Restructuring the Local Rural Road System

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The construction of new local rural roads and the improvement of existing rural roads are major components of most economic development plans in developing countries. However, many observers believe that the problem in the United States is that there are too many local rural roads. Most of today's local rural roads and bridges were constructed in the late 1800s and early 1900s when traffic consisted of horse-pulled wagons and light vehicles that served many small farms and rural households. The number of farms and households on these roads has declined sharply in recent decades, and most vehicles traveling on them are heavier and wider than those for which the roads were originally designed. The physical condition of this road system is deteriorating, and funds are insufficient to maintain and reconstruct these roads to the level needed to accommodate the large vehicles currently traveling on them. A recent analysis indicated that a modest road abandonment program would result in cost savings to local governments greater than the additional costs to the traveling public of driving on rerouted roads. This analysis, which is an extension of the earlier research just mentioned, examines how paving a core system of local rural roads would affect the benefits and costs of local rural road abandonment. The results of this analysis indicate that the direct benefits of constructing a core of paved local rural roads are fewer than the costs of building the paved core. However, the estimated benefits do not account for cost savings from overhead traffic that may travel on the newly paved road, economic development, or changes in traffic origins and destinations. The main conclusion of this analysis is that the paved core has little impact on the benefit-cost ratios of road abandonment.

THE PROBLEM

Investments in local rural roads are a major component of economic development plans in many developing countries. The basic strategy of these investments is to improve the quality of roads and to reduce the cost of access to people and products, especially farmers and agricultural products. The type of investments in local rural roads varies with the needs of individual countries. In Southeast Asia, many local rural roads are designed to accommodate pedestrians, bicycles, oxcarts, and light motorized vehicles. China recently embarked on a program to construct 96,000 km of rural roads to provide all-weather access to isolated villages and to provide access to people and products, mostly coal and agricultural products, to railroads, and to other regions in the country. The 1982 Food Program in the Soviet Union calls for construction of 130,000 km of general-use roads and 150,000 km of intra-farm roads in the next decade. One Russian economist estimates that it will be necessary to build 900,000 to 1,000,000 km of all-weather, paved roads to serve most of the rural population in the Soviet Union (*1*).

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The local rural road situation is different in the United States, in which the creation of 2.3 million road-miles dates back to the Ordinance of 1785, which was passed by Congress to open the land for settlement (*2*). The Ordinance established the 1-mi^2 grid pattern on which most roads built thereafter were based. Road use needs have changed significantly since 1785. The land is now settled; vehicle size and weight have increased dramatically; the days of long trips to deliver agricultural products after harvest are gone; and most farmers now live within a few miles of a grain elevator or other product markets. Many observers therefore believe that there are now too many local rural roads in the United States.

Many of today's local rural roads and bridges, which are defined as those under county or township jurisdiction, were built in the late 1800s and early 1900s when overland transportation for both passengers and freight was limited to horse and wagon or to the recently built railroad lines. Farms were small and farmers needed road access to homes, schools, churches, and markets.

During the 1920s and 1930s, local rural roads were mainly surfaced with gravel, and some bridges were replaced to carry 6- or 7-ton loads. Since then, the number of farms has declined but the size of farms has increased. Consequently, an increasing number of heavy vehicles travel on these rural roads. In most instances, a farmer increases the number of acres farmed by buying or leasing land from other farmers, frequently from non-adjoining farms. The increased scatter of tracts of land operated by one farmer that results often requires longer travel distances and larger farm equipment. Farmers are now using large tandem-axle and semitrailer trucks, farm tractor-wagon combinations, and combines to travel these roads from homesteads to fields and back.

Farm supply and marketing firms are also using large tandem-axle and semitrailer trucks for their pickups and deliveries. Moreover, the declining rural population in many areas is forcing school districts to use larger school buses to transport fewer children longer distances to consolidated schools. These larger school buses weigh up to 15 tons when fully loaded and cannot cross bridges that are posted at less than their gross loaded weights. Heavier vehicles demand increased maintenance, resurfacing, and reconstruction costs because gravel and paved roads deteriorate much faster under the heavier weights.

Precise data on the condition of the local rural road system are not available. Among the ample evidence that the system is deteriorating rapidly is a recent survey taken in Illinois. Farmers and agribusiness representatives rated about half of the Illinois local rural roads as needing more than regular maintenance, and rated over 20 percent of these roads as needing major repair (*3*). The most common complaints in the survey about local rural roads were that (a) overweight vehicles are breaking up road surfaces, (b) the lack of paved surfaces

creates dust and rideability problems, (c) road widths and other design characteristics are inadequate for today's large farm equipment and heavy trucks, and (d) narrow lanes create safety problems.

The condition of local bridges is also of great concern. On January 1, 1986, 167,985, or 55 percent, of all the bridges inventoried in the United States operating without federal aid were found to be deficient (*4*). In addition, 121,507, or 40 percent, of the 304,948 bridges inventoried were posted or should have been posted at less than legal weight limits. This means that many heavy farm vehicles cannot or should not travel over these bridges, which is an obvious problem for farmers with full truckloads of agricultural commodities to deliver. However, even these statistics understate the magnitude of the problem. Bridges less than 20 ft long were not included in the inventory, and there are thousands of such structures that need replacement or rehabilitation.

The distribution of deficient bridges among states 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, Arkansas, Tennessee, Mississippi, and Illinois. States in the Northeast, Midwest, Southeast, and Southwest regions of the United States are included in groups with a high percentage or a large total number of deficient bridges.

To a large extent, the county road system faces many of the same problems that the railroad system encountered in the late 1960s and early 1970s. The physical condition of the county road system is deteriorating. The heavier vehicles traveling on the system are causing more damage, whereas the available money, in real terms, to maintain and rebuild the system is not keeping up with the rate of deterioration. Although federal and state motor vehicle fuel taxes have increased sharply in recent years, there is increasing pressure to reallocate a larger share of these taxes to roads that are under city and state jurisdictions instead of local jurisdictions. Moreover, a substantial share of the funds to maintain local rural roads comes from property taxes. The recent decline in rural property values throughout much of rural America will place downward pressure on this source of rural road funds. In short, the problem is that funds are insufficient to properly maintain the existing road system for the types of vehicles that are traveling on it.

Public debate about the county roads has focused mainly on the deteriorating condition of the system. The implicit assumption behind much of this debate is that the system should be maintained as it currently exists. However, an increasing number of observers believe that the number of miles of local rural roads could be reduced either by abandonment or conversion to private drives. 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 a county road system (*2*).

Residents on roads that are being considered for abandonment or conversion to private drives argue that these actions will force farmers and rural residents to drive longer distances, and that the additional travel and maintenance costs will exceed the cost savings of removing these roads from the public system.

Many writers have discussed the deteriorating condition of the local rural road and bridge system (*5*). However, only a few studies have attempted to identify alternative solutions (*2, 3, 6-10*). Fewer yet have attempted to quantify the impacts of the deteriorating roads and bridges on all travel costs or the impacts of alternative solutions on travel costs and local government costs. The Pennsylvania Department of Transportation identified which roads in two Pennsylvania counties were most important to the rural agricultural areas for the transport of agricultural products to market and supplies to the farm (*11*). Tucker and Thompson examined the impact of alternative rural road development and maintenance policies on grain marketing costs in southeastern Michigan (*12*). The results of their study indicated that grain marketing costs would decrease as the road system is improved, but the savings in grain transport costs would be far less than the costs of the road improvement. Nyamaah and Hitzhusen used a circuity model to estimate the rerouting costs to road users when 15 rural bridges in Ohio were posted or closed (*13*). The model indicated that the benefits from bridge repair or replacement were substantially greater than the county engineers estimated. Chicoine and Walzer surveyed farmers, township officials, and agricultural and rural business officials to identify their opinions and attitudes on a wide range of rural road and bridge questions and issues (*6*).

Hamlett et al. analyzed the benefits and costs of abandoning low-volume gravel- and earth-surfaced local rural road segments that contained no property access (*8*). The analysis indicated that if a small number of road segments with no property access were abandoned in three different areas in Iowa, the additional travel costs incurred from rerouting the traffic around the abandoned roads would be less than the maintenance and investment cost savings derived from abandoning the roads. However, as the number of abandoned roads was increased, the travel costs for the rerouted traffic increased faster than the maintenance and investment cost savings derived from abandoning the roads, which suggested that the optimal level of abandonment had been exceeded. This analysis is extended in this paper by examining the impact of paving a core system of local rural roads on the benefits and costs of road abandonment.

Although this study focused on three areas in Iowa, its findings have a broader scope of application. Even though other rural areas of the United States may produce different agricultural products, most have a similar grid-based road network, and most face the same basic problem: funds are insufficient to maintain the same number of miles of road at a service level high enough to accommodate the type of traffic now operating on these roads. Developing nations may face a slightly different version of this problem: insufficient money is available to construct as dense an infrastructure as exists in most developed countries. The methodology described in this paper can be applied to different data and road networks. Developing nations might also find it useful to construct hypothetical road and bridge systems, and apply the method of analysis described briefly in the following paragraphs, and in more detail in Baumel et al. (*10*).

METHOD OF ANALYSIS

Study Areas

The county roads in the three 100-mi^2 areas in Iowa discussed earlier were included in the analysis. These three study areas

were selected for their differences in terrain, quality of roads and bridges, and the level and type of economic activity. Area 1, located in east central Iowa just north of Cedar Rapids, has a large nonfarm population, a productive cash-grain agriculture, a relatively high percentage of paved roads, and a level terrain. Area 2, located in southwest Iowa, has a relatively small population of farm and nonfarm residents; a relatively large but declining livestock industry; a high percentage of gravel, oiled, and earth surface county road systems; and a hilly terrain with many bridges. Area 3, located in north central Iowa, has a small farm and nonfarm population, a high cash-grain agriculture, a relatively well-developed paved road system, and level terrain. Data for the study were gathered by interviewing all residents of the three study areas. Townships located within two of the areas were sampled, and surveys for similar households were substituted for those few households that refused to be interviewed. A more detailed description of the data follows in a later section.

Previous Analysis

In the Baumel et al. study, a "base solution" was created for each study area, which consisted of computerizing the road network as it actually existed in 1982, and using a computer model to route the traffic patterns as they were reported in the survey (*10*). For each alternative solution analyzed, changes were made to the computerized road network, and the 1982 traffic patterns were rerouted by computer over the "new" network. Changes in costs to the traveling public were thus defined as the difference between the previous solution's estimate of the cost of traveling on that road system and the estimated cost of traveling on the new road network. In this report, the paved core solution was compared to the base solution. A set of low-volume road segments with no property access was then abandoned in the computer network and benefit-cost ratios were calculated for the abandonment solutions. Two solutions per study area were developed: a paved core solution, and a paved core with some roads abandoned solution.

Paved Core Analysis

First, an analysis was made of the cost savings to the traveling public from paving a core system of local rural roads. Because vehicle travel costs are lower on paved roads than on gravel- or earth-surfaced roads, total vehicle travel costs should decline when using the paved core system. Then the estimated cost of paving and maintaining the core system over the original road network was annualized and compared with the savings to the traveling public. Travel cost savings were defined as follows:

$$C_t = TC_{j-1} - TC_j \tag{1}$$

where

C_t = travel cost savings from paving and maintaining a paved core system;

TC_{j-1} = the total annual vehicle transportation costs before the j^{th} set of road segments is upgraded; and

TC_j = the total annual vehicle transportation costs after the j^{th} set of road segments is upgraded.

The cost of paving and maintaining the road system over the original was defined as follows:

$$C_{pm} = UPG_j + (MC_j - MC_{j-1}) + (REC_j + REC_{j-1}) + (RES_j - RES_{j-1}) + (BREC_j + BREC_{j-1}) + (BMC_j - BMC_{j-1}) \tag{2}$$

where

C_{pm} = change in the annualized cost of paving and maintaining a paved core system;

UPG_j = the total annualized upgrading cost for the j^{th} set of road segments;

MC_j = the total annual road maintenance cost after the j^{th} set of road segments is upgraded;

MC_{j-1} = the total annual road maintenance cost before the j^{th} set of road segments is upgraded;

REC_j = the total annualized life-cycle roadbed reconstruction cost after the j^{th} set of road segments is upgraded;

REC_{j-1} = the total annualized life-cycle roadbed reconstruction cost before the j^{th} set of road segments is upgraded;

RES_j = the total annualized life-cycle road resurfacing cost after the j^{th} set of road segments is upgraded;

RES_{j-1} = the total annualized life-cycle road resurfacing cost before the j^{th} set of road segments is upgraded;

$BREC_j$ = the total annualized life-cycle bridge reconstruction cost after the j^{th} set of road segments is upgraded;

$BREC_{j-1}$ = the total annualized life-cycle bridge reconstruction cost before the j^{th} set of road segments is upgraded;

BMC_j = the total annual bridge maintenance cost after the j^{th} set of road segments is upgraded; and

BMC_{j-1} = the total annual bridge maintenance cost before the j^{th} set of road segments is upgraded.

Abandonment Analysis

A benefit-cost analysis was used to evaluate the economics of abandoning selected road segments in the three study areas after the core system was paved. The benefits derived from keeping the roads selected for abandonment were defined as the additional travel costs incurred by the traveling public when the roads were removed from the system. The traveling public would incur additional travel costs when roads were abandoned because some traffic must travel longer distances to reach an intended destination, or travel on lower-quality road surfaces. The costs of keeping the roads considered for abandonment included the variable and fixed road maintenance, road resurfacing and reconstruction, and bridge maintenance and reconstruction costs on the abandoned roads minus the variable maintenance, resurfacing, and reconstruction costs transferred to the roads inheriting the traffic from the abandoned roads. The costs also included the land rental value forgone from using the land for roads instead of agricultural production, minus the cost of converting the land from road to agricultural use.

The following benefit-cost ratio was used to evaluate whether a road segment, group of road segments, or bridge should have

remained in the county road system after the core system was paved:

$$\frac{B}{C_{j_A}} = (TC_j - TC_{j-1}) \, [(MC_{j-1} - MC_j) + (REC_{j-1} - REC_j) + (RES_{j-1} - RES_j) + (BREC_{j-1} - BREC_j) + (BMC_{j-1} - BMC_j) + (VL_j - ROW_j)]^{-1} \quad (3)$$

where

$\frac{B}{C_{j_A}}$ = the abandonment benefit-cost ratio of the j^{th} set of road segments;
TC_j = the total annual vehicle transportation costs after the j^{th} set of road segments is abandoned;
TC_{j-1} = the total annual vehicle transportation cost before the j^{th} set of road segments is abandoned;
MC_{j-1} = the total annual road maintenance cost before the j^{th} set of road segments is abandoned;
MC_j = the total annual road maintenance cost after the j^{th} set of road segments is abandoned;
REC_{j-1} = the total annualized life-cycle roadbed reconstruction cost before the j^{th} set of road segments is abandoned;
REC_j = the total annualized life-cycle roadbed reconstruction cost after the j^{th} set of road segments is abandoned;
RES_{j-1} = the total annualized life-cycle road resurfacing cost before the j^{th} set of road segments is abandoned;
RES_j = the total annualized life-cycle road resurfacing cost after the j^{th} set of road segments is abandoned;
$BREC_{j-1}$ = the total annualized life-cycle bridge reconstruction cost before the j^{th} set of road segments is abandoned;
$BREC_j$ = the total annualized life-cycle bridge reconstruction cost after the j^{th} set of road segments is abandoned;
BMC_{j-1} = the total annual bridge maintenance cost before the j^{th} set of road segments is abandoned;
BMC_j = the total annual bridge maintenance cost after the j^{th} set of road segments is abandoned;
VL_j = the annual value of the land if the j^{th} set of road segments is not maintained; and
ROW_j = the annualized cost of converting the right-of-way of j^{th} set of road segments to agricultural production.

If the value of the ratio in Equation 2 was less than 1, the net benefit to the traveling public of keeping the road in the system would be less than the cost of keeping the road in the system. If the ratio was greater than 1, the net benefit to the traveling public would be greater than the cost.

Network and Algorithm

The benefits derived from keeping a road or group of roads in the system were measured as the change in travel cost to the traveling public after a road or group of roads was abandoned in the computer model. Except for school bus and post office travel costs, the benefits accruing to the traveling public 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 (*9*). The network model for each study area included all roads by type of surface; all bridges by load-bearing capacity; all property and field tract access points; and all trips by origin, destination, and vehicle type. Travel costs were defined as the variable vehicle cost per mile by type of road surface times the number of miles traveled by each vehicle type on each type of road surface. Dijkstra's algorithm was chosen to estimate the minimum-cost routing of travel from each origin to each destination for each vehicle type because it preserved the origin-destination relationship and required relatively few operations to find an optimal solution. The actual estimation of the benefit to the traveling public of keeping a road or group of roads in the system was calculated as follows:

1. The computerized algorithm was run to route the trips through the study area to obtain the total miles traveled and cost of this travel.
2. The computerized road network was adjusted by removing a set of road segments.
3. The algorithm was run again to reroute trips through the adjusted road network to obtain the total miles traveled and cost of the travel on the adjusted network.
4. The change in travel costs between the two solutions became the estimated benefit from keeping all the roads indicated for abandonment in the system.

The basic assumptions behind the network model used in this analysis were as follows:

1. Travel costs are a linear function of distance traveled for each vehicle and surface 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 relatively small changes in distance between an origin and a destination resulting from a change in the road system.
4. Travel routes are selected to minimize travel costs.
5. Vehicles with a gross weight greater than the rated loading of a bridge cannot cross that bridge.

Detailed specifications of the network model are presented in Pautsch et al., and more complete abandonment results are presented in Hamlett et al. (*8, 9*).

School bus and post office travel costs could not be estimated by the network model because much of the routing of these vehicles depended on how the routes were structured outside the study areas. Existing school bus routes were used to estimate travel costs for Step 1 of the study. The school buses were then rerouted manually after selected roads were removed from the system to obtain the change in school bus travel costs resulting from road abandonment. Postal service travel routes and costs before and after selected roads were eliminated from the system were estimated by U.S. Postal Service officials.

Maintenance Costs

The total maintenance cost for paved, gravel, and dirt roads is the sum of the fixed maintenance costs and the variable maintenance costs of the roads.

The fixed portion of maintenance cost is independent of traffic level and composition, and is associated with signing, slope erosion, ditching, and snow removal. The variable portion of maintenance cost for gravel and dirt roads is expressed as a function of the average daily traffic level of the road, whereas the variable portion of maintenance cost for paved roads is expressed using kip loadings (*10*).

The basic assumption underlying the variable maintenance cost of a paved road is that a portion of the cost varies directly with the number of standardized (18 kip) axle loads passing on the road. Each type of pavement is designed to withstand a projected number of 18 kip loadings during the expected life of the road. An increase in the number of axle loadings in the form of more trips or heavier vehicles will increase the maintenance cost of the road surface. Variable maintenance costs for paved roads were estimated by using the following equation:

$$VMC = \frac{TK}{AK} \bullet AVMC \bullet D \tag{4}$$

where

VMC	=	variable maintenance cost;
TK	=	total number of standardized (18 kip) loadings applied in 1982;
AK	=	average annual standardized (18 kip) axle loadings embodied in pavement;
$AVMC$	=	average annual variable maintenance cost per mile of road; and
D	=	length of the road segment in miles.

Equation 4 adjusts the average annual maintenance per mile of road for changes in the number of trips and the size and weight of vehicle travel.

The periodic reconstruction and resurfacing costs were annualized over a 45-yr life cycle. The opportunity cost of keeping the land in roads instead of alternative uses was assumed to be the annual rental value of nearby land minus the annualized cost of converting land from abandoned road right-of-way to use in agricultural production.

THE DATA

Travel Patterns

Data on 1982 personal and farm travel were obtained from a traffic survey of households and farms in the three study areas (*10*). Data were obtained on the exact location of each respondent's home and land tracts within and outside the study areas, as well as the location of all home and field driveways. In addition, the number of yearly trips by vehicle type was collected for each farm or household in the following categories:

- The origin of deliveries to each home and field tract;
- The origin and destination of pickup truck and farm equipment trips;
- Intra- and off-farm product hauling by type of product, origin, and destination;
- Personal trips by origin and destination; and
- The origin of visits to each household.

Of the 753 farms that were interviewed, 727 completed farm questionnaires, for a response rate of 96.5 percent. Of the total of 1,205 households that were interviewed, 1,146 completed questionnaires, for a response rate of 95.1 percent. Neighbors were questioned about the characteristics of farms and households for those that refused to be interviewed, and questionnaires from respondents with similar traits were substituted in their place.

The questionnaire did not include data on school bus, post office, and overhead traffic because this traffic did not originate and terminate within the study area. School bus routes were obtained from school districts that operated buses in the study areas. The U.S. Postal Service provided data on postal routes and costs. A "stop-and-go" traffic survey was conducted in study Area 1 to obtain data on overhead traffic traveling through but not originating or terminating in the study area. Because of their rural characteristics, study Areas 2 and 3 were judged to have an insignificant amount of overhead traffic on county roads.

Vehicle Travel Costs

Over 100 different types of vehicles traveled over the county roads in the three study areas. The large number of vehicles made it necessary to group several different types of vehicles together, and to then estimate costs for a typical vehicle in each group. The major vehicle groups for which travel costs were estimated were automobiles; pickup trucks; school buses; commercially owned vans and trucks; garbage trucks; farmer-owned single-axle, tandem-axle, and semitrailer trucks; and three farm combine sizes and four farm tractor sizes, each pulling seven sizes of grain wagons or farm tillage equipment. Variable operating costs per mile were estimated for each of these vehicle groups operating on paved, gravel, and dirt roads in which variable operating costs include fuel, oil, tires, maintenance, and travel time. Variable costs were assumed to be a linear function of the number of miles traveled on each surface type, and were therefore estimated in cents per mile. The costs were based on 1982 prices and representative vehicles. In cases where 1982 prices were not available, those prices that were available were adjusted to 1982 price levels. The cost-per-mile estimates and the estimation procedures are described in Hansen et al. (*14*).

A travel time penalty was added to the travel cost of the time-critical farming operations of planting and harvesting, if changes in the road system created additional travel distances for these operations. The travel time penalty was estimated by calculating how much it would cost the farmer to increase machine capacity in order to drive the additional distance and complete the time-critical farming operation in the same total time required before the change in the road system. A description of this procedure is presented in Baumel et al. (*10*).

Maintenance costs for paved roads and reconstruction and resurfacing costs for all roads were obtained from the Iowa Department of Transportation (*15*). Maintenance costs for bridges and paved, gravel, and dirt roads, as well as the costs of converting land from abandoned road right-of-way to use in agricultural production, were obtained from county engineers.

RESULTS

The base solution in each study area estimated total miles and variable travel costs over the full 1982 road network. A set of

roads was then "paved" to provide a core network of paved roads in each study area, and the network model was rerun to estimate total miles and travel costs with the paved core. Low traffic volume road segments with no property access points were then removed from the computerized road network, and the model was rerun to estimate total miles and travel costs for the abandonment solution. The number of miles of roads that were paved or abandoned by the study area solution is shown in Table 1.

TABLE 1 NUMBER OF MILES OF ROAD PAVED OR ABANDONED BY STUDY AREA SOLUTION

Study Area	Solution	Additional Paved Miles	Miles Abandoned
1	1	29.5	0
1	2	29.5	5.25
2	1	17.25	0
2	2	17.25	9.25
3	1	32.5	0
3	2	32.5	17.75

The estimated changes in travel costs from the base solution to the paved solution and from the paved solution to the abandonment solution by type of travel are shown in Table 2. Total travel costs declined sharply in each paved core solution, and the largest portion of these savings accrued to household and farm travel.

In the abandonment solutions, travel costs increased for all types of travel except for overhead traffic, which had no cost change because no overhead traffic traveled on the abandoned roads. The largest increases in travel costs were for farm traffic, mostly because distances to fields or to farmsteads are typically short, and have fewer rerouting options than the long-distance household trips required to shop and to travel to schools, churches, and other destinations. The long-distance household trips frequently can be rerouted with little or no additional distance. Another reason for the large increase in farm travel costs resulting from road abandonment is that farm vehicle travel costs per mile are sharply higher than for other types of vehicles; therefore, a relatively small change in distance has a great impact on farm travel costs.

The estimated changes in annual road maintenance and investment costs for the three paved core and the three abandonment solutions are shown in Table 3. The average annual net change in the cost of paving roads ranged from $8,554 per paved mile in Area 3 to $10,284 per paved mile in Area 2. These costs were net of the costs of maintaining and reconstructing the roads if they were to remain gravel roads.

The average annual cost savings of road abandonment ranged from $6,621 per mile in Area 3 to $11,024 in Area 2. These cost savings were net of the maintenance and reconstruction costs transferred to roads that would have inherited the traffic from the abandoned roads. This wide range of cost savings is due almost entirely to the large number and length of the bridges on the roads abandoned in the hilly terrain of Area 2.

The estimated maintenance and reconstruction costs in this analysis are the annualized costs needed to maintain an acceptable level of service for the type of traffic on these roads. Some would argue that these cost savings exceed the amount of money currently expended on these roads. However, the system is deteriorating under the current level of expenditures. These roads and bridges will eventually need to be reconstructed to the levels assumed by these cost estimates, or the local government will face large court claims.

The benefits and costs of paving and the benefit-cost ratios for the abandonment solutions, both before and after paving, are shown in Table 4. The direct benefits for the three paving solutions were all less than the net paving costs. This means that the direct reductions in travel costs that resulted from paving a core system were less than the net paving costs. The estimated benefits did not include any cost savings from overhead traffic that may travel over the newly paved roads, changes in traffic origins and destinations resulting from the paved core, or benefits from economic development. Therefore, no benefit-cost ratios were calculated for the paved-core solutions.

The benefit-cost ratios of road abandonment were also all less than one. This means that the additional travel costs from reducing the size of the system were less than the maintenance and investment costs to keep the abandoned roads in the system. However, the benefit-cost ratios from road abandonment for the same set of roads before paving were also less than one and only slightly higher than after paving. This indicates that travel cost savings from paving the roads had relatively little impact on the additional travel costs incurred by abandoning the roads.

TABLE 2 ESTIMATED CHANGE BY STUDY AREA IN TRAVEL COSTS RESULTING FROM PAVING A CORE ROAD SYSTEM, THEN ABANDONING LOW-VOLUME ROADS

	Change in Travel Costs					
	Area 1 ($)		Area 2 ($)		Area 3 ($)	
Travel Type	Pave 29.5 mi	Abandon 5.25 mi	Pave 17.25 mi	Abandon 9.25 mi	Pave 32.5 mi	Abandon 17.75 mi
Households	-153,451	7,355	-25,326	6,226	-19,997	8,992
Overhead	-11,703	0	-	-	-	-
Farm	-16,020	9,473	-14,250	28,768	-25,346	33,165
Farm time penalties	-712	1,858	-321	2,182	-1,359	5,365
School bus	-2,108	5,547	-672	1,051	-1,010	3,818
Post office	0	2,305	0	1,340	0	9,305
Total	-183,994	26,538	-40,569	39,567	-47,712	60,645

TABLE 3 ESTIMATED CHANGE BY STUDY AREA IN 1982 ANNUAL MAINTENANCE AND INVESTMENT COSTS FROM PAVING A CORE SYSTEM, THEN ABANDONING SELECTED ROADS

	Change in Travel Costs					
	Area 1 ($)		Area 2 ($)		Area 3 ($)	
Change in	Pave 29.5 mi	Abandon 5.25 mi	Pave 17.25 mi	Abandon 9.25 mi	Pave 32.5 mi	Abandon 17.75 mi
Road costs						
Variable maintenance	-29,584	501	-10,501	675	-10,936	-11,895
Fixed maintenance	-32,813	-12,258	-29,014	-20,957	-40,232	-42,174
Resurfacing	67,489	13	35,173	51	69,731	-2,386
Reconstruction	-124,728	-7,604	-34,871	-11,116	-36,922	-19,014
Paving	382,369	-	215,535	-	290,243	-
Bridge costs						
Maintenance	0	-1,284	0	-10,159	0	-3,120
Reconstruction	3,268	-8,441	1,084	-57,807	6,108	-19,618
Net land rental value less land reconstruction costs	0	-7,184	0	-2,663	0	-19,313
Total	266,001	-36,257	177,406	-101,976	277,992	-117,520
Average net change per mi	9,017	-6,906	10,284	-11,024	8,554	-6,621

TABLE 4 CHANGE BY STUDY AREA IN TRAVEL AND ANNUAL MAINTENANCE AND INVESTMENT COSTS AND BENEFIT-COST RATIOS FOR ABANDONMENT BEFORE AND AFTER PAVING

	Area 1 ($)		Area 2 ($)		Area 3 ($)	
	Pave 29.5 mi	Abandon 5.25 mi	Pave 17.25 mi	Abandon 9.25 mi	Pave 32.5 mi	Abandon 17.75 mi
Change in travel costs	-183,994	26,538	-40,569	39,567	-47,712	60,645
Change in annual maintenance and investment costs	266,000	-36,258	177,406	-101,977	277,992	-117,520
Benefit-cost ratio	-	0.73	-	0.39	-	0.52
Abandonment benefit-cost ratio prior to paving (*8*)	-	0.77	-	0.39	-	0.71

SUMMARY AND CONCLUSIONS

This study estimated the impact of the construction of a core of paved roads on the benefits and costs of abandoning low-volume roads in three study areas in Iowa. The following conclusions can be drawn from the results of this analysis:

- Construction of a core of paved roads results in a decline in travel costs, primarily because vehicle costs are lower on paved roads. However, net maintenance and investment costs increase sharply with the paved core.
- The reduced travel costs that result from the use of the paved core are less than the increased maintenance and investment costs in each of the three areas. However, the reduced travel costs do not include any cost savings from overhead traffic that may travel on the newly paved roads or from changes in origins and destinations as a result of use of the paved core or benefits from economic development. Therefore, these results should be interpreted only in terms of their impact on abandonment decisions and not in terms of whether to pave or not.
- A core of additional paved roads has little or no impact on the benefit-cost ratios of road abandonment. The benefit-cost ratios for keeping the three sets of low-volume roads in the three study areas declined only marginally after construction of the paved core in Areas 1 and 3, and not at all in Area 2. Abandonment becomes only slightly more economical after paving in Areas 1 and 3, and is equally valued before and after paving in Area 2. Abandonment of a small number of low-volume roads with no property access remains a highly economical option in all three study areas.
- It is possible that the indirect benefit of the paved core on other investment strategies could make the construction of a paved core in Area 1 an economical option, or that another set of roads could be paved economically there. However, further analysis is needed to test this hypothesis.

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Financing and Maintaining Low-Volume Roads in the Midwestern United States

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Rural governments in the Midwest have encountered major difficulties maintaining the roads and bridges that are needed to serve rural regions and the agricultural industry. Advances in farming technology have resulted in the use of larger and heavier equipment, which has placed greater load-bearing requirements on low-volume roads and bridges. Weakened property tax bases and shrinking federal and state intergovernmental assistance are resulting in stringent fiscal conditions for responsible local rural governments. Four issues are examined in this paper. First, the uses of rural roads by the farm sector are reviewed. Second, the condition of roads and bridges is described, including detail regarding the costs of upgrading the transportation structures to an acceptable condition. Third, the main revenue sources that fund rural roads and bridges are discussed, including a review of the expected trends in these sources. Fourth, policy options to address the rebuilding of rural road systems are considered. Infrastructure financing issues are not easily addressed. Rising costs, increased demands driven by advancing agricultural technologies and nonfarm business activity, and shrinking revenues are forcing disinvestment unless new revenue sources are used. The magnitude of the costs of upgrading the system to acceptable levels, however, is so large that local rural governments do not have the fiscal capacity to make needed improvements without financial help from states and the federal government. Timing is critical because further delays and continued disinvestment may force costs to rise in the future.

The condition of the nation's infrastructure has been a cause of national concern. Policymakers realized that the cost of upgrading the infrastructure to an acceptable level of perfor-

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