ 27,383	$ 77,549

Table 3.25. Estimated per mile savings on private drives to counties and abutting landowners, Shelby and Hamilton study areas, 1982

	Per mile savings	
Savings to	**Shelby**	**Hamilton**
Counties	$ 4,053	$ 4,076
Abutting landowners	−2,097	−1,634
Net savings	$ 1,956	$ 2,442

year for each road converted to private drive. The conclusion is that converting dead-end roads to private drives would result in substantial net savings to society. However, the abutting landowners would be worse off because the road and bridge maintenance costs would shift to them.

Paved Core Analysis

About 10 percent of the Linn and Hamilton County study area roads and 5 percent of the Shelby area roads are paved state or interstate highways. In addition, approximately 21, 6, and 18 percent of the Linn, Shelby, and Hamilton study area roads are paved county roads, respectively. This relatively large percentage of paved roads raises several questions:

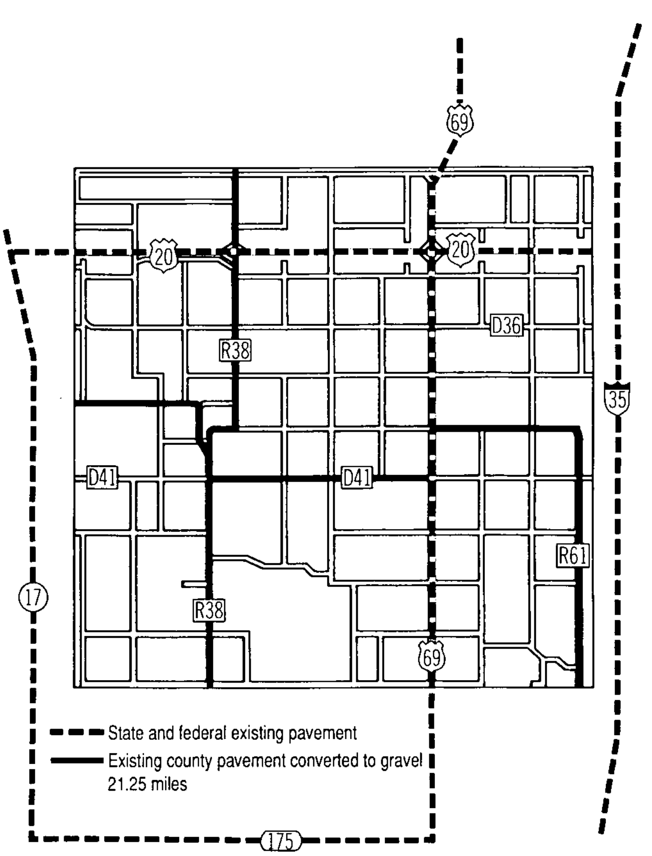
1. Should a largely rural county road system include any hard-surface paved roads?
2. Should rural counties construct additional paved roads?

The Shelby and Hamilton study areas are largely rural. Only 25 and 40 percent of the households in the Shelby and Hamilton areas were non-farm, respectively, whereas 84 percent of the Linn area households were non-farm. Moreover, the Linn County study area had four times as many households as the Shelby and Hamilton areas. Thus, there appears to be little reason to question the number of miles of paved road in the Linn study area. However, the questions are relevant for the Shelby and Hamilton study areas.

We are unable to answer fully the questions on the benefits and costs of the existing paved roads or additional paved roads because no overhead traffic data were collected for the Hamilton and Shelby study areas. Nevertheless, a benefit-cost analysis of the 21.25 miles of the existing non-border paved road in the Hamilton study area changed them to gravel surfaces in the computerized road network, (Figure 3.10). Then, using the 1982 origins and destinations data, traffic was rerouted over the gravel network. The results of this computer solution were then compared to the 1982 base solution to estimate the benefits and costs of paving the 21.25 miles of Hamilton area roads. The paving costs were taken from the 1982 Needs Study and then discounted back to the actual paving years, which ranged from 1958 to 1968. The discount rate was the 5.6 percent real interest rate used throughout this analysis. The discounted paving costs were then annualized over the 45-year design life of paved roads. The bridges on these roads were assumed to be reconstructed when the roads were paved. The same discounting and annualizing procedure was used to estimate the annual cost of reconstructing the bridges on the 21.25 miles of paved roads.

The only originating and terminating traffic data available on the border area roads are from farms that have tracts of land within each study area; therefore, only the non-border roads within the

Figure 3.10. Hamilton County study area: County paved roads converted to gravel



Hamilton County study area and the traffic on these roads were included in the estimation of the benefits and costs of paving for this solution.

Table 3.26 presents the estimated total miles traveled in the no-paved-road solution and the base solution, and the change in miles traveled. Total miles traveled increased by 148,312 miles in the base solution as a result of the 21.25 miles of paved roads. Almost 88 percent of the travel miles was by households. Only 12.1 percent of the increase in total miles traveled was by farm vehicles, mostly by pickup trucks. Travel miles increased with the paved roads because drivers went to paved roads as soon as possible to reduce the travel costs per mile. Some farm travel—principally farm to field and field to farm—actually decreased as a result of the paved roads. There was no change in school bus and post office travel because these vehicles follow fixed routes regardless of the type of surface.

Table 3.27 presents the total travel costs and the change between the no-paved and paved solutions. Total travel costs declined $146,341 in the no-paved-roads solution. About two-thirds of the reduction in travel costs was for household travel. Only 33.2 percent was for farm travel; most of this reduction was for pickup trucks traveling to nearby towns or to further destinations. There were only small cost savings for farm equipment and for hauling inputs and outputs to and from the farm.

Table 3.28 shows the change in annual road and bridge maintenance and reconstruction costs as a result of paving 21.25 miles of gravel roads. The major additional cost was $195,585 of paving and resurfacing the 21.25 miles. Variable maintenance costs also increased because of the increased travel miles. However, these costs were more than offset by the reduced variable and reconstruction costs on the gravel roads that were paved.

Table 3.26. Estimated total miles driven in the Hamilton County study area under the base solution and in the solution with no paved county roads, 1982

	Solution with no paved county roads		Base solution with 21.25 miles of paved county roads		Change from no paved county roads to 21.25 miles of paved county roads	
Type of travel	Miles	Percent of total	Miles	Percent of total	Miles	Percent of total
Household						
Auto	2,617,243	61.8	2,738,593	62.5	121,350	81.8
Pickup	216,423	5.1	224,067	5.1	7,644	5.1
Truck	49,222	1.2	50,651	1.2	1,429	1.0
Subtotal	2,882,888	68.1	3,013,311	68.8	130,423	87.9
Farm						
Auto	36,070	0.8	36,351	0.8	281	0.2
Pickup	949,013	22.4	967,610	22.1	18,597	12.5
Truck	94,012	2.2	94,219	2.1	207	0.2
Tractor-wagon	40,887	1.0	40,040	0.9	−847	−0.6
Tractor pulling equipment or alone	116,662	2.8	116,271	2.6	−391	−0.3
Combine	11,234	0.3	11,276	0.3	42	0.1
Subtotal	1,247,878	29.5	1,265,767	28.8	17,889	12.1
Other						
School bus	46,800	1.1	46,800	1.1	0	0.0
Post office	55,387	1.3	55,387	1.3	0	0.0
Subtotal	102,187	2.4	102,187	2.4	0	0.0
Grand total	4,232,953	100.0	4,381,265	100.0	148,312	100.0

Table 3.27. Estimated total cost in the Hamilton County study area under the base solution and in the solution with no paved county roads, 1982

	Solution with no paved county roads		Base solution with 21.25 miles of paved county roads		Change from no paved county roads to 21.25 miles of paved county roads	
Type of travel	Cost	Percent of total	Cost	Percent of total	Cost	Percent of total
Household						
Auto	$ 686,149	47.5	$ 598,823	46.1	$ −87,326	59.7
Pickup	68,089	4.7	61,403	4.7	−6,686	4.6
Truck	27,387	1.9	23,713	1.8	−3,674	2.5
Subtotal	$ 781,625	54.1	$ 683,939	52.6	$ −97,686	66.8
Farm						
Auto	$ 9,671	0.7	$ 8,827	0.7	$ −844	0.6
Pickup	305,706	21.1	278,332	21.4	−27,374	18.7
Truck	44,064	3.0	37,892	2.9	−6,172	4.2
Tractor-wagon	59,592	4.1	55,621	4.3	−3,971	2.7
Tractor pulling equipment or alone	156,375	10.8	149,346	11.5	$−7,029	4.8
Combine	18,428	1.3	17,730	1.4	−698	0.5
Timeliness	2,567	0.2	0	0.0	−2,567	1.7
Subtotal	596,403	41.2	547,748	42.2	−48,655	33.2
Other						
School bus	$ 18,519	1.3	$ 18,519	1.4	$ 0	0.0
Post office	49,628	3.4	49,628	3.8	0	0.0
Subtotal	68,147	4.7	68,147	5.2	0	0.0
Grand total	$ 1,446,175	100.0	$ 1,299,834	100.0	$ −146,341	100.0

Table 3.28. Additional annual road bridge maintenance and reconstruction costs to provide 21.25 miles of paved county road, Hamilton County study area, 1982

Type of cost	Additional annual costs of paving 21.25 miles of gravel road
Road costs	
Variable maintenance	$ −66,896
Fixed maintenance	−62,012
Reconstruction	−28,671
Paving and resurfacing	195,585
Bridge costs	
Maintenance	0
Reconstruction	9,158
Total cost	$ 47,164

Table 3.29. Net annual savings from paving 21.25 miles of county roads, Hamilton County study area, 1982

Type of savings	Savings from paving 21.25 miles of gravel roads
Annual savings in travel costs from the 21.25 miles of paved roads	$ 146,341
Annualized net savings of paving and maintaining 21.25 miles of road	−47,164
Net savings	$99,177

Table 3.29 shows the net benefits from paving the 21.25 miles of county roads in Hamilton County. The net savings from the reduced 1982 travel costs over the annualized 1958-1968 road paving cost and 1982 maintenance and reconstruction costs were $99,177 and $4,667, respectively, per year per mile paved. Thus, the early decision to pave 21.25 miles of gravel road in the Hamilton County study area was highly economical. We are unable to evaluate the economics of paving additional roads beyond the 21.25 miles because of the lack of overhead traffic in the Hamilton County study area.

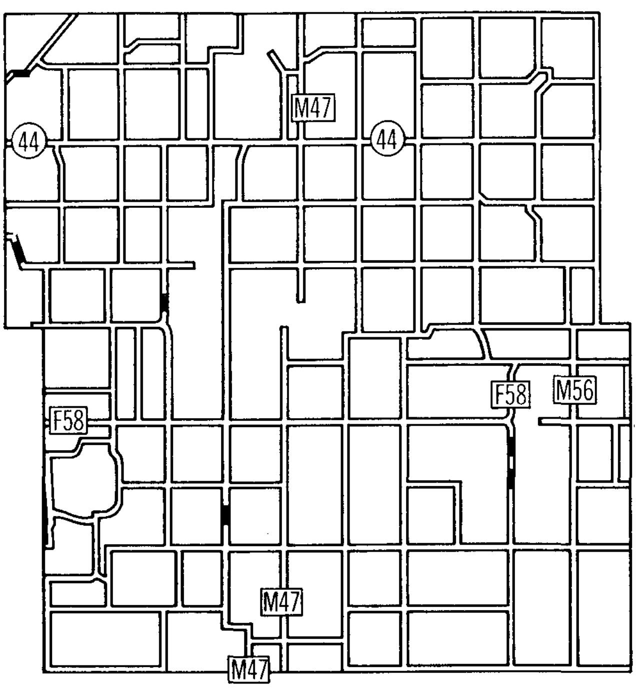
Reconstructing Bridges to Legal Weight Limits

Many bridges in the local rural road system are rated at sub-legal load limits and/or are too narrow for some types of farm equipment. In all other solutions in this analysis, roads and bridges were periodically and simultaneously reconstructed on the life cycle shown in Table 2.10. To estimate the impact of eliminating these sub-legal load and narrow bridges from the system, two solutions were run in which selected bridges were widened to 24 feet on gravel roads and to 30 feet on paved roads and reconstructed to carry legal load limits. However, no roads were reconstructed in these solutions prior to the life cycle bridge reconstruction time. The criteria for selecting the bridges to be widened and reconstructed were:

A. Shelby study area
   1. Average vehicle traffic must be at least 40 per day
   2. Bridges must have a load limit of less than 29 tons
B. Linn study area
   1. All sub-legal bridges located in the northern half of the study area

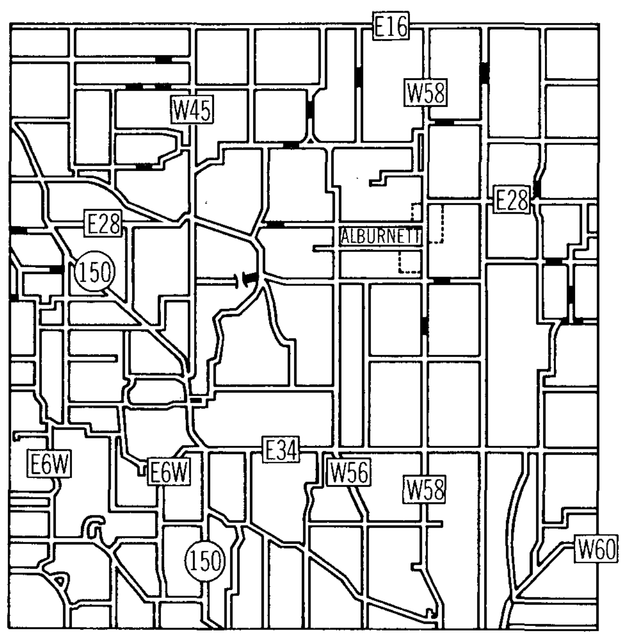
Figures 3.11 and 3.12 show the locations of the reconstructed bridges. In the Linn study area solution, 21 bridges with a total of 18,737 square feet of deck were reconstructed to the legal load limit, which added a total of 29,697 square feet of deck space to the bridges. In the Shelby area solution, six bridges with a total of 9,275 square feet were reconstructed to the legal load limit and widened, which added a total of 15,000 square feet to the bridges.

Figure 3.11. Shelby County study area: Reconstructed bridges



Bridges examined for reconstruction
6 bridges

Figure 3.12. Linn County study area: Reconstructed bridges



Bridges examined for reconstruction
21 bridges

Table 3.30. Change in total miles driven from the base solution resulting from reconstructing bridges in the Shelby and Linn study areas, by vehicle type, 1982

	Change in miles driven			
	Shelby (reconstruct 6 bridges)		Linn (reconstruct 21 bridges)	
Type of travel	Miles	Percent	Miles	Percent
Household				
Auto	0	0.0	0	0.0
Pickup	0	0.0	0	0.0
Truck	−25	4.0	−3,485	68.6
Subtotal	−25	4.0	−3,485	68.6
Farm				
Auto	0	0.0	0	0.0
Pickup	0	0.0	0	0.0
Truck	−341	55.0	−153	3.0
Tractor-wagon	−254	41.0	−385	7.6
Tractor pulling equipment or alone	0	0.0	−979	19.3
Combine	0	0.0	−79	1.5
Subtotal	−595	96.0	−1,596	31.4
Other				
School bus	0	0.0	0	0.0
Post office	0	0.0	0	0.0
Subtotal	0	0.0	0	0.0
Grand total	−620	100.0	−5,081	100.0

Table 3.30 shows the change in total miles driven resulting from the reconstruction of 6 Shelby and 21 Linn study area bridges. Total miles driven declined only 620 miles in the Shelby area and 5,081 miles in the Linn area. Almost all of the reduction in travel miles in the Shelby area was for farm travel, mostly by trucks and tractors pulling wagons. In the Linn study area, about two-thirds of the reduced travel miles was by non-farm trucks. Most of the remaining reduction in miles traveled was by farm equipment. The differences in the reduction of travel miles between the two study areas are related to the differences in the bridge selection criteria and the type of vehicle travel.

Table 3.31 shows the change in travel cost resulting from widening and reconstructing the bridges. Travel costs in the Shelby study area declined $674 from the bridge reconstruction. Most of the cost savings were for heavy farm trucks and tractors pulling wagons. In the Linn study area, travel costs declined $16,790. These travel cost reductions included heavy non-farm and farm trucks and tractors pulling wagons.

Table 3.32 presents the annual change in road and bridge maintenance and investment costs resulting from widening and reconstructing the bridges. In the Shelby study area, net road maintenance and investment costs increased $248 per year, while bridge maintenance costs increased $4,580 per year and bridge reconstruction costs increased $17,983 per year, resulting in a net additional road and bridge cost of $22,811 per year.

In the Linn study area, early bridge widening and reconstruction increased variable road maintenance costs because of the shifting of traffic between roads. Bridge maintenance increased because of the widening of the bridges. The total annual cost of reconstructing the 21 bridges earlier than their life cycle schedule is estimated to be $41,624.

Table 3.31. Change in total travel cost from the base solution resulting from reconstructing bridges in the Shelby and Linn study areas, by vehicle type, 1982

	Change in travel costs			
	Shelby (reconstruct 6 bridges)		Linn (reconstruct 21 bridges)	
Type of travel	Miles	Percent	Miles	Percent
Household				
Auto	$ 0	0.0	$ 0	0.0
Pickup	0	0.0	0	0.0
Truck	−13	1.9	−8,072	48.1
Subtotal	−13	1.9	−8,072	48.1
Farm				
Auto	$ 0	0.0	0	$ 0.0
Pickup	0	0.0	0	0.0
Truck	−294	43.6	−3,159	18.9
Tractor-wagon	−333	49.4	−1,134	6.7
Tractor pulling equipment or alone	0	0.0	−2,381	14.2
Combine	0	0.0	−244	1.4
Timeliness	−34	5.1	−1,800	10.7
Subtotal	−661	98.1	−8,718	51.9
Other				
School bus	$ 0	0.0	$ 0	0.0
Post office	0	0.0	0	0.0
Subtotal	0	0.0	0	0.0
Grand total	$ −674	100.0	$ −16,790	100.0

Table 3.32. Change in annual county road and bridge costs resulting from reconstructing and widening selected bridges, Shelby and Linn study areas, 1982

	Change in annual road and bridge costs	
Type of cost	Shelby (reconstruct 6 bridges)	Linn (reconstruct 21 bridges)
Road costs		
Variable maintenance	$ −281	$ 8,951
Reconstruction	3,520	−962
Resurfacing	−2,991	36
Bridge costs		
Reconstruction	17,983	24,831
Maintenance	4,580	8,768
Net change in costs	$ 22,811	$ 41,624

Table 3.33 summarizes the travel cost savings to the traveling public and the additional costs to the counties from widening and reconstructing bridges. In the Shelby study area, the travel cost savings from widening and reconstructing bridges to legal load limits were only 3 percent of the cost to the county. In the Linn area, the the travel cost savings to the public were only 40 percent of the cost to the counties to widen and reconstruct the bridges. The conclusion from the bridge reconstruction solution is that, given the remaining bridges in the Shelby and Linn study areas, it is not economical to reconstruct the 6 and 21 bridges prior to the regular life cycle road and bridge reconstruction times.

Table 3.33. Annual net savings from reconstructing and widening bridges, Shelby and Linn study areas, 1982

	Net savings	
Type of savings	**Shelby (reconstruct 6 bridges)**	**Linn (reconstruct 21 bridges)**
Savings to the traveling public	$ 674	$ 16,790
Road and bridge savings to the counties	−22,811	−41,624
Net savings	$ −22,137	$ −24,834
Net savings per bridge per year	$ −3,690	$ −1,183

Chapter 4

Impacts, Implications, and Further Research

The major impact of road abandonment on travel miles and costs falls on farm travel. In five of the six abandonment solutions and in the H_2 private drive solution, the change in miles driven by farm vehicles was greater than the change in miles driven by household, post office, and school bus vehicles. The only abandonment solution that had greater impact on households than on farms was the L_1 solution in the Linn County study area. There are two major reasons why the impact of road abandonment are greater on farms than on household traffic.

1. The per mile cost of most farm-vehicle travel is higher than the per mile cost of vehicles serving households.
2. The relatively short distances of most farm trips reduce the rerouting options and therefore increase the additional miles required to reach the destinations.

The impacts of road abandonment vary among farms. Obviously, the farmers most affected by road abandonment are those who use the roads that would be abandoned. However, farmers who operate many tracts of land incur a larger share of total farm-equipment travel than farmers who operate few tracts (Table 4.1).

In the Hamilton County study area, the 12.6 percent of farmers who operate six or more tracts of land incurred 20 percent of the change in total farm-equipment miles resulting from the H_1 road abandonments. In the Shelby County study area, the 6 percent of the farmers operating six or more tracts of land had 14.1 percent of total change in farm-equipment miles resulting from abandonment of the S_1, S_2, and S_3 roads. Moreover, these large farmers tend to use the very large tractors and combines that have the highest cost per mile of travel. Therefore, large farmers will incur an even greater share of the total change in travel costs resulting from a reduction in the total road system.

Table 4.1. Percent increase in farm-equipment miles resulting from road abandonment, and percent of farmers operating six or more tracts of land, Hamilton and Shelby County study areas, 1982

	Percent increase in total miles driven	
Vehicle	**Hamilton**	**Shelby**
Tractor-wagon	19.6	14.2
Tractor pulling equipment or alone	18.4	13.3
Combines	32.3	25.4
Weighted average in farm-equipment miles	20.0	14.1
Percent of farmers operating 6 or more tracts of land	12.6	6.0

School buses and post office vehicles incur major changes in miles driven in the area service B and conversion of dead-end roads to private drive solutions for the following reasons.

1. School buses must serve all residences with school-age children and post office vehicles must serve all residences. This service requirement limits the ability of school districts and the postal service to adjust their routes to minimize distance traveled in response to road abandonment.
2. The vehicle cost per mile of school buses and post office vehicles is higher than that for vehicles serving household travel.

If dead-end roads are converted to private drives, post office regulations require that rural residences continue to receive direct mail service at the present mail box location. There are no regulations that require school buses to continue to pick up and deliver children to residences on private drives. The decision to serve these residences directly rests with individual school districts.

Accident Liability on Private Roads

Once a public road is transferred to private property, the property owner is responsible for accident liability. A major question arising from the transfer of responsibility is "What is the impact of the accident liability for private drives on insurance rates and coverage?" To obtain information on this question, three insurance companies that sell large amounts of farm insurance in Iowa were asked to make a judgment on the impacts on insurance rates of converting public roads to private drives.

The responses varied among the three insurance companies. All three company representatives indicated that there was insufficient exposure from converting public roads to private drives to statistically determine the impact on rates and coverage. The sales representative of the first insurance company indicated that the increased exposure on longer private lanes could increase the premiums on the liability coverage by up to 10 percent, or a total additional cost of between $5 to $10 per farm per year.

The underwriter of the second insurance company indicated that most of the large liability claims against farmers are for accidents involving farm equipment on public roads. Thus, converting public roads to private roads would reduce the liability exposure of farm equipment on public roads. Moreover, private roads would reduce the probability of liability claims against farmers resulting from animal escape. The same underwriter felt that converting public roads to private drives could reduce liability premiums, or at the worst, result in no change in premiums.

The underwriter of the third insurance company indicated that "turning public roads into private drives would increase the insurance company's exposure and hence rates unless: (1) the road can be made to appear as a private drive to the traveling public by means of a gate, a large sign close to the edge of the road, or other devices, and (2) the road is maintained to the degree that a reasonable and prudent person would maintain a private drive."

On the issue of multiple ownership of the private drive, the sale representative of the first insurance company stated that two or more owners of the private drive could create litigation problems for the insurance companies. The underwriter representatives of the other two insurance companies stated that multiple ownership of the private drive would create no problems that would increase liability rates.

Legal and Political Implications

In addition to the economic costs associated with the abandonment of roads, which are included in the benefit-cost analysis in this study, there is one other possible cost that should be considered. There can be substantial legal costs and damage awards associated with a road abandonment. The possibility and extent of these costs depend, in large part, on the state laws in effect in various states. Since these costs vary widely from case to case, it was not possible to include them in the benefit-cost analysis.

It is possible that the present laws in some states may preclude any possibility of road abandonment, private drives, or low-maintenance area service B roads. Changes in public attitudes and state laws may be needed before these net savings can be realized. Some areas that may need to be addressed are:

1. A reasonable method of compensation for change from public to private access
2. A method of arbitration of disputes between adjoining landowners affected by the change
3. Exemption of the local government authority from legal action upon completion of established guidelines
4. Legislation to strengthen existing laws regarding road abandonment, private drives, and low-maintenance roads
5. A method of educating the public on the benefits and costs of alternative road system changes, to enable the public to improve the quality of its input into the policy making process

Suggestions for Further Research

Agriculture continues to undergo major structural changes, which are likely to result in fewer but larger farms. There is a need to estimate the impact of these structural changes on traffic levels, and the implications of the changing traffic levels on this benefit-cost analysis.

This study incorporated a large number of roads and all property access points in the model in an attempt to minimize error from the failure to include all traffic in each solution. The high cost of obtaining each computer solution limited the analysis to groups of roads, rather than individual roads. A small computer model that can be run on a microcomputer is needed to analyze the investments and costs of alternative investment strategies on individual road segments.

Most of the costs used in this analysis were obtained from the Iowa Department of Transportation's Quadrennial Needs Study, from the study area county engineer, and from previously published studies on travel costs. Updated and carefully documented investment and travel costs are needed to conduct similar studies in other areas and states.

Appendix A.

Description of the Model and Algorithm

This appendix presents the mathematical model and computer algorithm used to estimate the savings of alternative investment strategies for a local rural road and bridge system. In addition, the benefit-cost models used to evaluate these strategies are presented.

The network model used in this analysis finds the minimum-cost routes from each origin to its specified destination for a given vehicle type. A network consists of a set of nodes connected by a set of arcs. A node represents a point where a trip originates, is relayed, or terminates. An arc is the road distance between two nodes; arcs allow traffic to flow between nodes.

Define $Q = (q_1, q_2, q_3, q_4)$ to be a vector where each of its components denote the following

- 1_1 = the code number for the location of the origin
- q_2 = the code number for the location of the destination
- q_3 = the code number for the vehicle type used
- q_4 = the number of trips made.

Define A to be the set of all Q gathered from the questionnaire. The model can be expressed as a linear programming problem as follows

$$\text{Minimize} \quad \sum_{Q} q_4 G_Q \qquad \text{(A.1)}$$

subject to

$$\sum_{j} f_{q_1}j - \sum_{j} f_{jq_1} = 1 \text{ for all } Q \in A \qquad \text{(A.2)}$$

$$\sum_{j} f_{q_2}j - \sum_{j} f_{jq_2} = -1 \text{ for all } Q \in A \qquad \text{(A.3)}$$

$$\sum_{j} f_{ij} - \sum_{j} f_{ji} = 0 \text{ for all } i \neq q,$$

$$i \neq q_2 \text{ for all } Q \in A \qquad \text{(A.4)}$$

$$WT_{ij} \geq WG_{q_3} \text{ for all } Q \in A \qquad \text{(A.5)}$$

$$f_{ij} = 0, 1 \text{ for all } Q \in A \qquad \text{(A.6)}$$

$$G_Q = \sum_{i} \sum_{j} f_{ij} \, Dist_{ij} \, (CPMG_{q3} \, G_{ij} + CPMD_{q_3} \, D_{ij} + CPMP_{q_3} \, H_{ij}) \qquad \text{(A.7)}$$

= the cost of making one trip from origin q_1 to destination q_2 with vehicle q_3;

f_{ij} = the amount of traffic flowing from the i^{th} node to the j^{th} node;

$Dist_{ij}$ = the distance from the i^{th} node to the j^{th} node;

$CPMG_{q_3}$ = the cost per mile of traveling over a gravel surface with vehicle q_3;

G_{ij} = 1 if the arc from the i^{th} node to the j^{th} node has a gravel surface, otherwise $G_{ij} = 0$;

CPMDq = the cost per mile of traveling over an earth surface with vehicle q_3;

D_{ij} = 1 if the arc from the i^{th} node to the j^{th} node has an earth surface, otherwise $D_{ij} = 0$;

$CPMP_{q_3}$ = the cost per mile of traveling over a paved surface with vehicle q_3;
H_{ij} = 1 if the arc from the i^{th} node to the j^{th} node has a paved surface, otherwise $H_{ij} = 0$;
WT_{ij} = the weight constraint of the arc connecting the i^{th} node to the j^{th} node;
WG_{q_3} = the weight of vehicle q_3;
i = beginning node;
j = ending node.

Equation (A.2) guarantees that the trip specified from origin q_1 to destination q_2 with vehicle type q_3 leaves the origin q_1. Equation (A.3) guarantees that the trip specified from origin q_1 to destination q_2 with vehicle type q_3 enters destination q_2. Equation (A.4) ensures the conservation of travel as it moves through the network. These three equations hold for each Q in set A. Equation (A.5) ensures the weight constraint of a bridge is not violated.

The problem expressed in (A.1) through (A.7) can be viewed as finding the minimum-cost route from node q_1 (the origin) to node q_2 (the destination) for vehicle type q_3 for each Q in set A. One method of solving this problem is to find the minimum-cost route from one node (origin q_1) to all the other nodes in the network. The minimum-cost routes can be found efficiently using a computer algorithm.

Dijkstra's Algorithm

Dijkstra's algorithm develops the shortest route tree or route by fanning out from the origin. The advantage of this procedure is that once an arc is part of the tree, it never leaves the tree, and once a node value is permanently assigned, it does not change. Therefore, the shortest route to all permanently labeled nodes is known, regardless of whether or not the remaining nodes are labeled. Dijkstra's algorithm has been cited as the most efficient algorithm to solve this problem and is the main solution technique employed in the rural road and bridge model.

Dijkstra's algorithm finds the minimum distance and corresponding route from a specified source node to all other nodes in the network. The algorithm assigns a temporary label and a permanent label to each node in the network. The temporary label represents an estimate of the shortest distance from the source node to each other node. Once a temporary label can no longer be improved, it is declared permanent. The permanent label represents the minimum distance from the source node to that node.

Initially, every node except the source node is given a temporary label equal to the distance of the arc connecting that node directly to the source node. If a node is not directly connected to the source node, the node is given a temporary label equal to infinity. The permanent label of the source node is set at zero and the permanent labels of the remaining nodes are calculated by the following iterative procedure.

Step I

Inspect all temporary labels of nodes not previously declared permanent. Declare the node with the minimum temporary label as permanent and set its permanent label equal to the value of its temporary label.

Step II

Compare the remaining temporary labels to the sum of the last-declared permanent label and the direct distance from the last node declared permanent to the node under consideration. The minimum of these two values is the new temporary label for that node. Then repeat Step I.

This process continues until all the nodes have been declared as permanent. Once a node is assigned a permanent label, its temporary label is excluded from the calculations in Step II.

The algorithm simply works backwards to find the distance-minimizing route from the source node to some mode j (ending node). It compares the permanent label of node j to the sum of the direct distance from some node i. If these two values are euqal, then node i is used in finding the shortest distance from the source node to node j and is therefore part of the route. This routine is repeated until the entire route is found.

Example Solution

Suppose the problem is to find the distance-minimizing solution in traveling from node 1 (the source node) to all the other nodes in the undirected network given in Figure A.1. The numbered nodes are circled and the distances between nodes are shown above the arrows. The distance matrix for this network is shown in Table A.1. This matrix

Figure A.1 Sample problem network for application of Dijkstra's algorithm

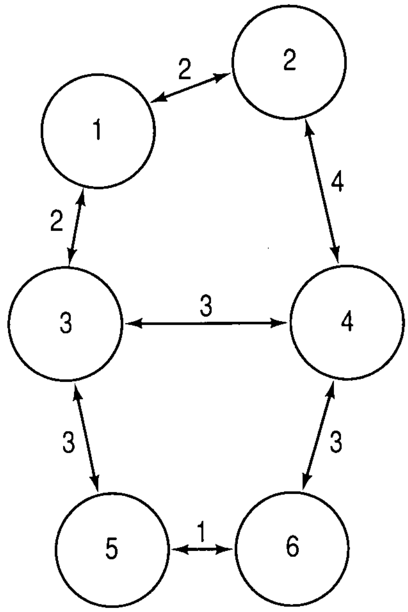


Table A.1. Distance matrix from node *i* to node *j* for the network given in Figure A.1

	node *j*					
node *i*	**1**	**2**	**3**	**4**	**5**	**6**
1	∞	2	2	∞	∞	∞
2	2	∞	∞	4	∞	∞
3	2	∞	∞	3	3	∞
4	∞	4	3	∞	∞	3
5	∞	∞	3	∞	∞	1
6	∞	∞	∞	3	1	∞

Table A.2. Summary of the computational steps used in solving the same problem via Dijkstra's algorithm

	node					
step	**1**	**2**	**3**	**4**	**5**	**6**
1	[0]	∞	∞	∞	∞	∞
2		$\min(\infty,0+2)=2$	$\min(\infty,0+2)=2$	$\min(\infty,0+\infty)=\infty$	$\min(\infty,0+\infty)=\infty$	$\min(\infty,0+\infty)=\infty$
3		[2]	2	∞	∞	∞
4			$\min(2,2+\infty)=2$	$\min(\infty,2+4)=6$	$\min(\infty,2+\infty)=\infty$	$\min(\infty,2+\infty)=\infty$
5			[2]	6	∞	∞
6				$\min(6,2+3)=5$	$\min(\infty,2+3)=5$	$\min(\infty,2+\infty)=\infty$
7				[5]	5	∞
8					$\min(5,5+\infty)=5$	$\min(\infty,5+3)=8$
9					[5]	8
10						$\min(8,5+1)=6$
11						[6]

contains the direct distance of traveling from node i to node j. If a node is not directly connected to another node, the direct distance is set at infinity. The algorithm initially sets the permanent label of node 1 (the source node) to zero and the temporary label of the remaining nodes to infinity. The next step is to compare the temporary label of node j ($j \in [2,6]$) to the sum of the permanent label of node 1 and the direct distance from node 1 to node j. The minimum of these two values is the new temporary label of node j. The direct distance from node 1 to node j is found in the j^{th} column of the first row in the distance matrix.

The third step is to find the minimum value of the updated temporary labels and declare that node as permanently labeled. This is shown in Table A.2, with the [ ] indicating the node as being declared permanently labeled. In the case of ties, a node is chosen arbitrarily. Step four is similar to the second step except node 2 is now the last permanently labeled node. Hence the sum of the permanent label of node 2 and the direct distance from node 2 to node j ($j \in [3,6]$) is compared with the temporary label of node j. The remaining steps are summarized in Table A.2

The distance matrix and the permanent labels are used to find the distance-minimizing routes. Suppose the problem is to find the shortest route from node 1 to node 6. The first step is to find the node preceding node 6 on the shortest route. Using the sixth column of the distance matrix and the permanent labels, the permanent label of node 6 is compared with the sum of the permanent label of node i ($i \in [1,5]$) and the direct distance from node i to node 6. If these two values are equal, as in the case when i = 5, then that node precedes node 6 on the optimal route. The next step is to find the node which precedes node 5 on the optimal route. Hence the permanent label of node 5 is compared with the sum of the permanent label of node i ($i \in [1,4]$) and the direct distance from node i to node 5. This process is repeated until the entire route is found. The reader can verify that the optimal route from node 1 to node 6 is 1-3-5-6.

Algorithm Modifications

Dijkstra's algorithm was modified slightly in the application to the rural road and bridge problem. The first alteration was to eliminate the distance matrix. There are over 500 nodes in each of the three study areas. This means the distance matrix would be larger than a 500 × 500 matrix. Even though the distance matrix is symmetric, the computer storage requirement exceeds 900K. The following method reduced the amount of computer storage to 156K and greatly increased the computational efficiency of Dijkstra's algorithm.

Figure A.1, which has 6 nodes and 14 arcs, illustrates the alteration. First, two arrays, array A and array B, were dimensioned to the number of arcs in the network. Array A contains the node numbers that are directly connected to each node and array B contains the direct distance. Secondly, two arrays, array P1 array P2, were dimensioned to the number of nodes in the network. The i^{th} cell in array P1 contains the beginning location of the node numbers connected to node i stored in array A, while the i^{th} cell in array P2 contains the ending location of node numbers connected to node i stored in array A.

The new computer representation of the network is shown in Table A.3. The fourth cell (i.e., when i = 4) of P1 and P2 contain the numbers 8 and 10 respectively. This indicates that the nodes directly connected to node 4 are stored in cells 8, 9, and 10 of array A and the distances are stored in cells 8, 9, and 10 of array B. Storage area requirements are reduced because only the nodes directly connected to other nodes and the respective distances are stored.

Table A.3. An alternative method of representation of the network presented in Figure A.1

i	Pl	*i*	P2		A		B
1	1	1	2	1	2	1	2
2	3	2	4	2	3	2	2
3	5	3	7	3	1	3	2
4	8	4	10	4	4	4	4
5	11	5	12	5	1	5	2
6	13	6	14	6	4	6	3
				7	5	7	3
				8	2	8	4
				9	3	9	3
				10	6	10	3
				11	3	11	3
				12	6	12	1
				13	4	13	3
				14	5	14	1

Table A.4. Vehicle variable costs in cents per mile on paved surfaces and surface adjustment ratios by vehicle type

		Surface adjustment ratios		
Type of vehicle	Cents per mile on paved surfaces	Paved to gravel	Paved to earth	Paved to B roads
Automobile	20.2	1.39	1.77	1.98
Pickup	24.4	1.39	1.77	1.98
Pickup-pulling trailer	35.3	1.39	1.77	1.98
Commercial van	40.2	1.39	1.77	1.98
Commercial semitrailer				
Empty	51.5	1.47	1.92	2.14
Loaded	55.4	1.48	1.96	2.16
Garbage truck	77.2	1.47	1.92	2.14
Farmer-owned single-axle truck				
50 percent loaded	32.3	1.46	1.91	2.11
Pulling empty pup trailer	33.5	1.46	1.91	2.11
Pulling loaded pup trailer	39.6	1.46	1.91	2.11
Pulling empty grain wagon	32.9	1.46	1.91	2.11
Pulling loaded grain wagon	39.0	1.46	1.91	2.11
Farmer-owned tandem-axle truck				
Empty	37.1	1.47	1.92	2.14
Loaded	42.4	1.48	1.96	2.16
Pulling empty pup trailer	40.9	1.46	1.91	2.11
Pulling loaded pup trailer	53.0	1.46	1.91	2.11
Pulling empty grain wagon	40.3	1.46	1.91	2.11
Pulling loaded grain wagon	52.4	1.46	1.91	2.11
Farmer-owned semitrailer				
Empty	33.5	1.46	1.91	2.11
Loaded	37.4	1.46	1.91	2.11
Tractor (alone)	118.4	1.14	1.14	1.14
Tractor pulling:				
Equipment	119.4	1.14	1.14	1.14
125-bushel wagon—empty	118.7	1.14	1.14	1.14
125-bushel wagon—loaded	120.5	1.20	1.20	1.20
250-bushel wagon—empty	118.7	1.14	1.14	1.14
250-bushel wagon—loaded	122.3	1.20	1.20	1.20
350-bushel wagon—empty	118.8	1.14	1.14	1.14
350-bushel wagon—loaded	123.9	1.20	1.20	1.20
450-bushel wagon—empty	136.9	1.14	1.14	1.14
450-bushel wagon—loaded	145.6	1.20	1.20	1.20
550-bushel wagon—empty	137.7	1.14	1.14	1.14
550-bushel wagon—loaded	148.3	1.20	1.20	1.20
350-bushel tandem—empty	137.1	1.14	1.14	1.14
350-bushel tandem—loaded	150.7	1.20	1.20	1.20
450-bushel tandem—empty	145.9	1.14	1.14	1.14
450-bushel tandem—loaded	166.0	1.20	1.20	1.20
650-bushel grain buggy—empty	140.3	1.14	1.14	1.14
650-bushel grain buggy—loaded	151.9	1.20	1.20	1.20
Combines:				
2-row combine	101.7	1.12	1.12	1.12
4-row combine	146.1	1.12	1.12	1.12
6-8 row combine	161.7	1.12	1.12	1.12

The computational efficiency of Dijkstra's algorithm is also increased with this new computer representation of the network. This alteration limits the second step of Dijkstra's algorithm and the route-finding process to only the nodes directly connected to the last permanently declared node.

Thus far, Dijkstra's algorithm has been discussed only in terms of minimizing the distance between two nodes. The algorithm can also be used to minimize the cost of traveling between two nodes. This is accomplished by storing in array B the direct cost of traveling, rather than the direct distance, from node i to node j. The direct cost of traveling from node i to node j is the product of the direct distance from node i to node j and the vehicle cost per mile of the specific vehicle type. The vehicle cost depends on the road surface of the arc connecting node i to node j, as well as on the vehicle type. A separate computer run of the algorithm would be necessary to estimate travel cost for each vehicle type, since the cost of traveling over a paved, gravel, or earth surface is different for all vehicles. Since there were over a hundred different vehicles in this analysis, a method to decrease the number of computer runs was imperative. With a few simplifications, groups of vehicles could be routed in the same computer run. The ratios of the vehicle-mile cost on gravel surface to vehicle-mile cost on paved surface, and the ratios of earth surface cost relative to paved surface cost were calculated for each type of vehicle (Table A.4). The values of these ratios were found to be very similar for vehicles with similar weight characteristics. Thus for simplicity and computer efficiency, vehicles with similar ratio values were grouped together. For example, the ratios for cars, pickups, commercial delivery vans, and pickups pulling a trailer indicated that the cost per mile of traveling over a gravel surface is 1.39 times the cost of traveling over a paved surface, and the cost per mile of traveling over an earth surface is 1.77 times the cost of traveling over a paved surface. Within each group of vehicles, pseudodistances are calulated based on the ratios. All these grouped vehicles then comprise a single computer run. For the above example, the pseudodistance of a gravel arc is equal to 1.39 times the actual distance of the arc and 1.77 times the actual distance of the arc for an earth surface. If the arc has a paved surface, the pseudodistance is equal to the actual distance of the arc. Equations (A.8) and (A.9) express the relative cost of traveling over a gravel and earth surface for all these vehicle types.

$$\frac{CPMG_{q_3}}{CPMP_{q_3}} = 1.39 \qquad (A.8)$$

$$\frac{CPMD_{q_3}}{CPMP_{q_3}} = 1.77 \qquad (A.9)$$

where the variables are as previously defined. Use of these ratios results in slightly different vehicle costs per mile in Table A.4 than are presented in Tables 2.13, 2.14, and 2.15. These slight differences, caused by the ratios, greatly reduced the computational costs and made only a slight difference in the results of the analysis. The variable costs per mile for farm tractors operating alone, or pulling farm equipment and various sizes of wagons are averaged over all sizes of tractors weighted by the frequency of tractor sizes obtained from the questionnaire.

Substituting (A.8) and (A.9) into (A.7) and rewriting yields (A.10).

$$G_{Q_3} = CPMP_{q_3} \sum_i \sum_j f_{ij} \left(Dist_{ij} H_{ij} + 1.39\ Dist_{ij} G_{ij} + 1.77\ Dist_{ij} D_{ij}\right) \qquad (A.10)$$

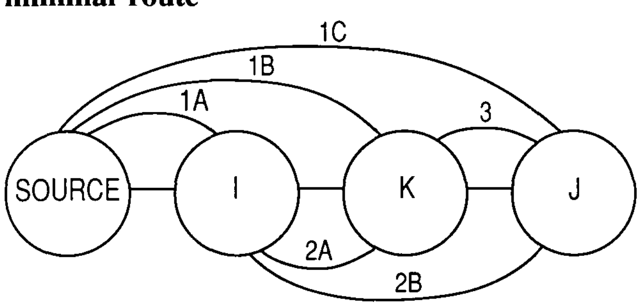
Equation (A.10) is minimized when the sum of the terms in brackets is minimized for each origin and destination pair. The pseudodistance of an arc is the sum of the terms in parentheses. Thus, Dijkstra's algorithm can be used in a single computer run to minimize the total transportation cost of several vehicles by minimizing the psuedodistances of the arcs. The minimized cost of q_4 trips from an origin to a destination with vehicle type q_3 is simply the minimized psuedodistance of traveling through the network multiplied by the vehicle type's cost per mile of traveling over a paved surface and by q_4 trips.

The computer program picks a node in the network as the source node and begins Dijkstra's iterative procedure on the psuedodistance of the arcs. The final result will be the minimized cost of traveling from the source node to all the other nodes in the network. But upon closer inspection, other minimal routes are being obtained. Dijkstra's algorithm operates on the logic that if a shortest path from the source node ton node j is known and node i belongs to this path, then the minimal path from the source node to node i is known, and it is the portion of the original path ending at the i^{th} node. This logic can be extended to two nodes i and k on the known shortest path from the source node to node j. If this is the case (Figure A.2), the following minimum cost routes are known.

1. The minimum cost routes from the source node to the i^{th}, k^{th}, and j^{th} nodes are known. The minimum cost of the routes is the cost per mile of traveling over a paved surface with vehicle q_3 multiplied by the value of the permanent label for the i^{th}, k^{th}, and j^{th} nodes, respectively.
2. The minimum cost routes from the i^{th} node to the k^{th} and j^{th} node are known. The minimal distance of the route from the i^{th} to the j^{th} node is the cost per mile of traveling over a paved surface with vehicle q_3 multiplied by the difference of the values of the permanent labels for nodes k and i. The minimum cost from node i to node j is found in a similar manner.
3. The minimum cost route from the k^{th} node to the j^{th} node is known. The minimum cost of this route is simply the cost per mile of traveling over a paved surface with vehicle q_3 multiplied by the difference of the permanent labels for nodes j and k.

The computer model selects a node as the source node and calculates the psuedodistance from the source node to all the other nodes in the network. The computer checks to see if the minimized-cost route between any of the origin-destination pairs lies on the minimized-cost path from the source node to any other node in the network. If the origin-destination pair is on any of these routes, all the minimized-cost routes between the origin and destination will have been calculated. The number of trips between the original and destination will then be spread evenly over all the routes that are of equal cost. If the route for an origin-destination pair is not found, the computer will select another node to be the source node. This process continues until a minimized-cost route is found for all origin-destination pairs.

Figure A.2 Minimum routes found when the minimal route from the source node to node *j* is known and nodes *i* and *k* lie on the minimal route



The following equation was used to evaluate the investment strategies included in this study.

$$NB_i = (TC_{Bi} - TC_{Ai}) + (MC_{Bi} - MC_{Ai}) + (REC_{Bi} + REC_{Ai}) + (RES_{Bi} - RES_{Ai}) + (BMC_{Bi} - BMC_{Ai}) + (BREC_{Bi} - BREC_{Ai}) + (VL_i + ROW_i) - PDREC_i - PDMC_i - PDBREC_i - PDBMC_i \qquad (A.11)$$

where

NB_i = the net benefits of the i^{th} investment strategy

TC_{Bi} = the total annual vehicle transportation costs before implementing the i^{th} investment strategy

TC_{Ai} = the total annual vehicle transporation costs after implementing the i^{th} investment strategy

MC_{Bi} = the total annual road maintenance cost before implementing the i^{th} investment strategy

MC_{Ai} = the total annual road maintenance cost after implementing the i^{th} investment strategy

REC_{Bi} = the total annualized life cycle roadbed reconstruction cost before implementing the i^{th} investment strategy

REC_{Ai} = the total annualized life cycle roadbed reconstruction cost after implementing the i^{th} investment strategy

RES_{Bi} = the total annualized life cycle road resurfacing cost before implementing the i^{th} investment strategy

RES_{Ai} = the total annualized life cycle road resurfacing cost after implementing the i^{th} investment strategy

BMC_{Bi} = the total annual bridge maintenance cost before implementing the i^{th} investment strategy

BMC_{Ai} = the total annual bridge maintenance cost after implementing the i^{th} investment strategy

$BREC_{Bi}$ = the total annualized life cycle bridge reconstruction cost before implementing the i^{th} investment strategy

$BREC_{Ai}$ = the total annualized life cycle bridge reconstruction cost after implementing the i^{th} investment strategy

VL_i = the value of additional land obtained by implementing the i^{th} investment strategy

ROW_i = the annualized cost of converting the right-of-way of the additional land obtained by implementing the i^{th} investment strategy into agricultural production

$PDREC_i$ = the annualized life cycle private drive roadbed reconstruction cost incurred by implementing the i^{th} investment strategy

PDMC = the annual private drive maintenance cost incurred by implementing the i^{th} investment strategy

$PDBREC_i$ = the annualized life cycle private drive bridge reconstruction cost incurred by implementing the i^{th} investment strategy

$PDBMC_i$ = the annual private drive bridge maintenance cost incurred by implementing the i^{th} investment strategy.

If legal costs or damage awards were included in the analysis, the annualized value of these costs would be subtracted from (A.11).

Appendix B.

Procedure for Estimating Maintenance, Reconstruction, and Resurfacing Costs

Paved Maintenance Cost

The basic assumption underlying the maintenance cost for a paved road is that a portion of the cost varies directly with the number of axle loadings passing on the road. Therefore, the first step in estimating the maintenance costs was to express all vehicles in terms of equivalent 18,000-pound (18-kip) axle loadings that the road would sustain through one pass by each vehicle. The remaining portion of the maintenance cost is fixed and is independent of the traffic level or composition. This fixed portion of the maintenance costs is associated with signing, slope erosion, ditching, and snow removal.

Variable Maintenance Cost

Pavements are designed to withstand the projected number of 18-kip loadings during the expected life of the road, usually 20 years. An increase in the projected number of 18-kip loadings (additional and/or heavier vehicles) within a given period of time will increase the maintenance cost of the road surface.

The measure of pavement condition used is the Pavement Serviceability Index (PSI). This surface roughness index ranges from 5.0 downward to 0.0 with the upper limit being the indication of the best condition possible.

Tables B.1 and B.2 show the remaining 18-kip load applications a pavement can be expected to sustain before resurfacing is needed at PSI of 2.0. Therefore, if the pavement was assumed to be new at 4.5 PSI and needing resurfacing at 2.0, the values in Tables B.1 and B.2 can be used as estimates of the total number of 18-kip loads the pavement can sustain before it needs resurfacing.

The columns in Tables B.1 and B.2 headed "design terms" are the pavement structure indicators used to determine the number of lads a road can withstand before it requires resurfacing. The origin of the roughness measurement is the American Association of State Highway and Transportation Officials

Table B.1. Remaining 18-kip applications to a rigid pavement in very good condition before resurfacing will be required at PSI = 2.0, in thousands of applications by alternative design terms[a]

Design term	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
6.	—	—	—	—	—	—	—	—	—	—
7.	1,309	1,445	1,592	1,753	1,927	2,116	2,322	2,544	2,785	3,046
8.	3,327	3,632	3,961	4,316	4,700	5,112	5,558	6,035	6,549	7,102
9.	7,695	8,331	9,016	9,743	10,529	11,363	12,260	13,219	14,236	15,332
10.	16,489	17,730	19,046	20,450	21,943	23,523	25,212	26,996	28,900	30,917
11.	33,045	35,310	37,714	40,244	42,914	45,751	48,753	51,928	55,259	58,790
12.	62,503	66,435	70,550	74,920	79,488	84,333	89,392	94,733	100,369	106,243
13.	112,460	118,932	125,777	132,954	140,475	148,320	156,603	165,272	174,341	183,823

[a]Initial road PSI = 4.5

SOURCE: American Association of State Highway Officials Committee on Transportation. August, 1962. *Manual of Instructions for Pavement Evaluation Survey.*

(AASHTO) Road Test of 1958-60. On the PSI measurre of road surface roughness, the maximum value of 5.0 indicates a smooth surface. A decline in the index value to the selected value of 2.0 in Tables B.1 and B.2 indicates an increase in surface roughness.

The design term relates the number of passes of a standard 18,000 pound axle load to the load-carrying capacity of the various pavement layers. In this study, the design term indicates the number of standard axle loads that can pass over a pavement before the roughness (PSI) reaches 2.0 for each flexible or rigid pavement thickness. The design term for each paved road in the three study areas was computed from pavement type and thickness information supplied by the counties and Iowa Department of Transportation (DOT) records.

Tables B.3 and B.4 present the traffic equivalence factors for single axles and tandem axles on rigid pavements. These tables indicate the 18-kip equivalence for a range of kip-loads on rigid pavements with slab thickness ranging from 6 to 11 inches.

Tables B.5 and B.6 present the traffic equivalence factors for single axles and tandem axles on flexible pavements for selected kip loadings and structural numbers.

Table B.7 indicates the number and type of axles and the loading on each axle for all vehicles in this study. Tables B.3-B.7 yield the number of 18-kip equivalent loads that each vehicle applies to a pavement. The 18-kip equivalent number is multiplied by the yearly traffic level on the road to obtain the total number of 18-kip loadings that the vehicle applies to the road. Summing over all vehicle types yields the annual number of 18-kip loadings applied to a road. For example, suppose a commercial van traveled 10,000 times over a road with a rigid pavement with a slab thickness of six. Table B.7 shows the commercial van having two single axles weighing 2,800 and 2,400 pounds, respectively. By interpolating between two- and four-axle load kips in Table B.3, the front axle applies 0.00092 kip equivalents to the road surface, while the rear axle applies 0.00056 kip equivalents. Hence, the commercial van applies 0.00148 kip equivalents to the road on each pass and 14.8 kip equivalents when the commercial van travels over the road 10,000 times.

The total number of 18-kip loadings a road can withstand in its lifetime from Tables B.5 and B.6 was divided by the life of the road to yield the total number of 18-kip loadings a road can withstand in a year.

Table B.2. Remaining 18-kip applications for a flexible pavement in very good condition before resurfacing will be required at PSI = 2.0 for alternative design terms[ab]

Design term	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
2.	(416)	(656)	(1,021)	(1,530)	(2,271)	(3,315)	(4,763)	(6,746)	(9,428)	(13,309)
3.	18	24	32	42	55	71	92	117	148	189
4.	233	289	357	438	535	651	788	950	1,141	1,366
5.	1,629	1,937	2,294	2,712	3,196	3,758	4,406	5,154	6,014	7,003
6.	8,137	9,434	10,914	12,601	14,522	16,705	19,177	21,979	25,147	28,717
7.	32,745	37,264	42,346	48,037	54,424	61,555	69,515	78,406	88,280	99,293
8.	111,486	125,017	140,043	156,675	175,009	195,285	217,631	242,220	269,296	299,082

[a]Figures in parentheses are units; all others in thousands.
[b]Initial PSI = 4.2

SOURCE: American Association of State Highway Officials Committee on Transport. August, 1962. *Manual of Instructions for Pavements Evaluation Survey.*

Table B.3. Traffic equivalence factors for single axles on rigid pavement where PSI = 2.0

Axle load kips	Slab thickness in inches					
	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.03	0.03	0.03	0.03	0.03
10	0.09	0.08	0.08	0.08	0.08	0.08
12	0.19	0.18	0.18	0.18	0.17	0.17
14	0.35	0.35	0.34	0.34	0.34	0.34
16	0.61	0.61	0.60	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.55	1.56	1.57	1.58	1.58	1.59
22	2.32	2.32	2.35	2.38	2.40	2.41
24	3.37	3.34	3.40	3.47	3.51	3.53
26	4.76	4.69	4.77	4.88	4.97	5.02
28	6.59	6.44	6.52	6.70	6.85	6.94
30	8.92	8.68	8.74	8.98	9.23	9.39
32	11.87	11.49	11.51	11.82	12.17	12.44
34	15.55	15.00	14.95	15.30	15.78	16.18
36	20.07	19.30	19.16	19.53	20.14	20.71
38	25.56	34.54	24.26	24.63	25.36	26.14
40	32.18	30.85	30.41	30.75	31.58	32.57

SOURCE: *AASHO Interim Guide for Design of Pavement Structures. 1972.*

Table B.4. Traffic equivalence factors for tandem axles on rigid pavements where PSI = 2.0

Axle load kips	Slab thickness in inches					
	6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.05	0.05	0.05	0.05	0.05	0.05
16	0.09	0.08	0.08	0.08	0.08	0.08
18	0.14	0.14	0.13	0.13	0.13	0.13
20	0.22	0.21	0.21	0.20	0.20	0.20
22	0.32	0.31	0.31	0.30	0.30	0.30
24	0.45	0.45	0.44	0.44	0.44	0.44
26	0.63	0.64	0.62	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.13	1.13	1.14	1.14	1.14	1.14
32	1.48	1.45	1.49	1.50	1.51	1.51
34	1.91	1.90	1.93	1.95	1.96	1.97
36	2.42	2.41	2.45	2.49	2.51	2.52
38	3.04	3.02	3.07	3.13	3.17	3.19
40	3.79	3.74	3.80	3.89	3.95	3.98
42	4.67	4.59	4.66	4.78	4.87	4.93
44	5.72	5.59	5.67	5.82	5.95	6.03
46	6.94	6.76	6.83	7.02	7.20	7.31
48	8.36	8.12	8.17	8.40	8.63	8.79

SOURCE: *AASHO Interim Guide for Design of Pavement Structures. 1972.*

Note: For tandem axle loads under 10 kips, the following equivalence factors were utilized: 0.0004 for 4 kips, 0.0014 for 6 kips, and 0.004 for 8 kips.

Table B.5. Traffic equivalence factors for single axles on flexible pavement where PSI = 2.0

Axle load	Slab thickness in inches					
kips	6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.002	0.003	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.04	0.04	0.03	0.03	0.03
10	0.08	0.08	0.09	0.08	0.08	0.08
12	0.16	0.18	0.19	0.18	0.17	0.17
14	0.32	0.34	0.35	0.35	0.34	0.33
16	0.59	0.60	0.61	0.61	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.60
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.38	10.03	9.24	8.65	8.73	9.17
32	14.00	13.51	12.37	11.46	11.48	12.17
34	18.55	17.87	16.30	14.97	14.87	15.63
36	24.20	23.30	21.16	19.28	19.02	19.93
38	31.14	29.95	27.12	24.55	24.03	25.10
40	39.57	38.02	34.34	30.92	30.04	31.25

SOURCE: *AASHO Interim Guide for Design of Pavement Structures. 1972.*

Table B.6. Traffic equivalence factors for tandem axles on flexible pavement where PSI = 2.0

Axle load	Structural number					
kips	1	2	3	4	6	8
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.01	0.02	0.02	0.01	0.01	0.01
14	0.02	0.03	0.03	0.03	0.02	0.02
16	0.04	0.05	0.05	0.05	0.04	0.04
18	0.07	0.08	0.08	0.08	0.07	0.07
20	0.10	0.12	0.12	0.12	0.11	0.10
22	0.16	0.17	0.18	0.17	0.16	0.16
24	0.23	0.24	0.26	0.25	0.24	0.23
26	0.32	0.34	0.36	0.35	0.34	0.33
28	0.45	0.46	0.49	0.48	0.47	0.46
30	0.61	0.62	0.65	0.64	0.63	0.62
32	0.81	0.82	0.84	0.84	0.83	0.82
34	1.06	1.07	1.08	1.08	1.08	1.07
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.76	1.75	1.73	1.72	1.73	1.74
40	2.22	2.19	2.15	2.13	2.16	2.18
42	2.77	2.73	2.64	2.62	2.66	2.70
44	3.42	3.36	3.23	3.18	3.24	3.31
46	4.20	4.11	3.92	3.83	3.91	4.02
48	5.10	4.98	4.72	4.58	4.68	4.83

SOURCE: *AASHO Interim Guide for Design of Pavement Structures. 1972.*

Note: For tandem axle loads under 10 kips, the following equivalence factors were utilized: 0.0004 for 4 kips, 0.0014 for 6 kips, and 0.004 for 8 kips.

Table B.7. Vehicle axle weights by type of vehicle, in pounds

Vehicle description	Number of axles	Individual axle loadings[a] First	Second	Third	Fourth	Fifth	Sixth
Car	2	1,750	1,750	—	—	—	—
Commercial van	2	2,800	2,400	—	—	—	—
Pickup	2	1,750	1,750	—	—	—	—
Single-axle truck—half loaded	2	6,150	13,300	—	—	—	—
Tandem-axle truck—empty	2	6,900	11,700T	—	—	—	—
Tractor with equipment	3	3,800	12,800	4,000	—	—	—
Pickup with trailer	3	1,750	1,750	6,000T	—	—	—
Garbage truck	2	7,000	29,000T	—	—	—	—
Commercial semitrailer—empty	3	9,000	13,400T	9,500T	—	—	—
Tractor	2	3,800	12,800	—	—	—	—
Tractor with equipment	3	3,800	12,800	4,000	—	—	—
Combine, 2-row	2	8,000	3,000	—	—	—	—
Combine, 4-row	2	12,615	3,700	—	—	—	—
Combine, 6-row	2	13,926	4,640	—	—	—	—
Tractor with 125-bu. wagon—empty	4	3,800	12,800	500	500	—	—
Tractor with 250-bu. wagon—empty	4	3,800	12,800	520	520	—	—
Tractor with 350-bu. wagon—empty	4	3,800	12,800	730	730	—	—
Tractor with 450-bu. wagon—empty	4	3,800	12,800	1,070	1,070	—	—
Tractor with 550-bu. wagon—empty	4	3,800	12,800	2,190	2,190	—	—
Tractor with 2 350-bu. wagons—empty	6	3,800	12,800	730	730	730	730
Tractor with 2 450-bu. wagons—empty	6	3,800	12,800	1,070	1,070	1,070	1,070
Single-axle truck with pup trailer—empty	3	5,500	6,600	6,640T	—	—	—
Farm semitrailer—empty	3	9,000	13,400T	9,500T	—	—	—
Tandem-axle truck with pup trailer—empty	3	6,900	11,700T	6,640T	—	—	—
Single-axle truck with 250-bu. wagon—empty	4	5,500	6,600	520	520	—	—
Single-axle truck with 350-bu. wagon—empty	4	5,500	6,600	730	730	—	—
Tandem-axle truck with 450-bu. wagon—empty	4	6,900	11,700T	1,070	1,070	—	—
Tractor with grain buggy—empty	3	3,800	12,800	7,240	—	—	—
Tandem-axle truck wtih 550-bu. wagon—empty	4	6,900	11,700T	2,190	2,190	—	—
Tandem-axle truck with 2 350-bu. wagons—empty	6	6,900	11,700T	730	730	730	730
Tandem-axle with 2 450-bu. wagons—empty	6	6,900	11,700T	1,070	1,070	1,070	1,070
Commercial semitrailer—loaded	3	9,800	28,800T	29,400T	—	—	—
Tandem-axle truck—loaded	2	20,000	34,000T	—	—	—	—
Farm semitrailer—loaded	3	9,800	33,000T	33,000T	—	—	—
Single-axle truck with pup trailer—loaded	3	6,800	20,000	24,000T	—	—	—
Tandem-axle truck with pup trailer—loaded	3	20,000	34,000T	24,000T	—	—	—
Tractor with 125-bu. wagon—loaded	4	3,800	12,800	4,000	4,000	—	—
Tractor with 250-bu. wagon—loaded	4	3,800	12,800	7,520	7,520	—	—
Tractor with auger wagon—loaded	3	3,800	12,800	20,000	—	—	—
Tractor with 350-bu. wagon—loaded	4	3,800	12,800	10,530	10,530	—	—
Tractor with 450-bu. wagon—loaded	4	3,800	12,800	13,670	13,670	—	—
Tractor with 550-bu. wagon—loaded	4	3,800	12,800	17,590	17,590	—	—
Tractor with 2 350-bu. wagons—loaded	6	3,800	12,800	10,530	10,530	10,530	10,530
Tractor with 2 450-bu. wagons—loaded	6	3,800	12,800	13,670	13,670	13,670	13,670
Single-axle truck with 250-bu. wagon—loaded	4	6,800	20,000	7,520	7,520	—	—
Single-axle truck with 350-bu. wagon—loaded	4	6,800	20,000	10,530	10,530	—	—
Tandem-axle truck with 450-bu. wagon—loaded	4	18,660	34,000T	13,670	13,670	—	—
Tandem-axle truck with 550-bu. wagon—loaded	4	14,820	30,000T	17,590	17,590	—	—
Tandem-axle truck with 2 350-bu. wagons—loaded	6	10,000	27,880T	10,530	10,530	10,530	10,530
Tandem-axle truck wtih 2 450-bu. wagons—loaded	6	10,000	15,000T	13,670	13,670	13,670	13,670

[a]T represents a tandem axle, otherwise the axle is a single axle.

SOURCES: Iowa Department of Transportation, "1982 Truck Weight Study," Ames, Iowa.
Implement and Tractor, 1983, Red Book Issue, 98 (5).
Selected farm implement manufacturers. 1983. Unpublished sales brochures.
Heart of Iowa Coop. 1983. Unpublished scale weights, Roland, Iowa.
Parker Industries. "Gravity Beds and Combine Related Specification Sheets." Jefferson, Iowa.

The average maintenance cost for county paved roads in each study area was obtained from the Iowa DOT Quadrennial Need Study for Study Years 1982 through 2001. In each study area, the average annual fixed maintenance cost was subtracted from the annual average total maintenance cost to obtain the annual average variable maintenance cost per mile of paved road.

Variable maintenance costs for each paved road were estimated by (B.1).

$$VMC = \frac{KA}{YK} * AVMC * Dist \qquad (B.1)$$

where

VMC = variable maintenance cost
KA = the total number of 18-kips applied in 1982
YK = the yearly allocation of 18-kip applications
AVMC = the average variable maintenance cost per mile of road and
Dist = the distance of road.

The variable maintenance costs calculated by (B.1) were unrealistically high for many paved county roads in each study area. The lifetime kip loadings of these roads were being consumed in less that one year. It was assumed, based on past county practices, that engineers would resurface the roads rather than rebuild the roads on an annual basis. The upgrading procedure consisted of adding sufficient pavement to increase the lifetime kip loadings to 500,000. Assuming a 20-year life, the additional six inches of pavement would withstand 25,000 28-kip applications per year. The estimated cost of resurfacing a paved road with six inches of pavement for the three study areas is presented in Table B.8.

Equation (B.2) represents the alternative method of calculating variable maintenance costs for paved roads in this study.

Table B.8. Estimated cost of resurfacing with six inches of pavement, by study area

Study area	Cost per lane mile	Annualized cost per lane mile
Hamilton	$ 25,881	$ 2,278.91
Shelby	25,881	2,278.91
Linn	30,684	2,685.96

Table B.9. Maintenance cost per mile of gravel road as a function of average daily traffic and an intercept

County	Road surface	Cost per average daily traffic	Intercept
Hamilton	paved	$ 0.94	$ 1,160
	gravel	4.70	2,376
	earth	1.52	2,026
Shelby	paved	1.54	1,083
	gravel	8.75	2,765
	earth	1.52	2,026
Linn	paved	1.94	1,400
	gravel	6.25	2,525
	earth	1.52	2,026

$$VMC = UPC + \frac{KA}{R} *AVMC * Dist \qquad (B.2)$$

where
UPC = the annualized upgrading cost and
R = 500,000 kip applications spread over 20 years.

The variable maintenance of a paved road used in this analysis is the minimum value of (B.1) and (B.2). Hence, (B.3) represents the maintenance cost equation for paved roads.

$$MC = (FMC * Dist) + S \qquad (B.3)$$

where
MC = maintenance cost
FMC = the fixed maintenance cost per mile of road and
S = the minimum value of variable maintenance cost calculated in equations (B.1) and (B.2).

Gravel and Earth Maintenance Costs

Table B.9 expresses maintenance cost for paved, gravel, and earth roads as a function of the average daily traffic (ADT) level and an intercept term. The ADT level was calculated for all gravel and earth roads in each of the three study areas. The ADT was multiplied by its appropriate coefficient to yield the variable portion of maintenance cost. The total maintenance cost was obtained by adding the fixed portion of the maintenance cost to the variable maintenance cost and multiplying by the distance of the road.

Reconstruction and Resurfacing Costs

Tables B.10 and B.11 show the reconstruction and resurfacing costs of roads in each of the three study areas obtained from the Iowa DOT "Quadrennial Need Study for Study Years 1982 through 2001." From Table B.11, a lane mile of gravel road in Hamilton County with an ADT of 97 or 99 requires $12,399 in reconstruction costs every 60 years. A gravel road with an ADT of 101 requires $26,121 in reconstruction costs every 60 years. The increase in reconstruction costs is zero when traffic increases from 97 to 99 ADT. Adding two more ADT 99 to 101, increases reconstruction costs $13,722.

The values in Table B.10 and B.11 were interpreted as the reconstruction or resurfacing costs for the midpoint of its ADT group for highway group numbers 3 and 7. Highways are grouped by ease of entry and length of trip. For example, highway group 1 consists of interstate highways with long trip length and full access control. Highway group 8 consists of rural roads with very short trips and no access control. A lane mile of gravel road in Hamilton County with an ADT of 62.50 requires $12,399 in reconstruction costs every 60 years. The midpoint traffic levels for highway group numbers 3 and 6 were 3,250 and 250 ADT, respectively. The minimum reconstruction and resurfacing cost of paved and gravel roads were represented by highway group numbers 5 and 8. The slope was calculated between each of the midpoints. The revised reconstruction and resurfacing cost equations are shown in Tables B.12 and B.13.

Long-term investments in paved road reconstruction and resurfacing were annualized over a 45-year life cycle. Table B.14 presents the timing of future reconstructions and resurfacings for paved roads over one life cycle of road. The present value of future reconstruction and resurfacing costs is calculated by (B.4).

Table B.10. Resurfacing cost per lane mile of road by road type, traffic level, and highway group, 1982

Highway group number	ADT group	Surface type	Study area		
			Hamilton	Shelby	Linn
3	over 1,500	paved	$ 32,877	$ 32,877	$ 38,892
4	400-1,500	paved	30,094	30,094	35,583
5	under 400	paved	25,881	25,881	30,684

Table B.11. Reconstruction costs per lane mile of road by road surface, traffic level, and highway group, 1982

Highway group number	ADT group	Surface type	Study area		
			Hamilton	Shelby	Linn
3	over 1,500	paved	$ 183,867	$ 263,684	$ 307,642
4	400-1,500	paved	123,505	165,865	193,695
5	under 400	paved	58,141	73,092	85,659
6	over 100	gravel	26,121	36,088	42,179
7	25.1-100	gravel	12,399	19,043	22,113
8	0-25	earth	7,824	11,977	13,867

Table B.12. Resurfacing cost equations per lane mile of road by road surface, traffic level, and study area

ADT group	Surface	County	Resurfacing cost equations
Over 1,500	paved	Hamilton	W = $1.21Z + $30,094
		Shelby	W = 1.21Z + $30,094 where Z = ADT − 950
		Linn	W = 1.44Z + $35,583
400-1,500	paved	Hamilton	W = $7.66Z + $25,881
		Shelby	W = 7.66Z + $25,881 where Z = ADT − 400
		Linn	W = 8.91Z + $30,684
Under 400	paved	Hamilton	W = $25,881
		Shelby	W = $25,881
		Linn	W = $30,684

Table B.13. Reconstruction cost equations per lane mile of road by road surface, traffic level, and study area

ADT group	Surface	County	Reconstruction cost equations
Over 1,500	paved	Hamilton	Y = $26.24Z + $123,505
		Shelby	Y = 42.53Z + $165,865 where Z = ADT − 950
		Linn	Y = 49.54Z + $193,695
400.1-1,500	paved	Hamilton	Y = $118.84Z + $58,141
		Shelby	Y = 168.68Z + $73,092 where Z = ADT − 400
		Linn	Y = 196.43Z + $85,659
Under 400	paved	Hamilton	Y = $58,141
		Shelby	Y = $73,092
		Linn	Y = $85,659
Over 100	gravel/earth	Hamilton	Y = 73.18Z + $12,399
		Shelby	Y = 90.91Z + $19,043 where Z = ADT − 62.50
		Linn	Y = 107.02Z + $22,113
25.1-100	gravel/earth	Hamilton	Y = 122.00Z + $7,824
		Shelby	Y = 188.43Z + $11,977 where Z = ADT − 25
		Linn	Y = 219.89Z + $13,867
0-25	gravel/earth	Hamilton	Y = $7,824
		Shelby	Y = $11,977
		Linn	Y = $13,867

Table B.14. The timing of future reconstructions and resurfacings over one life cycle for paved roads

The last time the road was reconstructed	Number of years in the future[a]		
	0	15	30
Before 1952	REC	RES	RES
1952-1966	RES	REC	RES
1967-1982	RES	RES	REC

[a]REC means a reconstruction is needed and RES means a resurfacing is needed.

$$V = \frac{C}{(1 + i)^n} \qquad (B.4)$$

where

PV = the present value of the investment
C = the reconstruction or resurfacing cost
n = the number of years in the future in which the reconstruction or resurfacing is required and
i = the interest rate

Equation (B.5) shows the method used for annualizing the present value of future investments over the life cycle of the road.

$$AC = PV \frac{i(1+i)^N}{(1 + i)^N - 1} \qquad (B.5)$$

where

AC = the annualized investment cost over the life cycle of the road
PV = the present value of the investment
N = the number of years in the life cycle of the road and
i = the interest rate

The life cycle of gravel and earth roads is 60 years. Gravel and earth roads were assumed to be in need of immediate reconstruction; hence, only (B.5) was needed to calculate the annualized investment cost over the life cycle of the road.

Long-term investments in bridge reconstruction were annualized over the life cycle of the road. Equations (B.4) and (B.5) were used to calculate the annualized bridge reconstruction cost over the life cycle of the road. Bridge reconstruction costs of $37 per square foot were taken from the 1982-2001 Iowa DOT Needs Study. Equation (B.6) shows the method of calculating bridge reconstruction costs.

$$BREC = 1.37 * \$37 * LGN * WDTH \qquad (B.6)$$

where

BREC = bridge reconstruction cost,
LNG = the length of the bridge, and
WDTH = the width of the bridge.

The width of a newly reconstructed bridge on gravel or earth road was assumed to be 24 feet, while the width of a newly reconstructed bridge on a paved road was assumed to be 30 feet. The factor 1.37 in (B.6) represents the increased length of the bridge after reconstruction and is taken from the 1982-2001 Iowa DOT Needs Study.

The interest rate used in this analysis was a real interest rate obtained by subtracting the 1982 inflation rate of six percent from the nominal interest rate on high grade municipal bonds of 11.57 percent. Thus, the real interest rate used to obtain the capital recovery on road investment costs was 5.6 percent.

Appendix C.

Procedure for Estimating Vehicle Travel Costs on Pave, Granular, and Earth-Surface Roads

Each vehicle was classified as either a road vehicle or a farm vehicle. Road vehicles include automobiles, pickups, commercial vans, semitrailer trucks, garbage trucks, school buses, and farmer-owned single-axle, tandem-axle, and semitrailer trucks. Farm vehicles include farm tractors and combines that are designed primarily for field work. After accounting for the various vehicles pulling different types of equipment, variable costs were estimated for 13 types of road vehicles and 21 types and sizes of farm vehicles. The following is a summary of the procedures used to estimate each cost component.

Fuel Cost

Fuel cost in cents per mile for each vehicle type was estimated as

$$F_i = [FP_i]\ [FP_i]^{\$}MI^{'} \qquad (C.1)$$

where

F_i = fuel cost in cents per mile for vehicle type i

FP_i = fuel price in cents per gallon for vehicle type i

FC_i = fuel consumption in miles per gallon for vehicle type i

For farm vehicles, fuel consumption in miles per gallon is defined as the ratio of speed in miles per hour divided by fuel consumption in gallons per hour or

$$FC_i = [S_i]\ [G_i] \qquad (C.2)$$

where

S_i = speed in miles per hour for farm vehicle type

G_i = fuel consumption in gallons per hour for farm vehicle type i. Behavioral relationships between G_i and the percent engine load for vehicle type i (EL) were estimated using least squares regression procedures and are used to estimate G_i for each vehicle type. The estimate for EL_i is obtained from (C.3).

$$EL_i = V_i + \frac{(D_i * S_i)}{375} \qquad (C.3)$$

where

V_i = percent of engine load for vehicle i with no trailing equipment or wagons

- V_i = 30 percent on gravel roads at 10 mph,
- V_i = 40 percent on paved roads at 11 mph,

D_i = the draft of vehicle i as defined in (C.4)

$$D_i = C_i * A_i \qquad (C.4)$$

where

C_i = adjustment coefficient to convert the weight of equipment being pulled by vehicle type i on a specified surface type to vehicle draft

A_i = weight of the equipment being pulled by vehicle type i.

Oil Cost

Oil cost in cents per mile for each vehicle type was calculated as

$$O_i = OP_i * OC_i \qquad (C.5)$$

where

O_i = oil cost in cents per mile for vehicle type i
OP_i = oil price per unit for vehicle type i
OC_i = oil consumption in quarts per mile for road vehicle type i. For farm vehicle type i, oil consumption in gallons per mile is defined as (C.6)

$$OC_i = (OM^i)\ [S_i]^{-1} \qquad (C.6)$$

where

OM_i = oil consumption in gallons per hour for farm vehicle type i, taken directly from the 1981 *Agricultural Engineering Yearbook,* is defined as (C.7):

$$OM_i = 0.00573 + 0.00021\ H_i \qquad (C.7)$$

where:

H_i = engine horsepower for farm vehicle type i
S_i = speed in miles per hour for farm vehicle type i.

Tire Cost

Tire cost in cents per mile for each vehicle type was estimated as

$$T_i = [N_{ik} * TP_{ik}]\ L_{ik}^{-1} \qquad (C.8)$$

where

T_i = tire cost in cents per mile for vehicle type i
k = type of tire (i.e. front, rear, trailer)
N_{ik} = number of the tire type k on vehicle type i
TP_{ik} = price of tire type k for vehicle type i
L_{ik} = expected life in miles of tire type k for road vehicle type i.

For farm vehicle type i, the expected life in miles of tire type k is defined as

$$L_{ik} = M_{ik} * S_i \qquad (C.9)$$

where

M_{ik} = expected life in hours of tire type k for vehicle type i
S_i = speed in miles per hour for vehicle type i.

Maintenance Cost

Maintenance and repair cost in cents per mile for each vehicle type was taken from previous studies whenever possible. Where maintenance and repair costs for road vehicles was not available, maintenance cost for vehicle type i was estimated by

$$MC_i = \bar{R}_i\ [\bar{AM}_i]^{-1} \qquad (C.10)$$

where

MC_i = maintenance and repair cost in cents per mile for vehicle type i
$\bar{R}_i$ = average annual maintenance and repair cost in cents for road vehicle type i
$\bar{AM}_i$ = average annual miles driven by road vehicle type i.

Maintenance and repair cost in cents per mile for farm vehicle type i was estimated by

$$MC_i = R_i\ [AM_i] \qquad (C.11)$$

where

R_i = estimated total lifetime maintenance and repair cost for farm vehicle type i. The 1981-1982 *Agricultural Engineers Handbook* estimates R_i as shown in (C.12)

$$R_i = (0.120)\ (VP_i)\ (Q_i/1000)^{2.033} \qquad (C.12)$$

AM_i = total lifetime miles for farm vehicle type i and is estimated by (C.13)

$$AM_i = Q_i * S_i \qquad (C.13)$$

where

R_i = total lifetime repairs in cents for vehicle type i
VP_i = list price of vehicle type i
Q_i = estimated life in hours for vehicle type i
S_i = speed in miles per hour for vehicle type i.

Travel Time Component

Variable travel time cost in cents per mile for each vehicle type was calculated as

$$TT_i = (NA_i * W_i)(S_i)^{-1} \qquad (C.14)$$

where

TT_i = travel time cost in cents per mile for vehicle type i
NA_i = the average number of adults in vehicle type i
W_i = the estimated value of the adults' time in cents per hour for vehicle type i
S_i = the speed in miles per hour of vehicle type i.

Table C.1 presents the estimated travel time costs per mile for registered vehicles. The hourly wage rate used for a farm tractor and combine driver was $7.00 per hour.

Variable Costs by Surface Type

The fuel, oil, tire, maintenance, and travel time cost components were estimated for each road vehicle and then summed to arrive at a base variable cost function reflecting the surface combination which corresponded to the data used to develop the cost functions. The surface combination for the school bus variable cost estimate was 43 percent paved, 50 percent gravel, and 7 percent earth surface travel. The farmer-owned single-axle, tandem-axle, and semitrailer surface combination was assumed to be 50 percent paved and 50 percent gravel surface travel. The base variable cost estimates for the remaining road vehicles assumed 100 percent of travel on paved surfaces. Each base variable cost function was then adjusted to gravel variable cost by using Winfrey's (1969) 40 MPH paved-to-gravel adjustment factor of 1.4. The earth surface adjusted equation was

Table C.1. Estimated time value in cents per mile for registered vehicles

Vehicle	Time value in cents per mile
Automobile	9.8
Pickup truck	9.6
Commercial van	21.5
Commercial semitrailer truck	21.5
Garbage truck	29.4
School bus	10.0
Farmer-owned single-axle truck	10.8
Farmer-owned tandem-axle truck	10.8
Farmer-owned semitrailer truck	10.8

$$CM_E = 2G - 1 \qquad (C.14)$$

where
G = ratio of

$$\frac{\text{operating costs of vehicle j on gravel roads}}{\text{operating costs of vehicle j on paved roads}}$$

Winfrey's surface adjustment factors reflect the changes in variable running cost that occur due to changes in surface types. These variable cost changes are the result of road characteristics—firmness, abrasiveness, roughness, dustiness, and looseness of the surface. Winfrey's adjustment factors include fuel, oil, tires, maintenance, and depreciation. The travel-time cost component was also included in the adjustment factors because of the speed differentials on different surface types.

The following modification of Winfrey's surface adjustment factor, used to estimate registered vehicle travel costs on area service B roads, was recommended by the advisory committee:

$$CMB = 2G - 0.8 \qquad (C.15)$$

where

CMB = cost per vehicle mile on area service B roads.

Winfrey provided surface adjustment factors only for road vehicles. Consequently, the fuel, oil, tire, maintenance, and travel-time costs for farm vehicles were estimated for each type of vehicle on both paved and gravel surfaces. The impact of surface type on variable costs is reflected in the estimated speed, engine load (including draft), and tire wear. The estimated cost components were then summed by surface type to arrive at vehicle cost functions for each farm vehicle on paved and gravel surfaces. Farm vehicle costs were assumed to be constant on gravel, earth, and area service B surfaces.

Appendix D.

Procedure for Estimating Travel-Time Penalty

Some farm equipment travel resulting from a change in the road system has an extra cost in addition to the usual fuel, tire wear, labor, oil, and maintenance costs. Farmers will incur an opportunity cost from the increased travel time if it prevents finishing the planting or harvesting of a crop in the optimal time period. If, for example, a field could not be planted in one day and overnight the weather changed to rain, several days may pass before planting is completed. Assuming a corn crop and an initial planting date of May 14, a two-day delay in planting can reduce yield by approximately 1.6 percent (Edwards and Boehlje 1980). Assuming a 100-bushel per acre yield with a corn price of $2.50 per bushel, a two-day planting delay would cost $4 per acre. Thus, when a farmer is forced to travel longer distances because of a change in the road system, a travel-time penalty is incurred.

When faced with increased travel time, a farmer can minimize losses by several strategies:

1. Allow the yield to decline—called timeliness loss
2. Work longer hours
3. Change the crop mix
4. Farm fewer acres
5. Increase the size of farm machinery—called machine capacity

Predicting the cost of implementing any of the five strategies should give an estimate of the travel time penalty.

In this study, the travel time penalty cost is based on the cost of increasing machine capacity to permit the farmer to operate the same amount of land in the same total time as before the change in the road system. For example, if the farmer spends an extra 10 minutes on the road, machine capacity is increased enough to allow the same acres to be covered in ten fewer minutes.

Estimating Increased Machinery Capacity

The amount of increased machinery capacity can be estimated by using measures of effective field capacity and road speed. The effective capacity for a machine is the estimated number of acres a given machine can cover in one hour. For example, a 4-row, 30-inch planter has an estimated field capacity of 4.6 acres/hour (PM 696, ISU Extension Service, 1976).

Assuming a farmer maintains an average road speed of 10 MPH on a gravel road, an extra mile traveled on gravel requires six additional minutes. If the farmer gives up six minutes of field time because of one additional mile of travel, then his machine capacity must increase enough to cover the same ground in six less minutes.

The change in machine capacity per extra mile traveled can be represented by the following equations:

$$\Delta A_{iji} = [MC_j]\,[MPH_{jk}]^{-1} \qquad \text{(D.1)}$$

where

ΔA_{ijk} = the change in acres per extra mile traveled, which farmer i must cover with increased machine capacity for the j^{th} machine on the k^{th} surface type to compensate for the extra road mile traveled,

MC_j = the machine capapcity in acres per hour for the j^{th} machine,

MPH_{jk} = the speed in miles per hour of the j^{th} machine on the k^{th} road surface type, and with the following:

$$\Delta C_{ijk} = \frac{\Delta A_{ijk}}{Y_{ij}} \qquad \text{(D.2)}$$

where

ΔC_{ijk} = the change in capapcity required per extra mile traveled for farmer i using machine j on the k^{th} surface type,

Y_{ij} = the total work time of farmer i where work time is the total of travel and field time, using machine j on surface type k.

The percent change in capacity required is estimated by (D.3)

$$PCC_{ijk} = \frac{\Delta C_{ijk}*100}{CC_{ij}} \quad (D.3)$$

where

PCC_{ijk} = the percent change in machine capacity required per extra mile traveled by farmer i, using machine j,

CC_{ij} = the total machine capacity of farmer i, defined by

PCC_{ijk} can also be written as

$$PC_{ijk} = \left[\frac{\Delta A_{ijk}}{Y_{ik}} \right] \left[\frac{Y_{iJ}}{A_{ij}} \right] = \frac{\Delta A_{ijk}}{A_{ijk}} \quad (D.4)$$

Field Capacity Calculations

The harvesting, planting, and tillage operations were the only field operations considered as time-critical. The effective field capacities for different sizes of farm equipment used in these operations are presented in Table D.1. Average machine capacities are shown in Table D.2.

The capacities of planting machinery were combined because the farm travel questionnaire data did not separate planter trips by planter size. A weighted average planter field capacity was estimated using weights based on the judgment of an Iowa State University (ISU) agricultural engineer. The weights are essentially representative of the number of each planter size used by farmers. Except for differentiating between six- and eight-row combines, combine sizes were known from the questionnaire data. Therefore, separate field capacities were used for two-row, four-row, and six- and eight-row combines.

Using (D.3), the percentage change in machinery required to compensate for the time lost in each extra mile traveled on paved and gravel surfaces was estimated for five farm sizes. The sizes were taken from the Iowa Farm Business Association (Averages for the Year 1982, Grain). The average rotated acres and range of acres of the five farm sizes are:

Average rotated acres	Range of acres
147	0-179
202	180-259
298	260-359
398	360-499
736	500+

The percentage change in capacity for the five machines and five farm sizes is presented in Table D.3. The estimated percentage changes in capacity required for each additional mile of travel are based on a speed of 11 MPH on paved roads and 10 MPH on gravel roads.

The data estimates in Table D.4 indicate that smaller farms require a larger percentage increase in capacity per additional mile traveled than larger farms. The reason is that small farms use smaller equipment than large farms and thus require a larger percentage increase in capacity to offset travel time on roads.

Table D.1. Estimated machine field capacities

Machine	Effective field capacity in acres per hour
4-row, 30-inch planter	4.6
6-row, 30-inch planter	6.7
8-row, 30-inch planter	8.7
2-row, 38-inch combine	1.5
4-row, 30-inch combine	2.3
6-row, 30-inch combine	3.2
8-row, 30-inch combine	3.9
5-foot offset disk	6.6

SOURCE: Ayers and Williams. 1976.

Table D.2. Machine field capacities for tillage, planting, and harvesting averaged over sizes of machines

Machine	Effective field capacity in acres per hour
Planter	6.7
2-row combine	1.5
4-row combine	2.3
6-8 row combine	3.5
Disk	6.6

Table D.3. Percent change in capacity required for each mile traveled on paved and gravel surfaces for five farm sizes, by type of equipment

Farm size in acres	Type of equipment									
	Planter		Disk		2-row combine		4-row combine		6-8 row combine	
	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel
0-179	0.41	0.46	0.41	0.45	0.09	0.10	0.15	0.16	0.22	0.24
180-259	0.30	0.33	0.30	0.33	0.07	0.07	0.11	0.11	0.16	0.18
260-359	0.20	0.22	0.20	0.22	0.05	0.05	0.07	0.08	0.11	0.12
360-499	0.15	0.17	0.15	0.17	0.03	0.04	0.05	0.06	0.08	0.09
500+	0.08	0.09	0.08	0.09	0.02	0.02	0.03	0.03	0.04	0.05

Table D.4. Results of the linear regressions of the percentage change in fixed cost on the percentage change in capacity

Machine	R_2	Slope
Planter	0.75	1.31
Combine	0.71	0.46
Disk	0.96	1.79

The cost of this increased capacity was based on the relationship between the cost of changing the effective field capacity and percentage change in machinery-fixed cost. That is, the cost of increasing machine capacity was estimated by a percentage change in fixed cost.

The assumption underlying this proposed relationship is that variable costs essentially remain constant with an increase in machine capacity. Labor does not change because the farmer is spending the same amount of total time; with an increase in travel time he just spends more time on the road and less in the field. Changes in other field-time related variable costs, such as fuel consumption, are small. Moreover, the additional wear on the equipment and fuel use because of extra road travel is taken into account by the variable running costs described in Appendix C.

The relationship between percentage change in field capacity and percentage change in fixed cost was estimated from data obtained from an analysis of farm machinery cost in central Iowa (Fulton, 1976).

This analysis provides values for fixed cost relative to hours of annual use for different machine/tractor combinations. The percentage change in capacity was estimated by (D.5):

$$PCC = \frac{S_1 - S_2}{S_2} * 100 \qquad (D.5)$$

where

PCC = percent change in capacity,
S_1 = size of machine,
S_2 = size of machine 2.

The relationship between annual fixed cost and percentage change in capacity was estimated by (D.6)

$$C_{ij} = b_j(PCC_{ij}) \qquad (D.6)$$

where

C_{ij} = the cost of increasing machine capacity, using machine j, predicted by PCC_{ij}.

Equation (D.5) was estimated for a planter, combine, and disk. Data were not available for other tillage equipment so the disk was assumed to be representative of tillage machines. The sloped (b_j) and R^2's for each regression are presented in Table D.5 None of the intercepts was significantly different from zero. All slopes were significant at the 0.0001 level.

Fixed Cost Calculations

The values of the fixed cost for each machine size were used to calculate an average fixed cost per machine. The values and the average fixed cost per machine are presented in Table D.5.

Cost Per Mile Calculations

A travel-time penalty cost per mile for different types of farm equipment for the five farm sizes was calculated using the relationship between percentage changes in fixed cost and in capacity. The results of these calculations are presented in Table D.6 for paved and gravel surfaces.

Table D.5. Annual fixed machinery cost by machine size and average annual fixed cost by type of machine

Machine type and size	Annual machine fixed cost in dollars	Average annual machine fixed cost
Disk		
10 feet	$ 316	
14 feet	462	
18 feet	604	
22 feet	1,000	
26 feet	1,208	
30 feet	1,425	$ 835.33
Planter		
4-38 inch rows	779	
6-30 inch rows	1,114	
6-38 inch rows	1,236	
8-30 inch rows	1,463	
8-38 inch rows	1,519	
12-30 inch rows	2,491	1,433.67
2-row combine		
2-38 inch rows	3,642	3,642.00
4-row combine		
4-30 inch rows	6,141	
4-38 inch rows	6,198	6,169.50
6-8 row combine		
6-30 inch rows	7,424	
6-38 inch rows	7,574	
8-30 inch rows	7,920	7,639.33

The farm questionnaire asked for the number of trips by tractors pulling farm equipment. Data from "Estimated Cost of Crop Production in Iowa" (ISU Extension Service 1984) were used to estimate the number of field trips attributable to tillage and planting operations. Assuming a 50 percent corn and 50 percent soybean crop mix, approximately one planting trip is made per 2.5 tillage trips. The disk and planter costs per mile were then weighted accordingly.

The travel time penalty costs were then combined into an average cost over all sizes of farms. A frequency distribution was run on the farm sizes from the questionnaire data from the three study areas. The travel time penalty costs per mile for the five farm sizes were combined into one number based on the farm size frequencies. Table D.7 contains the frequency and percents for the farm size ranges.

Table D.8 contains the estimated travel-time penalty costs. The travel-time penalty cost is significantly higher for planter/tillage equipment than for combines. The planter/tillage combination has a much higher capacity per acre or per given time period, which causes the cost of losing field time to be much higher.

Applying the Travel-Time Penalty

The travel-time penalty was charged only to tillage/planting and combining operations. The concept of a travel-time penalty is related to a possible yield loss from not finishing field operations in an optimal time period. The travel-time penalty was applied only to the change in planter/tillage and combine travel miles resulting from changes in the road system. The last trip back from the field was not charged a penalty. Once the operation is complete, the only cost for traveling was assumed to be the variable cost on the tractor, equipment, and combine.

Table D.6. Percent change in capacity and fixed cost by farm size and road surface, annual fixed cost by type of machine, and time-penalty cost per mile by farm machine, farm size, and road surface

Machine	Farm size (acres)	Percent change in capacity		Percent change in fixed cost		Annual fixed cost	Fixed cost per mile traveled	
		Paved	Gravel	Paved	Gravel		Paved	Gravel
Disk	147	0.41	0.45	0.73	0.81	$ 835.33	$ 6.10	$ 6.77
	202	0.30	0.33	0.54	0.59	835.33	4.51	4.93
	298	0.20	0.22	0.36	0.39	835.33	3.01	3.26
	398	0.15	0.17	0.27	0.30	835.33	2.26	2.51
	736	0.08	0.09	0.14	0.16	835.33	1.17	1.34
Planter	147	0.41	0.46	0.54	0.60	1,433.67	7.74	8.60
	202	0.30	0.33	0.39	0.43	1,433.67	5.59	6.16
	298	0.20	0.22	0.26	0.29	1,433.67	3.73	4.16
	398	0.15	0.17	0.20	0.22	1,433.67	2.87	3.15
	736	0.08	0.09	0.10	0.12	1,433.67	1.43	1.72
2-row combine	147	0.09	0.10	0.04	0.05	3,642.00	1.46	1.82
	202	0.07	0.07	0.03	0.03	3,642.00	1.09	1.09
	298	0.05	0.05	0.02	0.02	3,642.00	0.73	0.73
	398	0.03	0.04	0.01	0.02	3,642.00	0.36	0.73
	736	0.02	0.02	0.01	0.01	3,642.00	0.36	0.36
4-row combine	147	0.15	0.16	0.07	0.07	6,169.50	4.32	4.32
	202	0.11	0.11	0.05	0.05	6,169.50	3.08	3.08
	298	0.07	0.08	0.03	0.04	6,169.50	1.85	2.47
	398	0.05	0.06	0.02	0.03	6,169.50	1.23	1.85
	736	0.03	0.03	0.01	0.01	6,169.50	0.62	0.62
6-8 row combine	147	0.22	0.24	0.10	0.11	7,639.33	7.64	8.40
	202	0.16	0.18	0.07	0.08	7,639.33	5.35	6.11
	298	0.11	0.12	0.05	0.06	7,639.33	3.82	4.58
	398	0.08	0.09	0.04	0.04	7,639.33	3.06	3.06
	736	0.04	0.05	0.02	0.02	7,639.33	1.53	1.53

Table D.7. Number and percent of farms by farm size in the three study areas

Farm size in acres	Number of farms	Percent of farms
0-179	185	27.53
180-259	107	15.92
260-359	86	12.80
360-499	109	16.22
500+	185	27.53

Table D.8. Estimated travel-time penalty cost per mile by type of farm machinery and road surface, in dollars per mile

Machine	Paved	Gravel
Planter/tillage	$ 3.72	$ 4.13
2-row combine	0.83	0.99
4-row combine	2.29	2.47
6-8 row combine	4.36	4.79

Appendix E.

The Non-Farm and Farm Questionnaires

January 1983
Form III
NONFARM QUESTIONNAIRE

Department of Economics
and
Statistical Laboratory
Iowa State University

Rural Road Use Study

Household ID: ___ ___ (CO.) ___ ___ (TWP.) ___ ___ (SEC.) ___ ___ (H.H.)

Date ___ ___ (MO.) ___ ___ (DAY)

Start time ______________

Name of Respondent ____________________________

Interviewer ID # ___ ___

Iowa State University appreciates your help with this study. We will be asking for information about all travel for the members of this household. Your responses will be kept confidential and will be released as statistical summaries only. If a question seems unclear, let me know and I will try to clarify it. If you feel a question is too personal, you have the right to refuse to answer.

I'd like to begin with some general information about your household.

1. In 1982, how many people were living in this household? Include college students who may be away temporarily, as well as anyone else who lives here and has no other home.

__ __

2a. What is the first name of each household member?

[ASK b AND c FOR EACH HOUSEHOLD MEMBER]

b. What was ________ age on his/her last birthday?
(member)

c. What is ________ relationship to the head of the household?
(member)

a Household member	b Age	c Relationship
________	__ __	________
________	__ __	________
________	__ __	________
________	__ __	________
________	__ __	________
________	__ __	________
________	__ __	________
________	__ __	________

3. How many of these people operated a motor vehicle?

__ __

4. Now we would like some information about where household members go for various activities. We want the names of towns or cities, not the specific store, bank, etc.

In 1982, generally where did your family go ________? (activity) [ENTER NAME OF EACH CITY OR TOWN]

Activity	City/town
a) to do their shopping	________ ________ ________ ________
b) to school (preschool) or to attend school functions. Do not include rides on the school bus.	________ ________
c) to attend church services or activities	________
d) to attend social functions, visit friends and relatives or go for recreation	________ ________ ________
e) to attend meetings	________ ________
f) to do banking or other family business	________ ________
g) to see a doctor or dentist	________ ________
h) to work	________ ________
i) to do any other activities not mentioned (specify what) ________	________

[ENTER IN COLUMN a) BELOW THE NAME OF EACH TOWN OR CITY LISTED IN QUESTION 4
ASK QUESTIONS b THROUGH f FOR EACH CITY OR TOWN]

5a. Next we would like you to think about how frequently your family goes to each town or city. Please think of all household members as well as all the different reasons in order to determine how many total trips were taken. You may give your answer on a daily, weekly, monthly basis or as a total for the time period (season).

b. Thinking of the winter season, how often did household members go to ______ (city)?

[ENTER NUMBER AND CIRCLE FREQUENCY]

c. During the spring season, how often did household members go to ______ (city)?

d. During the summer season, how often did household members go to ______ (city)?

e. During the fall season, how often did household members go to ______ (city)?

[IF NO CHILDREN IN HOUSEHOLD, SKIP (f)]

f. When you go to ______ (city), what percent of the trips you take are to transport you children to and from their activities such as school, doctors, dentists and recreation and would not have been made otherwise?

a	b		c		d		e		f
	Winter		Spring		Summer		Fall		
City/Town	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	Percent
1.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
2.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
3.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
4.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
5.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
6.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
7.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %
8.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	__ __ __ %

6. We are interested in the types of vehicles household members used in 1982. These may be vehicles owned by others and used by household members for work (etc.) as well as your own vehicles.

a. How many automobiles did household members drive to and from this place in 1982?

___ ___

b. How many pickup trucks did household members drive to and from this place in 1982?

___ ___

[HAND R THE BLUE CARD]

c. Looking at the blue card, would you tell me, how many vehicles like these did household members drive to and from this place in 1982?

___ ___ [IF NONE, GO TO Q. 7]

d. Still looking at the card, please give me the code numbers for each vehicle driven to and from this place in 1982.

[ASK e FOR EACH VEHICLE]

e. To what cities and towns was this vehicle driven?

[ASK f FOR EACH TOWN]

f. Thinking of all the trips household members made to ___________ (city/town), what percent of the time was this vehicle driven?

d Vehicle	e City/town	f Percent of times
___ ___	____________ ____________	______ ______
___ ___	____________ ____________	______ ______
___ ___	____________ ____________	______ ______

7a. [HAND R THE STUDY AREA MAP AND YELLOW MARKER]

Would you look at this map which shows a part of your county. Here is where your home is located. Draw this lot on the map.

b. How many acres is this? __________

[HAND R THE RED PENCIL]

c. With this red pencil, place a line on the map to represent each access point you have to your place.

8a. In 1982, when household members traveled to the places we have just talked about, did they usually take the shortest route?

_____ Yes (Q. 9)

_____ No ——> Why not? ________________________________

____

____

[HAND R THE BLUE MARKER]

b. We would like to know exactly which routes were taken when people were not taking the shortest route. Using this marker, please draw each route on the map.

[IF NO TRUCKS IN Q. 6c, GO TO Q. 9]

c. With what vehicle was this route taken?

___ ___

9. In this final section we would like you to think about the traffic which came onto your place. We'll first talk about deliveries made to you.

a. In 1982, did you have any ________ (product) delivered?

[IF YES, ASK b AND c]

b. From what town or city were deliveries made?

[ASK c FOR EACH LOCATION]

c. During 1982, how many times did you have ________ (product) delivered from ______ (city)?

[ENTER NUMBER AND CHECK FREQUENCY IN COLUMN c]

Product	a Delivered? Yes	 No	b Location of dealer	c No. of times	 Da	 Wk	 Mo	 Yr
Diesel fuel or gasoline	1	2	________ ________	__ __ __ __				
LP gas (propane) or fuel oil	1	2	________ ________	__ __ __ __				

[HAND R THE ORANGE CARD]

10a. Would you look at the orange card which lists products which may have been delivered to you. Thinking of any products like these, would you tell me, in 1982 did you have any of these kinds of deliveries made to your place?

___ Yes
___ No (Q. 11)

b. What types of products were delivered?

[LIST ALL IN COLUMN b AND ASK c AND d FOR EACH]

c. From what town or city was the ______ delivery made?
(type)

[ASK d FOR EACH LOCATION]

d. During 1982, how many times did you have ______ delivered from ______?
(type) (city)

[ENTER NUMBER AND CHECK FREQUENCY IN COLUMN d]

(b) Type of delivery	(c) Location of dealer	(d) No. of times	Da	Wk	Mo	Yr
		__ __ __ __				
		__ __ __ __				
		__ __ __ __				
		__ __ __ __				
		__ __ __ __				

11a. During 1982, did you have __________ come to your place?
(visitor)

[IF YES, ASK b AND c]

b. Generally, what city or town were these people coming from?

c. During 1982, how many times did __________ come to your place from ______?
(visitor) (city)

[ENTER NUMBER AND CHECK FREQUENCY IN COLUMN c]

Type of visitor	a Have?		b Where from? (city, town)	c No. of times				
	Yes	No			Da	Wk	Mo	Yr
Repairmen or workmen	1	2	______ ______	__ __ __ __				
Salespeople	1	2	______ ______ ______	__ __ __ __ __ __				
Guests or relatives or neighbors	1	2	______ ______ ______ ______	__ __ __ __ __ __ __ __				
Hired help such as a cleaning lady, baby-sitters or yardmen	1	2	______	__ __				
Any others? [Specify who] ______	1	2	______ ______	__ __ __ __				

This completes our interview. Is there anything else you would like to tell us about your travel?

____

____

Iowa State University appreciates your help with this project.
Would you like the results of this study?

Ending time ___ ___ : ___ ___

Total minutes of interview ___ ___ ___

[INTERVIEWER COMPLETE THIS PORTION AFTER LEAVING RESPONDENT'S HOME]

In general, how would you rate the reliability of the information given?

1 = very reliable

2 = generally reliable

3 = not very reliable } Why? _______________________

4 = poor }

____

____

Was there anything about the respondent or interview setting which you feel affected the quality of the interview?

___ No

___ Yes ——> Explain _______________________

____

____

February 1983

Form IV

FARM QUESTIONNAIRE

Department of Economics
and
Statistical Laboratory
Iowa State University

Rural Road Use Study

Household ID: __ __ CO. __ __ TWP. __ __ SEC. __ __ H.H.

Date __ __ MO. __ __ DAY

Start time ____________

Name of Respondent ______________________________

Interviewer ID # __ __

Iowa State University appreciates your help with this study. We will be asking for information about all travel for the members of this household as well as all members of your farming operation. We are interested in road and vehicle usage. Your responses will be kept confidential and will be released as statistical summaries only. If a question seems unclear, let me know and I will try to clarify it. If you feel a question is too personal, you have a right to refuse to answer. Let's begin with some general information about your farming operation in 1982.

95

[HAND R STUDY AREA MAP AND YELLOW MARKER. INDICATE TO R THE LOCATION OF HOMEBASE]

1. Would you look at this map of a portion of your county. Here is the exact location of your home. Would you please draw the approximate boundaries of the land that makes up this home tract.

[NUMBER THIS TRACT 1]

2. In 1982, how many different tracts, including your home tract, did you operate on your own, in partnership or in a corporation?

____ ____ [IF ONE, GO TO Q. 4a]

[A TRACT IS A UNIT OF LAND SEPARATED BY A ROAD OR OTHER LAND NOT OPERATED. IF THE LAND IS ADJACENT OR NOT SEPARATED, THIS SHOULD BE ONE TRACT]

3. Now we would like you to identify the other tracts you operated in 1982. Let's begin with the tracts that fall within the boundaries of this map. Please locate each of these tracts by drawing the approximate boundaries.

4a. [NUMBER EACH TRACT AND ENTER TRACT NUMBER IN COLUMN a IN THE TABLE. ASK b AND c FOR ALL TRACTS ON MAP]

b. How many acres are in tract ________?
(number)

c. How many access points do you have into tract ________?
(number)

[HAND R THE RED PEN]

d. With this red pen, would you place a line on the map indicating each access point (road,etc.) you have into tract ________.
(number)

[IF THE NUMBER OF TRACTS OUTLINED IS LESS THAN THE NUMBER IN Q. 2, GO TO Q. 6]

5. That seems to account for all the tracts you operate, but just to double check, let me ask you, in 1982, did you operate any tracts which are not within the boundaries of this map?

______ Yes

______ No ⟶ (Q. 8a)

6. Now we would like some information about each tract you operated which is outside the boundaries of this map. Would you put an X on the border of the map which represents approximately where each tract is located.

[NUMBER CONSECUTIVELY EACH OF THESE TRACTS AND ENTER THE NUMBERS IN COLUMN a. ASK b THROUGH f FOR EACH]

7a. I'd like to get some information about each of these tracts. Let's begin with tract ________.
(number)

b. In what county is this tract located?

c. In what township is this tract located?

d. What section is this tract in?

e. Where in the section is the tract located?

f. How many acres are in this tract?

a Tract number	b County	c Township	d Section number	e Where in section [e.g. NE corner]	f Number of acres

a Tract number	b No. of acres	c Number of access points
__1__	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______
______	________ acres	______

8a. In 1982, did you operate any of the tracts we have talked about with another farmer (in partnership, corporation, etc.)?

______ Yes

______ No (Q. 9)

[FOR OUR PURPOSES, A PARTNERSHIP IS AN INFORMAL OR FORMAL ARRANGEMENT WHERE TWO OR MORE FARMERS SHARE THE <u>WORK</u> OR LABOR IN A FARMING OPERATION]

b. What is the other farmer's name?

____

c. Does ______ (name) live within the boundaries of this map?

______ Yes

______ No (Q. 8e)

d. Place an X on the map to indicate where he lives.

[ON THE MAP, IDENTIFY THIS LOCATION AS "PARTNER" AND GO TO Q. 9]

e. Could you give me the exact location of your partner's home. [PROBE FOR LEGAL DESCRIPTION OR DIRECTION]

____

____

9. Now we would like you to think of the products that were either delivered to you or picked up by a member of your farming operation in 1982. We will only record information for products brought to tracts within the boundaries of the map.

[ASK a FOR ALL PRODUCTS]

a. In 1982 was ________ (product) brought to any of these tracts? [IF NO, GO TO NEXT PRODUCT]

b. Did you usually take a full truck load?

c. To which tracts was ________ (product) delivered?

d. During 1982, how many times was ________ (product) delivered to tract ________ (number)?

[HAND R THE GREEN CARD]

e. Looking at the green card which lists various types of delivery vehicles, tell me the code number for the type of vehicle which usually delivered the ________ (product)?

f. What is the name and location of the dealer who delivered the ________ (product)?

[PROBE FOR NUMBER OF TRIPS WITH DIFFERENT VEHICLES OR TO SEVERAL LOCATIONS]

Product	a Delivered?		b Full?		c & d								e	f
	Yes	No	Yes	No	Tract no.	Number of times	Tract no.	Number of times	Tract no.	Number of times	Tract no.	Number of times	Type of vehicle	Dealer & location
Diesel fuel or gasoline					__ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __		
	1	2	1	2	__ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __		
LP gas (propane) or fuel oil	1	2	1	2	__ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __		

Anhydrous ammonia or other liquid fertilizer	1	2	1	2	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___		
Dry fertilizer	1	2	1	2	___ ___	___ ___	___ ___	___ ___		
Herbicides/ Insecticides	1	2	1	2	___ ___	___ ___	___ ___	___ ___		
Seed, feed	1	2	1	2	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___		
Livestock (Type?) ____________	1	2	1	2	___ ___	___ ___	___ ___	___ ___		
Water	1	2	1	2	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___		
Any other deliveries (Specify) ____________	1	2	1	2	___ ___	___ ___	___ ___	___ ___		

10a. In 1982, did you take any equipment which was more than 16 feet wide on county roads? (Ex. a planter, combine, cultivator)

_____ Yes

_____ No (Q. 11a)

b. What type of equipment was that?

____

____

____

____

c. What was the width of this equipment when traveling on county roads?

____________________ ft. wide

11a. Please think about all the vehicles and farm equipment that you or other members of your farming operation drove on the county roads in the study area. In 1982, did you ever take an alternate route ________?
(reason)

[IF YES, ASK b AND c]

b. With what equipment or vehicles did you take an alternate route ________?
(reason)

[HAND R THE BLUE MARKER AND MAP]

c. We are going to call this route ______________. Using this marker, would
(letter from c)

you draw the route you took ________?
(reason)

[REPEAT a THROUGH c FOR ALL REASONS]

Reason	a Take Yes	a Take No	b What equipment	c Route letter
because of narrow bridges	1	2		A
because of weight limits on bridges	1	2		B
because of weight limits on roads	1	2		C
because of dirt roads	1	2		D
to avoid heavy traffic on roads	1	2		E
to use gravel roads with a tractor	1	2		F
to avoid gravel roads with a car	1	2		G
for any other reason ______ (Specify)	1	2		H

[HAND R THE WHITE CARD]

12. Now we'd like you to think about the use of pickup trucks on your farm. Would you look at the white card which lists reasons a pickup might be used. Keeping these reasons in mind, we'd like you to think about how often you or other members of your farming operation traveled with a pickup on county roads to <u>each</u> tract you operated.

[ASK a THROUGH e FOR EACH TRACT R OPERATES]

a. In 1982, during the winter months, how often did someone go to tract ________ (number) with a pickup?

b. In 1982, during the spring months, how often did someone go to tract ________ (number) with a pickup?

c. In 1982, during the summer months, how often did someone go to tract ________ (number) with a pickup?

d. In 1982, during the fall months, how often did someone go to tract ________ (number) with a pickup?

e. When you traveled to tract ________ (number), generally, which tract were you coming from?

	a Winter		b Spring		c Summer		d Fall		e
Tract number	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	From which tract?
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___

13. Still thinking about your pickup, now we'd like to know all of the places you traveled off the farm with this vehicle for farm business or activities.

a. In 1982, to what cities, towns or locations did you or other members of your farming operation travel with a pickup to do farm business?

[DO NOT INCLUDE HAULING PRODUCTS HERE - THEY WILL BE RECORDED LATER]

[ASK b THROUGH e]

b. In the winter months, how often did someone go to __________ (location) with a pickup to do farm business?

c. In the spring months, how often did someone go to __________ (location) with a pickup to do farm business?

d. In the summer months, how often did someone go to __________ (location) with a pickup to do farm business?

e. In the fall months, how often did someone go to __________ (location) with a pickup to do farm business?

f. Thinking of all the trips made with a pickup to __________ (location), what percent were from tract 1?

[REPEAT FOR EACH CITY, TOWN, LOCATION]

a	b Winter		c Spring		d Summer		e Fall		f
City, town location	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	Percent from tract 1
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___
	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	______	D W M SEA.	___ ___ ___

14. [HAND R THE PINK CARD]

Listed on the pink card are types of farm vehicles. We want to know about the use of vehicles like these on your farm. Would you think about all of the vehicles used for activities you engage in from spring tillage through fall field work. Do not include grain hauling or the use of the pickups since we are recording those trips elsewhere. We will record trips with these vehicles to all tracts, but only want to consider trips if the vehicle traveled on county roads.

[ASK FOR ALL VEHICLES]

a. In 1982, was a ______________ used on your farm and driven on county roads?
(vehicle type)

[IF YES, ASK b THROUGH d]

b. Where did this _________ come from?
(vehicle)

[ASK c AND d FOR EACH TRACT VEHICLE CAME FROM]

c. To which tracts did the _________ go?
(vehicle)

[ASK FOR EACH ROUTE INDICATED IN b AND c]

d. How many times was that trip taken?

[REPEAT FOR EACH VEHICLE TYPE]

	a		b	c	d	b	c	d	b	c	d
	Used										
Vehicle type	Yes	No	Where from?	Where to?	No. of times	Where from?	Where to?	No. of times	Where from?	Where to?	No. of times
a tractor alone	1	2	___ ___	___ ___	___	___ ___	___ ___	___	___ ___	___ ___	___
			___ ___	___ ___	___	___ ___	___ ___	___	___ ___	___ ___	___

a tractor pulling farm equipment	1	2	__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
			__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
a pickup pulling farm equipment	1	2	__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
			__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
combines	1	2	__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
			__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
an automobile	1	2	__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
			__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
any other vehicles	1	2	__ __ __ __	____	__ __ __ __	____	__ __ __ __	____
Specify ____________			__ __ __ __	____	__ __ __ __	____	__ __ __ __	____

15. Now I am going to ask several questions about your farm machinery. On which tract or tracts is most of your farm machinery kept or stored?

____

16. How many combines did you use in 1982?

___ ___ [IF NONE, GO TO Q. 17]

a. Tell me the make and model of each combine?

b. How many rows is the cornhead?

c. What was the size of the beanhead?

a Make & model	b Cornhead	c Beanhead
	___ ___ rows	______ ft.
	___ ___ rows	______ ft.
	___ ___ rows	______ ft.

17. How many tractors did you use in 1982?

_______ [IF NONE, GO TO Q. 19]

[FOR EACH TRACTOR, ASK 18a, 18b and 18c]

18. I'd like to ask some questions about each tractor you used. Let's begin with the largest tractor.

a. What is the make and model of this tractor?

b. What horsepower is this tractor?

[ASK a FOR ALL, THEN ASK b AND c FOR EACH TRACTOR]

c. Thinking of all the times someone took a tractor on county roads in 1982, what percent of the time was this tractor used?

(a) Make & model	(b) Horsepower	(c) % of time used

19. How many trucks did you or other members of your farming operation own in 1982?

___ ___ [IF NONE, GO TO Q. 24]

20. How many of these were pickups?

___ ___

21. How many of these were single-axle trucks other than a pickup?

___ ___

22. How many of these were tandem-axle trucks?

___ ___

23. How many of these were semis?

___ ___

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24. Now we would like you to think about the products that were hauled from a tract to another location using county roads. This could include transporting from a field to on-farm storage, to the elevator, to market, as well as to any other location. Please include custom hauling, as well as hauling done by any other member of your farming operation. Include trips for products hauled in 1982 even if they were produced in another year.

[ENTER TRACT NUMBER IN COLUMN BELOW AND ASK ...]

a. What products were hauled from tract ________ (number) using county roads? [LIST PRODUCTS IN COL. a, THEN ASK b THRU f FOR EACH PRODUCT]

b. Approximately how many loads of ________ (product) were hauled using county roads?

c. Thinking of on-farm as well as off-farm locations, where was the ________ (product) hauled? [ASK d THRU f FOR EACH LOCATION

d. How many loads did you take to ________ (location)?

[HAND R YELLOW CARD] e. Looking at the yellow card, which lists types of hauling vehicles, would you tell me the code number for the type of vehicle used to haul the ________ (product) to ________ (location)?

f. When hauling grain, what was the average number of bushels hauled per trip to ________ (location)?

Tract number	a Product hauled	b Total no. of loads hauled	c Where to?	d No. of loads to location	e Type of vehicle	f Avg. bu. hauled
			________	__ __	__ __	________
			________	__ __	__ __	________
____			________	__ __	__ __	________
			________	__ __	__ __	________

25. In this section of the interview we would like some information about personal and family travel. First we will ask some questions about your household.

In 1982, how many people were living in this household. Include college students who may be away temporarily as well as anyone else who lives here and has no other home.

__ __

a. What is the first name of each household member? [ENTER IN COLUMN a]

[ASK b AND c FOR EACH HOUSEHOLD MEMBER]

b. What was ________ age on his/her last birthday?
(member)

c. What is ________ relationship to the head of the household?
(member)

a Household member	b Age	c Relationship
________________	__ __	________________
________________	__ __	________________
________________	__ __	________________
________________	__ __	________________
________________	__ __	________________
________________	__ __	________________
________________	__ __	________________

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26. How many of these people operated a motor vehicle?

__ __

27. Next we would like some information about where household members go for various activities. We want the names of towns or cities, not the specific store, bank, etc.

a. In 1982, generally where did your family go ________ (activity)? [ENTER NAME OF EACH CITY OR TOWN]

Activity	City/town
a) to do their shopping	________ ________ ________ ________
b) to school (preschool) or to attend school functions. Do not include rides on the school bus.	________ ________
c) to attend church services or activities	________
d) to attend social functions, visit friends and relatives or go for recreation	________ ________ ________

e) to attend meetings	______ ______
f) to do banking or other family business	______ ______
g) to see a doctor or dentist	______ ______
h) to work off the farm	______ ______
i) to do any other activities not mentioned (specify what) ______	______

[ENTER IN COLUMN a) BELOW THE NAME OF EACH TOWN OR CITY LISTED IN QUESTION 27
ASK QUESTIONS b THROUGH f FOR EACH CITY OR TOWN]

28a. Next we would like you to think about how frequently your family goes to each town or city. Please think of all household members as well as all the different reasons in order to determine how many total trips were taken. You may give your answer on a daily, weekly, monthly basis or as a total for the time period (season).

b. Thinking of the winter season, how often did household members go to ______ (city)?

[ENTER NUMBER AND CIRCLE FREQUENCY]

c. During the spring season, how often did household members go to ______ (city)?

d. During the summer season, how often did household members go to ______ (city)?

e. During the fall season, how often did household members go to ______ (city)?

[IF NO CHILDREN IN HOUSEHOLD, SKIP (f)]

f. When you go to ______ (city), what percent of the trips you take are only to transport your children to and from their activities such as school, doctors, dentists and recreation?

a	b		c		d		e		f
	Winter		Spring		Summer		Fall		
City/Town	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	No. of times	Frequency	Percent
1.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
2.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
3.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
4.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
5.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
6.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
7.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
8.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
9.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
10.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
11.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %
12.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	_____	D W M SEA.	___ ___ ___ %

[HAND R THE ORANGE CARD]

29a. Would you look at the orange card which lists products which may have been delivered to you. Thinking of any products like these, would you tell me, in 1982 did you have any of these kinds of deliveries made to your place?

___ Yes

___ No (Q. 30)

b. What types of products were delivered?

[LIST ALL IN COLUMN b AND ASK c AND d FOR EACH]

c. From what town or city was the ______ (type) delivery made?

[ASK d FOR EACH LOCATION]

d. During 1982, how many times did you have ______ (type) delivered from ______ (city)?

[ENTER NUMBER AND CHECK FREQUENCY IN COLUMN d]

(b) Type of delivery	(c) Location of dealer	(d) No. of times	Da	Wk	Mo	Yr

30. In this last section we'd like some information about people who came onto your place in 1982.

a. During 1982, did you have ________ (visitor) come to your place?

[IF YES, ASK b, c AND d]

b. To which tract did these ________ (visitors) usually come?

c. Generally, what city or town were these people coming from?

[IF RESP. CANNOT GIVE CITY OR TOWN, PROBE FOR DIRECTION]

d. During 1982, how many times did ________ (visitor) come from ______ (city) to your place? [ENTER NUMBER AND CHECK FREQUENCY COLUMN]

Type of visitor	a Have? Yes	No	b Where to (Tract no.)	c Where from? (city, town)	d No. of times	Da	Wk	Mo	Yr
Repairmen or workmen	1	2							
Salespeople	1	2							

Guests or relatives or neighbors	1	2				
Hired help such as a cleaning lady, baby-sitters or yardmen	1	2				
Veterinarian or farm hands	1	2				
Any others? [Specify who] ________	1	2				

31. We are interested in knowing what your plans are for the future.

a. Do you expect to be farming here in ____________?
(time period)

[IF NO, ASK a FOR NEXT TIME PERIOD]

b. Do you plan to change the size of your farming operation in ____________? [IF NO, GO TO NEXT TIME PERIOD]
(time period)

c. Would this change be an increase or a decrease?

	a Farming?		b Change size?		c How change?	
Time period	Yes	No	Yes	No	Inc.	Dec.
5 yrs.						
10 yrs.						
15 yrs.						
20 yrs.						

This completes our interview. Is there anything else you would like to tell us about your travel?

____

____

Iowa State University appreciates your help with this project.

Ending time ___ ___ : ___ ___

Total minutes of interview ___ ___ ___

[INTERVIEWER COMPLETE THIS PORTION AFTER LEAVING RESPONDENT'S HOME]

In general, how would you rate the reliability of the information given?

1 = very reliable

2 = generally reliable

3 = not very reliable } Why? ______________________________

4 = poor } ______________________________

____

Was there anything about the respondent or interview setting which you feel affected the quality of the interview?

___ No

___ Yes ——> Explain ______________________________

____

____

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