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Rural Road Financing Strategies: Two New Models Applied to North Dakota Counties

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16. Abstract

This study examines consolidation of road services by local governments, and explores the optimal mix of roads for rural counties. A methodology for measuring economies in the provision of local road services is presented. This methodology is unique in two ways: (1) it better accounts for relevant variables that explain expenditures so that economies of size can be measured more accurately; and (2) it does not require an extensive data set, so economies can be measured by region or state. A methodology for optimizing the mix of gravel and paved roads by local governments is also presented. This methodology measures the costs and benefits of converting gravel roads to paved, and paved to gravel.

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EXECUTIVE SUMMARY[1]

The financing of rural roads and bridges is an issue which has a great deal of importance at the national level. Local county and township officials nationwide are faced with a dilemma. The quality of rural roads and bridges is deteriorating rapidly, and the migration of rural residents to urban counties is resulting in a lower tax base in rural areas. Local officials now face a choice of increasing local finances for the maintenance and rehabilitation of rural roads and bridges, consolidating road services with other localities, or abandoning and reducing maintenance of some roads and bridges. Because of the declining tax base in rural areas, it is likely that cost reducing strategies will be necessary in the future.

This study examines consolidation of road services by local governments, and explores the optimal mix of roads for rural counties. A methodology for measuring economies in the provision of local road services is presented. This methodology is unique in two ways: (1) it better accounts for relevant variables that explain expenditures so that economies of size can be more accurately measured; and (2) it does not require an extensive data set, so economies can be measured by region or state. A methodology for optimizing the mix of gravel and paved roads by local governments is also presented. This methodology measures the costs and benefits of converting gravel roads to paved, and paved to gravel.

In applying the methodology for measuring economies of size to counties in North Dakota, significant economies of size in the provision of county road services are shown.

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This suggests that some consolidation of county road services in North Dakota may be beneficial, particularly for very small counties.

The benefit-cost analysis applied to North Dakota counties shows that there are several improvements that could be made in the mix of road services provided. Counties with very high traffic levels may benefit from converting some gravel mileage to paved, while those with very light traffic levels may benefit from converting some paved mileage to gravel.

Further research is needed in the provision of rural road services. More study is needed in modeling local official behavior, creating data collection and management systems at the county government level, and reducing the costs of providing rural road services.

CHAPTER 1

INTRODUCTION

The financing of rural roads and bridges is an issue which has a great deal of importance at the national level. Local county and township officials nationwide are faced with a dilemma. The quality of rural roads and bridges is deteriorating rapidly, and the migration of rural residents to urban counties is resulting in a lower tax base in rural areas. Local officials now face a choice of increasing local finances for the maintenance and rehabilitation of rural roads and bridges, consolidating road services with other localities, or abandoning and reducing maintenance of some roads and bridges.

Several recent trends have lead to a decrease in available finances for rural roads and bridges. These trends have included a decrease in federal funding for rural roads and bridges, fewer rural residents, the introduction of more fuel efficient cars, and fuel tax exemptions. At the same time that available finances for road and bridge repairs have decreased, the need for repairs has been increasing. There are several trends which illustrate the scope of the problem. First, the percentage of rural residents not involved in farming has increased. Second, the physical condition of rural roads and bridges has continued to deteriorate. Third, there has been a major increase in railroad abandonment. Over 33,000 miles of track have been abandoned in the U.S. since 1979.[2] Fourth, the distribution and marketing of bulk commodities has been concentrated through fewer facilities. When considered collectively, these four trends have placed considerable demands and constraints on low-volume roads and bridges.

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[2]USDA.

Furthermore, rural road and bridge repairs need to be performed in a timely manner. The Road Information Program (TRIP) suggests that the costs of repairing roads accelerates rapidly as road conditions worsen. Once a road has deteriorated to fair condition it rapidly deteriorates to poor condition, and the cost of repair per mile increases nearly five times. This suggests that considerable cost savings can be realized by not letting a road deteriorate beyond fair condition. The presence of inflation also suggests that repairs should be done in a timely manner. Because many revenues are based on user fees which are a constant dollar amount, and not tied to inflation (e.g. gasoline taxes in cents per gallon), revenues don't rise in proportion to prices; however, the costs of repair do. These differences reduce real revenues available for road and bridge repair.

The rural road and bridge dilemma has been heavily documented in recent years. Among the studies documenting the problem were those by Chicoine and Walzer, The Road Improvement Program (TRIP), and Marathon and Norton. Chicoine and Walzer performed extensive surveys of county and township officials in 1984 and 1986. Their surveys revealed poor conditions of township and county roads and bridges in the Midwest, along with inadequate funds to take care of these problems. TRIP examined trends responsible for recent decreases in local road funds. They listed factors such as increases in fuel efficiency of automobiles and tax exemptions on user fees for special interests as contributing to this decrease. Finally, Marathon and Norton examined federal funding of rural highways in 1988. They found that while rural residents received more in Highway Trust Fund (HTF) obligations than they contributed, the low population levels in rural counties meant that an average metropolitan county could expect to receive almost seven times as much in HTF obligations as an average rural county.

In addition to the studies documenting the rural road and bridge dilemma, there have been several studies that have looked for solutions. Solutions to the road and bridge dilemma can be grouped into two categories: cost-reducing solutions and innovative financing solutions.

Cost-reducing solutions have been advocated by Deller, Chicoine, and Walzer (1988), and by Hamlett, Brennan, and Baumel (1989). Deller, et al. used a translog cost function to show that economies of size and scope exist in the provision of low-volume road services.[3] These results suggest that consolidation of road services by rural jurisdictions may be beneficial. Hamlett, et al. examined strategies of reducing maintenance on some roads, privatization of some roads, and abandonment of some roads in rural areas. They found all of these strategies to be viable options in reducing the rural road and bridge problem.

Innovative financing solutions were advocated by several interest groups prior to the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. These interests advocated such solutions as the elimination of user tax exemptions, and allowing increased flexibility in the states' use of Highway Trust Funds.

Emerging trends suggest that the rural road and bridge dilemma may improve slightly. However, the situation remains tenuous at best. At the national level, one trend which may prove positive for rural road financing is the passage of the Intermodal Surface Transportation Efficiency Act. ISTEA has increased the states' flexibility in the

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3 There is some confusion as to the meaning of the terms economies of scale, economies of size, and economies of scope. Economies of scale are reductions in long run average costs resulting from an expansion of all input factors in fixed proportion. Economies of size are reductions in long run average costs resulting from expansion of output as input factors are expanded in the least-cost proportions (see Beattie and Taylor). Economies of scope are reductions in long run average costs resulting from joint production of multiple outputs (see Pappas and Hirschey).

use of Federal Highway Funds, and raised the total level of funding from the previous transportation bill. While states have more flexibility in road and bridge finance, a considerable amount of uncertainty remains as to how they will use (and should use) this increased flexibility. Also, in a recent survey of county highway administrators, the administrators found road and bridge quality had improved between 1985 and 1987 (Walzer and Chicoine). Finally, states are making use of new revenue sources, as well as expanding old revenue sources. Several states have encouraged private sector participation in road funding (TRIP). Private firms are often willing to contribute to road funding when it will improve access to new developments. States that did not use some of the traditional financing sources are beginning to use them. Several states have recently imposed fees on trucks and buses, imposed automobile registration fees, and approved the use of bonds for road and bridge finance (TRIP). However, at the local level, outmigration from rural areas continues to erode the rural tax base.

Merely looking for innovative financing methods may not solve the rural road and bridge problem. Some cost-reducing strategies will probably be necessary. Cost reduction strategies for localities may include consolidation of services with other jurisdictions, abandonment of roads, privatization of roads, and reduced maintenance of roads.

This study examines consolidation of road services by local governments, and explores the optimal mix of roads for rural counties. A methodology for measuring economies in the provision of local road services is presented. This methodology is unique in two ways: (1) it better accounts for relevant variables that explain expenditures so that economies can be more accurately measured; and (2) it does not require an extensive data set, so economies can be measured by region or state.[4] A methodology for optimizing the mix of gravel and paved roads by local governments is also presented. This methodology measures the costs and benefits of converting gravel roads to paved, and paved to gravel.

The next section of the study briefly reviews the literature examining economies of size in rural road services and the optimal provision of rural road services. This is followed by the introduction of a model of rural road expenditures that takes into account the preferences of local officials, local resources, traffic volumes, and truck volumes. Next, the results of the model estimation are presented. A brief discussion of the optimal conditions for rural road provision and mix follows. This includes a discussion of the differences in costs and benefits of paved and gravel roads, and a theoretical model showing the costs and benefits of conversion from gravel to paved or vice versa. The methodology for measuring the optimal mix of roads and the results of this measurement are presented next. Finally, implications of the study are examined.

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4 This may be crucial in areas where the number of counties with available data is so low that other data-intensive models are not useable.

CHAPTER 2

REVIEW OF LITERATURE

The review of literature is presented in two sections. The first section discusses economies of size in the provision of rural road services, and the second discusses the optimal mix of rural road services.

ECONOMIES OF SIZE

There are several reasons why economies of size might be realized in the provision of rural road services. First, since administrative and equipment costs are relatively fixed with respect to output (miles of road), increasing the miles of road will decrease this fixed cost per mile. Second, road maintenance crews may be more efficient for larger output levels. This may occur as workers are allowed to specialize in one particular form of maintenance (e.g. gravel maintenance) in larger government units, thus increasing their proficiency in that area. Third, volume discounts in material purchases may be realized by larger units.

There have been only three studies in the past twenty years which have examined economies in the provision of rural road services. These studies were by Lamb and Pine (1974), Lesher and Mapp (1974), and Deller, Chicoine, and Walzer (1988).

Lamb and Pine (1974) measured economies of size in the provision of county (and smaller non-county) road services. The authors used a model that related jurisdictional size (in square miles) to total road costs. They found the usual U shaped average cost curve associated with economies of size in their measurement of non-county costs[5], but

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[5]When economies of size are present, a U shaped long run average cost occurs. This means that long run average costs decrease with output expansion to a certain point, and then begin to increase at a certain output level. The eventual increase in long run average costs occurs because coordination of the firm by management becomes limited at very large firm size.

found the opposite shape for the average cost curve in their measurement of county costs. While this paper brought attention to the concept of consolidation of services, its use of square miles as a size measure and its finding of an inverted average cost curve for counties might be questioned.

Lesher and Mapp (1974) measured economies of size in the provision of county road services in total, as well as economies of size in maintenance, snow removal, and highway administration. The authors explained variations in county highway expenditures in New York state with road mileage, the number of county bridges, and motor vehicle registrations. Additional variables of weather, topography, property values, and road quality were originally included and dropped because of insignificance (possibly due to multicollinearity). Thus, while the study was valuable in illustrating the possible benefits of consolidation, its possible bias from exclusion of relevant variables is a major concern.

Deller, Chicoine, and Walzer (1988) measured economies of scope, as well as economies of size in the provision of township road services. The authors made a critical assumption about the behavior of rural officials in the provision of road services. This assumption is that local officials are cost minimizers, and their only goal in achieving a particular service level is to meet a minimum level. Thus, they used a translog cost function to measure size economies. The authors found significant economies of size and scope in the provision of township road services, and recommended consolidation of services as a possible solution.

All of these studies made valuable contributions in revealing possible size economies in the provision of rural road services. However, there is still a need for a model which accounts for the behavior of local officials and the resources available to local governments, and can be applied separately to individual states.

OPTIMAL MIX OF ROAD SERVICES

None of the previous studies have examined the optimal mix of road services between gravel and paved. However, one study examined the optimal restructuring of the road system through various policy options (Hamlett, Brennan, and Baumel, 1989). They used a simulation model in order to estimate the benefits and costs to society from four alternative policies. These policies were abandonment of those low volume roads not used for property access, the conversion of low-volume roads to low maintenance roads where the road does not provide access to homes, the return of some roads to private ownership, and the reconstruction of bridges to comply with legal load limits.[6]

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[6]In examining the policy of road abandonment, Hamlett, et al. measured the costs of abandonment as the increased travel costs attributable to the smaller road network. They measured the benefits of this policy as the savings in maintenance and reconstruction of the road system due to the reduced size of the system. An additional benefit of this policy, as measured by Hamlett, et al., was the value of the land that could go back into agricultural production because of the abandonment of some roads. However, a partially offsetting cost to this benefit was the cost of converting this abandoned road into land that is suitable for agricultural production.

Hamlett, et al. measured similar costs and benefits for the conversion of low volume roads to low maintenance roads. The only differences were that the travel cost increases per mile of conversion were not as large, the savings to local government per mile of conversion were not as large, and the benefits of conversion of land into agriculture that were realized in rural road abandonment were not realized in the conversion of roads to low maintenance.

In estimating the costs and benefits of conversion of low volume roads into privately owned roads, the authors measured similar costs and benefits to those realized in the abandonment scenario. However, some differences did exist. These included smaller increases in travel costs due to conversion into private roads, smaller portions of land available for conversion into agricultural land, and the addition of private maintenance costs for the roads.

The policy of reconstructing and widening bridges had one cost and one benefit. The benefit was a reduction in travel costs, while the cost was the new construction cost.

Hamlett, et al. found the benefits to outweigh the costs in three of the four policy alternatives. Road abandonment, the conversion of roads to low maintenance, and the privatization of roads were three policies that passed the cost/benefit test. The policy that didn't pass this test was the reconstruction and widening of bridges.

This study has made a valuable contribution to rural road and bridge finance because of its introduction of benefit-cost analysis to the topic. However a benefit-cost analysis is needed that takes into account opportunity costs realized by travelers, doesn't require simulation methodology, and takes overhead traffic into account.

The next section of the paper presents a model of county road expenditures which accounts for the preferences of local officials and the resources available at the local level, and can be applied to individual states with limited data sets. The issue of the optimal mix of roads will be taken up again later, after economies of size are investigated.

CHAPTER 3

EMPIRICAL MODEL FOR MEASURING ECONOMIES OF SIZE

In this section a log-linear model of county road expenditures is presented for the state of North Dakota. Complete data on 1990 county road expenditures were obtained from 30 counties in the state.[7]

The main improvement this study makes over previous studies measuring economies of size is that it models expenditures as expenditures (instead of as costs). Because the studies by Lamb and Pine, Lesher and Mapp, and Deller, Chicoine, and Walzer left out important variables which influence expenditures, they attributed too much of the variation in road expenditures to cost factors. This study measures expenditures as expenditures by accounting for cost factors (such as differences in traffic volumes and truck trips), local resource constraints, and county official preferences.

IMPROVEMENTS OVER PREVIOUS MODELS

All three previous studies omitted several important variables or made unrealistic assumptions. Unlike these previous studies, the preferences of county officials are explicitly accounted for in the model presented in this report. The preferences of county decision-makers reflect the behavioral motivations of elected officials and the fundamental tradeoff they face. In determining the level of highway spending during a given year, county officials must tradeoff the benefits of higher service levels (resulting from higher spending levels) against year-end fund balances (or savings). In essence, county officials are simultaneously considering these two objectives and establishing tradeoffs between them. Higher service levels (resulting from increased spending) tend to increase users'

[7]Some counties didn't respond to the survey, and others could not provide various data such as the number of township miles maintained by the county, the number of truck trips on county roads, etc.

satisfaction and thus enhance the short-run political stock of elected county officials. Alternatively, county officials must lay aside some funds for contingencies and major expenditures that may be needed in the future (including accumulations to provide matching funds). Setting aside funds for unexpected future expenditures may enhance the long-run political stock of elected county officials.

The translog cost function specified by Deller, Chicoine, and Walzer assumes that local highway officials minimize expenditures subject to a minimum service level goal. While this may be true in some cases, it is certainly not true in all cases. In fact, political realities would suggest that local officials maximize service level in a majority of cases.[8] Because local officials in charge of making decisions on service levels are elected, they are more likely to take a short run view of maximizing service level now rather than maximizing savings in case of future uncertainties. By assuming that county officials' preferences don't vary, Deller, et al. are excluding a relevant variable. The studies by Lamb and Pine, and Lesher and Mapp don't account for differences in local officials' preferences either.

One alternative to including county officials' preferences in a model may be the inclusion of a road quality index. Deller, et al. attempt to account for differences in service levels by including the miles of various kinds of roads as a constraint. However, service levels vary by highway condition as well as type. Lamb and Pine also include different types of roads without accounting for differences in condition. Lesher and Mapp initially use quality to explain expenditures, but drop it in their empirical results. Such omissions cause misspecification because differences in preferences are not accounted for.

The model used in this study allows the behavior of local officials to be accounted

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8 This point was also noted by Lesher and Mapp in 1974.

for, without making an assumption about how all local officials behave. Any generalized assumption about county officials' behavior would likely be in error, as not all officials have the same preferences. A county official preference measure is superior to a quality index, since perceived qualities may be affected by the county official's preferences.

Second, all three studies fail to account for differences in local resources. Deller, Chicoine, and Walzer account for intergovernmental revenues, but fail to account for differences in local revenues. This is a significant omission as a major portion of local road revenues comes from property taxes. Lamb and Pine include a composite measure of wealth, vehicle registration, and population. While this may have some relationship to local road resources it will also have a relationship to traffic volume. Direct measurement of local traffic volume and local road resources would provide a much better measurement of these factors. Lesher and Mapp include motor vehicle registrations as an explanatory variable. Again this variable is likely to give some indication of traffic volume and local revenues, but is not necessarily closely related to either. Inclusion of county revenues and local official preferences are very important. Counties which have more resources and commissioners with high preferences for spending are likely to spend more to maintain a higher service level.

Finally, traffic volume is only measured by one of the three studies, and none measure truck trips. Traffic volume will have a major impact on road expenditures, as increased traffic causes increased surface degradation, which necessitates greater expenditures. Heavy truck traffic imposes greater pavement damage than automobile traffic, and is therefore very important in determining road expenditures. Overall, the omission of key explanatory variables in the three previous models may lead to biased estimates of economies of size.

Another improvement this study makes is that, unlike the model used by Deller, Chicoine, and Walzer, the model used in this study can be applied to individual states in order to estimate the extent of size economies that might be realized. Because of differences in weather, the extent of agricultural activity, the topography of the land, and other factors, economies of size in road services are likely to vary widely across the country. Deller, et al.'s model requires a large data set. When analyzing the extent of size economies realized in county road services in an individual state, a large data set is not available. Thus, a model which allows estimation of size economies with a limited data set will be beneficial.

MODEL FORM AND DESCRIPTION

The following log-linear model is used to estimate county road expenditures.

$$lnEXPEND = \beta_0 + \beta_1 lnMILES + \beta_2 lnANNREV + \beta_3 lnADT + \beta_4 PERCT + \beta_5 PERCP + \beta_6 lnTRTRIP + \beta_7 WSL + u$$

where:

EXPEND	=	Total Road Expenditures
WSL	=	Weight the County Commissioner Placed on Service Level Relative to Savings
MILES	=	Total miles of road serviced by the county[9]
PERCT	=	Portion of road miles that are township roads
PERCP	=	Portion of road miles that are paved
ADT	=	Average daily trips per mile on county roads
ANNREV	=	Annual Road Revenues
TRTRIP	=	Portion of average daily trips that are by truck
u	=	Random error term

All variables in this model are in natural logarithms, except for the proportion of road miles that are township miles, the proportion of road miles that are paved, and the weight placed on service level by the county commissioner. These variables are not

9 Total road mileage includes township mileage maintained by the county.

specified in natural logs, since all have values of zero in some cases.[10] An advantage of specifying variables in natural logarithms is that parameter estimates can be interpreted as elasticities. Thus, economies of size can be estimated directly from the parameter value of miles.

$$n_c = \frac{\partial \ln EXPEND}{\partial \ln MILES} = \beta_1$$

A value of n_c below 1 would suggest increasing returns to size (economies of size); a value of n_c equal to 1 would suggest constant returns to size; and a value of n_c above 1 would suggest decreasing returns to size (diseconomies).

With this model, expenditures can be explained by cost and behavioral factors.[11] Furthermore, by holding behavioral and resource factors constant, economies of size can still be explained through this model of expenditures. Annual road revenues should have a positive effect on county road expenditures. Increases in annual revenues represent increases in resources for road services. The number of average daily trips per mile is also expected to have a positive influence on county road expenditures, *a priori*. This relationship is expected since increases in average daily trips (ADT) increase wear and tear on roads, necessitating increased maintenance and repair. Increases in the portion of road miles that are township miles should have negative effects on road expenditures

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10 The natural logarithm of zero is undefined.

11 This model does not include variables for differences in topography or weather since these factors are relatively homogeneous in the state of North Dakota. If topography and weather vary widely within a given state, variables accounting for these differences should be included.

because of differences in maintenance levels between county and township roads.[12] Increases in the portion of roads that are paved are expected to have positive effects on road expenditures. Paved roads require more maintenance than gravel or dirt roads. The portion of total ADT that consists of truck trips should have a positive influence on road expenditures. The addition of heavy truck traffic to rural highways accelerates highway deterioration.[13] Finally, the weight that the county official places on service level relative to savings is expected to have a positive influence on road expenditures. Increased importance on service level should indicate that the county official would prefer to spend more now in order to achieve high quality roads.

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12 Conversations with county officials indicated that township roads are typically bladed and maintained less frequently.

13 See Tolliver, 1989.

CHAPTER 4

EMPIRICAL RESULTS IN MEASURING ECONOMIES OF SIZE

The preceding model is estimated using ordinary least squares (OLS). Plots of the residuals against annual revenues and total mileage follow a random pattern, suggesting homoskedasticity. Thus, the traditional OLS estimators can be applied without achieving unwarranted confidence in the estimates.[14]

The estimated model is shown in Table 1.

TABLE 1: ESTIMATION OF COUNTY ROAD EXPENDITURES
DEPENDENT VARIABLE = lnEXPEND

Variable	Parameter Estimate	t-ratio
Intercept	0.1033[15]	----
lnMiles	0.5095	2.45*
lnANNREV	0.8024	7.45*
lnADT	0.2489	2.69*
PERCT	-0.6960	2.94*
PERCP	0.1848	0.30
lnTRTRIP	0.1620	1.24
WSL	0.0986	0.74

ADJUSTED R^2 = 0.9133 F = 44.62 N = 30
STANDARD ERROR OF THE ESTIMATE = .25868 *significant at the 5% level

As the Adjusted R^2 shows, this model explains over ninety percent of the variation in county road expenditures. In addition, its F statistic shows that the overall model is significant at the 5 percent level. These factors suggest that this is an effective model for explaining road expenditures.

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14 Since heteroskedastic variances are no longer minimum, applying OLS estimators under the assumption of homoskedasticity will underestimate the true variances. Thus, standard errors will also be underestimated, causing overestimation of t values.

15 This estimate of the intercept term is biased, since the model is in natural logs. The t-ratio for the natural log of the intercept showed an intercept not significantly different from zero. Because of the bias, the t-ratio is not reported here. However, this bias does not affect the estimation of lnEXPEND.

All of the parameter estimates have the expected signs. The total number of miles in the county has a positive sign and is significant at the 5 percent level. In addition, its parameter estimate is below one, suggesting increasing returns to size. The parameter value of .51 suggests that a one percent increase in mileage will lead to a .51 percent increase in expenditures. The annual road revenues also have a positive influence on road expenditures. This estimate is significant at the 5 percent level suggesting that the availability of greater local resources tends to increase the amount spent on roads during a given year. The parameter estimate for the average daily trips on county roads has a positive sign and is significant at the 5 percent level. This suggests that increased surface degradation resulting from increased trips results in increased spending on county roads. Increases in the portion of total mileage that is township mileage are shown to decrease expenditures per mile. This effect is also significant at the 5 percent level. Three variables don't have significant parameter estimates, but the signs of these estimates are as expected. Of these variables only PERCP appears to have a problem with collinearity. The results of the analysis indicate relationships among the proportion of miles that are paved, annual revenues, and miles. However, the major consequence of multicollinearity is high variances of collinear variables, and therefore, decreased confidence in their estimates. The parameter estimates of annual revenues and miles have small variances, as shown by the large t-statistics. These parameter estimates can be viewed with confidence. However, the parameter estimate of PERCP (proportion of miles that are paved) has a high variance and therefore a low t-statistic. Nevertheless, this variable must remain in the model to avoid a specification error. The variables lnTRTRIP and WSL have parameter values that are not significant at the 5 percent level. This may be due to the limited degrees of freedom present in this model. Still, t-values near 1 for both parameter estimates suggest that these variables are important in determining county road expenditures. Furthermore, omission of these variables would create a bias in the other parameter estimates.

These results suggest that there are other important factors besides costs in determining local road expenditures. The annual revenues available to a county exert the single greatest influence on North Dakota county road expenditures. This suggests that road expenditures in North Dakota depend greatly on the resources available at the local government level. Further, the weight placed on service level by county commissioners has a positive influence on North Dakota county road expenditures. While this variable was not significant, it is still believed to be important.[16]

An average expenditure curve is obtained from estimated values of $\hat{y}$ (where $\hat{y} = \ln \hat{Y}$) at the means of all variables except miles (miles are varied within the range applicable to North Dakota counties) by taking the antilog of $\hat{y}$ and dividing by miles. Although $\hat{Y}$ is an unbiased estimator of median response of Y given X's, it provides a biased estimator of the mean response of Y given X's for this type of model. Thus, the value of $\hat{Y}$ is adjusted by:[17]

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[16] One reason this variable might be insignificant even in larger samples is due to the difficulty associated with measuring it. The following question was designed to measure this variable: If your county road revenues were to decrease by $100,000, how much would you decrease each of the following? 1. expenditures 2. savings. An improved measure of county officials' preferences may improve the significance of this variable in the model.

[17] In this log-linear model, the value of Y hat is the median value of Y given X without the adjustment. See Don M. Miller, "Reducing Transformation Bias in Curve Fitting," *The American Statistician*, May 1984, Vol. 38, No. 2.

$$e^{1/2\sigma^2}$$

This adjustment produces approximately unbiased predicted values for the mean of Y given X.[18]

Since the average expenditure curve holds behavior, resources, and cost factors constant, it shows how costs are reduced as mileage increases. The average expenditure curve over the range of North Dakota county mileage is shown in Figure 1.

[18] Miller shows that this adjustment eliminates the major portion of the bias.

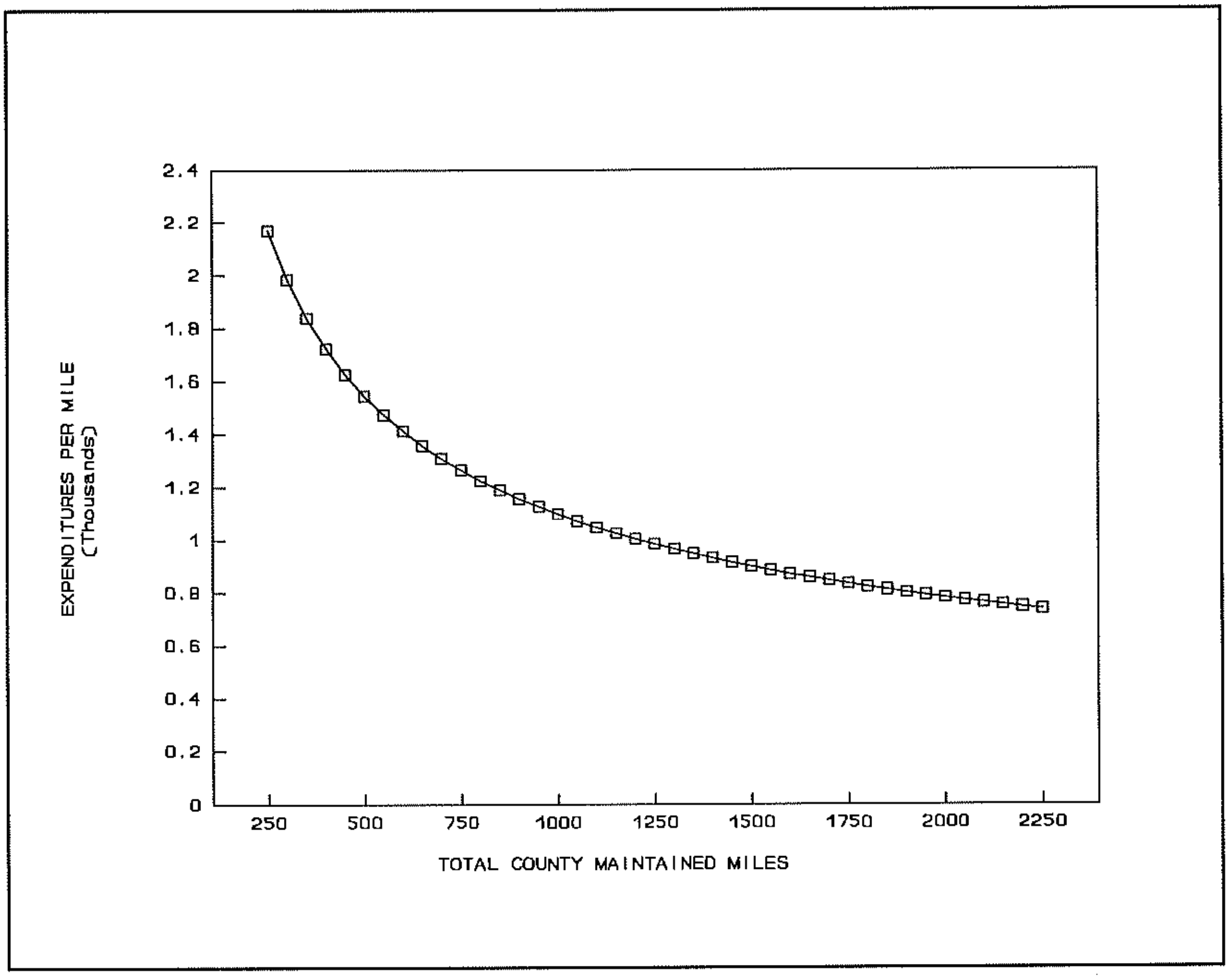

Figure 1

As Figure 1 shows, there are significant economies of size realized by North Dakota counties in the provision of road services. Furthermore, these economies are not exhausted within the range of mileage maintained by North Dakota counties. This suggests that significant economies could be gained from consolidation of county road services in North Dakota, particularly for very small counties. The next section of the report examines the optimal provision of rural road services.

CHAPTER 5

OPTIMAL PROVISION OF RURAL ROADS

Because rural roads are public goods, the use of market mechanisms in their provision is more difficult. For a private good, the optimal amount of the good is determined by market demand conditions. The optimal amount of the public good, on the other hand, cannot be determined by market forces.

A public good is a good that provides benefits to more than one person simultaneously. A pure public good has the property of being nonrivalrous in consumption (Musgrave, 1969). This means that the use of the good by one person does not take away from the benefits received by other persons from the use of this good. Another characteristic of a pure public good is the characteristic of nonexcludability (e.g. there is no way to exclude people from using the good).

Rural roads can be characterized as impure public goods since they are not totally nonrivalrous in consumption, but they do have the characteristic of nonexcludability. More specifically most rural roads are regional public goods since most of their benefits are received by local residents.

Because rural roads are not completely nonrivalrous in consumption, the use of the road by additional persons will take away from the benefits received by others in the use of this good. Unlike the classic example of congestion in urban roads, the rivalry in consumption of rural roads results primarily from pavement (or other surface) damage. Additional users of rural roads (particularly heavy trucks[19]) reduce the benefits to existing users by contributing to poor road conditions through incremental pavement damage.

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[19]See Tolliver, Denver D. *The Impacts of Grain Subterminals on Rural Highways, Vol. II,* Publication No. 75, Upper Great Plains Transportation Institute, North Dakota State University, Fargo, 1989.

With knowledge of the benefits that people receive from rural roads, the optimal provision of rural roads is straight forward. The classic Samuelson conditions for efficiency suggest that the sum of marginal benefits from road use received by all individuals should equal the marginal cost of producing the rural road capacity. Thus, in order to find the optimal amount of rural roads to produce, people's demand curves are added vertically and people are charged a tax according to the benefit they receive. This is known as Lindahl pricing.

However, knowledge of the benefits that people receive is seldom available, and attempts at preference revelation are difficult. One possible method for finding the benefits that people will receive from rural roads is to survey people on their preferences for rural road use in order to construct a marginal benefit (demand) schedule for each person. This method imposes a different problem, however; people have an incentive to understate their preferences for rural roads in order to lower their tax. This is known as the 'free-rider' problem. As all taxpayers in the community act as free riders, the level of rural roads provided and maintained using this methodology is much lower than the optimal amount.

Much of the theory of public goods is aimed at trying to provide solutions to the free-rider problem. This is done by attempting to find methods of preference articulation for the provision of public goods. Because of these problems, and other problems such as potential differences in paved and gravel maintenance costs between counties and potential benefits of consolidation of road services among counties, this study does not try to estimate the optimal amount of rural roads in North Dakota counties. Rather, this study uses a benefit-cost methodology to examine the choice between gravel and paved road investment within counties.

RURAL ROADS: BENEFITS AND COSTS

The choice between a gravel and a paved road is a function of the benefits provided by each, as well as the annualized costs of each. The benefits provided by a particular type of road are a function of several factors. These factors include the riding quality of the road, the cleanliness of the road (dust production), and the physical appearance of the road. Because the cleanliness and physical appearance of roads are relatively minor factors in rural areas, the critical factor in determining the benefits provided by a type of road is the riding quality of the road.

There are two main costs of highway use which will vary with the riding quality of the road. These costs are vehicle operating costs and opportunity costs. Vehicle operating costs are those costs incurred as a result of vehicle wear and tear, fuel consumption, and routine maintenance. Opportunity costs are those costs incurred as a result of time spent traveling. Since time spent traveling is time which could be spent for productive purposes, travelers incur an opportunity cost as a result of foregoing that productive activity. The annual benefits of a particular road are inversely related to the vehicle operating costs and opportunity costs realized on it.

The annualized costs of a particular road are also a function of several factors. These factors include the utilization of the road (primarily by trucks), the quality preferences by the local official, the size of the jurisdiction that is responsible for the road, the weather in the region, the topography of the region, and the surface type of the road. Since this analysis examines North Dakota county road services, topography and weather are generally constant. Further, while annualized road costs will vary across North Dakota counties due to differences in county official preferences, road utilization, and jurisdictional size, the difference in costs between gravel and paved roads can be presumed to be constant; i.e. gravel and paved road costs increase by the same amount with higher county official preferences, increased utilization, and smaller jurisdictional size.[20]

Thus, the decision on the optimal mix of roads in a county can be obtained by weighing the differences in annualized costs between gravel and paved roads, against the differences in user costs incurred on each type of road. The remainder of this study examines the optimal mix of roads in North Dakota counties.

THE BENEFITS AND COSTS OF CONVERTING RURAL ROADS TO ALTERNATIVE SURFACES

The cost of a particular trip to an individual can be formulated as the sum of vehicle operating costs and opportunity costs.

$$TC = VOC + OC$$

where:

TC	=	total cost
VOC	=	vehicle operating cost
OC	=	opportunity cost

Road user costs will typically be higher on gravel roads for several reasons. First, paved roads will permit greater vehicle speeds to be achieved with safety and comfort than gravel roads will allow. Second, the increased smoothness of paved roads produces less wear and tear on vehicles, and requires less fuel use, decreasing the vehicle operating costs incurred on paved roads compared to those incurred on gravel roads. Thus, the

[20]Actually, increases in utilization are likely to increase the costs of paved maintenance more than gravel maintenance. However, in areas of heavy utilization the total savings in vehicle operating costs and opportunity costs will also be very high for paved roads. Thus, in any area where utilization is high enough to have a significant impact on paved maintenance expenses, the annualized benefits of paved roads are likely to be influenced in a similar fashion.

vehicle operating costs and opportunity costs incurred on gravel roads will be greater than those incurred on paved roads.

The costs of vehicle operations and time will be constant in relation to the number of trips up to a certain point. However, once the number of trips on a certain stretch of road increases to a level where road deterioration occurs, the costs of vehicle operations and opportunity costs will increase with users. This increase occurs because poor road conditions will increase travel time and vehicle wear and tear. This is shown in Figure 2.[21]

As Figure 2 shows, the conversion of a mile of gravel road to paved will result in decreased vehicle operating costs and opportunity costs, and increased utilization of this particular section of road. The increase in utilization occurs because of the traditional price-demand relationship; as the price of the good decreases the quantity demanded increases. However, this increase is expected to be fairly small in the case of rural roads. The demand for rural road services is thought to be fairly inelastic, in general, as many rural trips are made for grain shipments, movement of farm machinery, access to basic services, and other necessary purposes. While some changes may occur in routes, increasing the utilization on a converted mile of road, the effects of the conversion on the choice between gravel and paved utilization for the county as a whole is difficult to predict. This is due to the fact that the increased utilization on a converted mile of road may be the result of a reduction in utilization on another nearby paved road, or a reduction in utilization on a nearby gravel road.

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[21]Figure 2 is adapted from Figure 4-8 in Boadway, Robin W. and David E. Wildasin *Public Sector Economics.* (2nd edn) Little, Brown and Company: Boston, 1984.

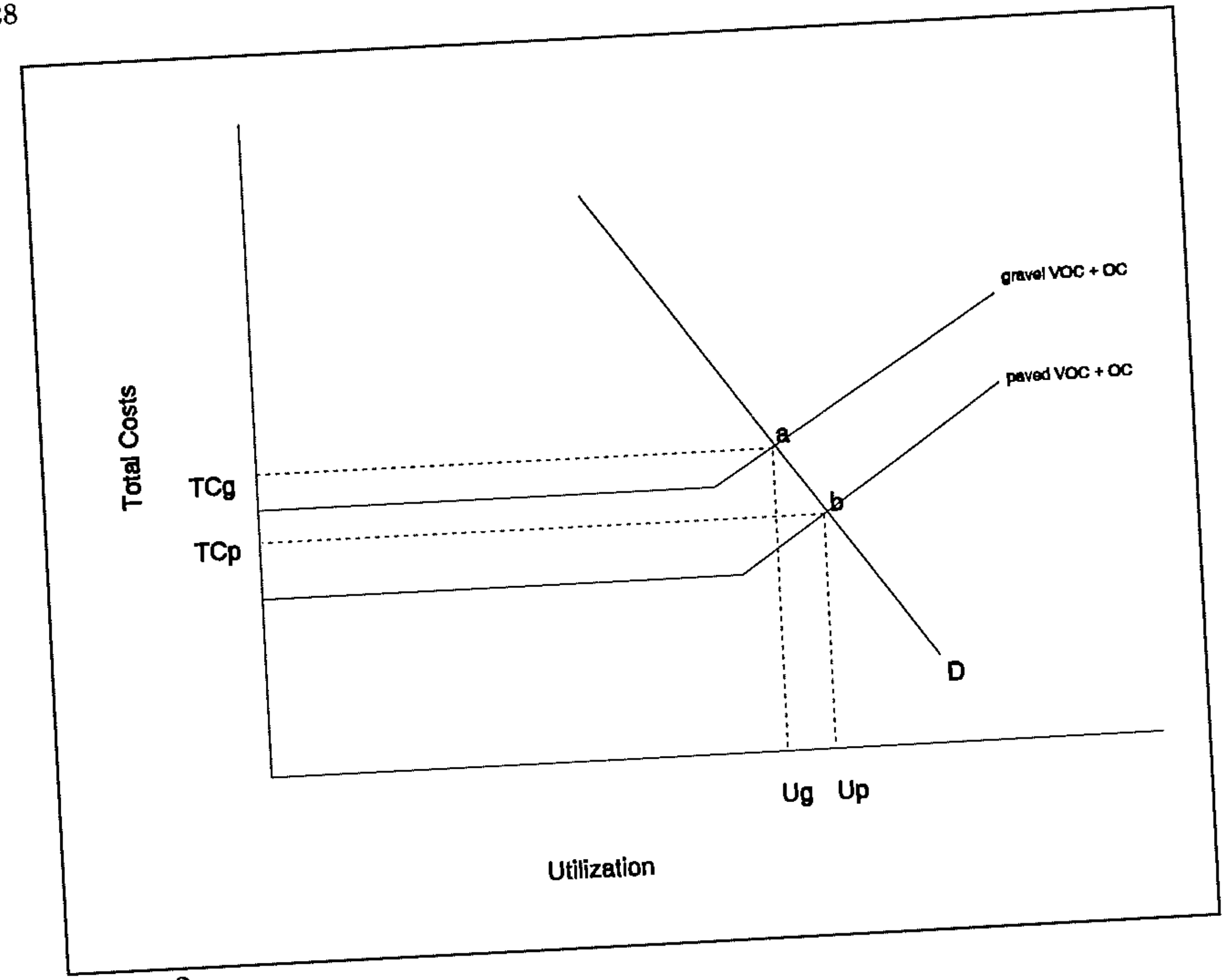

Figure 2

The total benefit of converting a gravel road into a paved road is shown as the area TCgabTCp in Figure 2, which is the total change in costs for all previous trips plus 1/2 of the change in utilization times the change in costs. The total cost of converting a gravel road into a paved road is the total increase in the annualized cost of maintenance and overlays. When the benefits of conversion are greater than the costs, then conversion will be beneficial. The next section of the report details the method for estimating costs and benefits of conversion.

CHAPTER 6

BENEFIT-COST METHODOLOGY

In order to determine the optimal type of road for a given road section, the benefits and costs of converting the road to the alternative type must be estimated and weighed against each other. If the section of road in question is gravel, the benefits and costs of converting this section to paved must be examined.

The annual benefits of converting a gravel road mile to a paved mile will be the total sum of the reduction in opportunity costs and vehicle operating costs to all users for the year.[22] The total trips for the year can be estimated by taking the average daily trip estimates for that mile and multiplying by 365 (days in the year).[23] This can be multiplied by the reduction in opportunity costs and vehicle operating costs per trip per mile in order to obtain the total annual benefits from converting that mile to paved.[24]

In order to estimate the reduction in opportunity costs per user per mile and vehicle operating costs per user per mile, road user costs must be estimated. The costs of road use are the total vehicle operating costs and opportunity costs, as was shown previously. In order to estimate road user costs, the Highway Performance Monitoring System Analytical Process[25] (HPMS) was used. The HPMS provides equations to

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[22]Secondary benefits may also result from reducing vehicle operating and opportunity costs for commercial operators. These may occur because reducing commercial operator costs may increase the prices of grain received by producers.

[23]Unlike the study by Hamlett, et. al, this will allow overhead traffic to be taken into account in determining the optimal road type.

[24]This only measures the benefits to existing traffic from road conversion. However, the increase in traffic on road sections is expected to be small for the reasons discussed previously.

[25]U.S. Department of Transportation, Federal Highway Administration. *Highway Performance Monitoring System Analytical Process, Volume II, Technical Manual,* December, 1987.

estimate changes in operating speed and vehicle operating costs at different Present Serviceability Ratings (PSR) for pavements (Figure 3).

PSR	Verbal Rating	Description
4 to 5	very good	Only new (or nearly new) pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavements constructed or resurfaced recently should be rated very good.
3 to 4	good	Pavements in this category, although not quite as smooth as those described above, give first-class ride and exhibit few, if any visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks.
2 to 3	fair	The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and more or less extensive patching.
1 to 2	poor	Pavements that have deteriorated to such an extent that they are in need of resurfacing.
0 to 1	very poor	Pavements which are in an extremely deteriorated condition and may even need complete reconstruction.

FIGURE 3 source: U.S. DOT, *Status of the Nation's Highways*, July, 1983.

The HPMS shows a rural minimum tolerable condition table which equates gravel surfaces to a PSR of 1.8. Thus, the speed and vehicle operating cost equations are calculated for a PSR of 1.8 for gravel roads. For paved roads, the equations are calculated for PSRs of 5.0, 4.9, 4.8 ... 2.1, and 2.0, and the average speed and vehicle operating cost is used. These are calculated using an initial speed of 46 miles per hour.[26]

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[26]This initial speed is taken from Table 32 on page N-16 of the HPMS. Table 32 assumes a rural 2 or 3 lane highway with an average highway speed of 55 or less and a passing sight distance of more than 90 percent. A volume/capacity ratio of 0 is used.

The speed equation from the HPMS is shown as follows:

$$SAF = 0.8613*(PSR)^{0.0928} * (1+H(IRS-35)) - H(IRS-35)$$

where: SAF = speed adjustment factor
PSR = pavement condition rating
IRS = initial running speed
H = 0.0130

This equation results in a value of 1 at a PSR of 5, and decreases as PSR decreases. The speed is found by multiplying the speed adjustment factor by the initial running speed (46). The speed for gravel roads was estimated to be 41.2462 MPH, while the speed for paved roads was estimated to be 44.1422 MPH. Dividing each of these into 60 gives minutes per mile of 1.35924 for paved roads and 1.45467 for gravel roads. This figure is multiplied by the 1992 average wage in North Dakota of $.1513 per minute ($9.08 per hour[27]) to arrive at opportunity costs of $.206 per vehicle mile of travel (VMT) for a paved road mile and $.220 for a gravel road mile.

The vehicle operating cost equation from the HPMS is shown as follows:

$$VCAF = 0.9818182 + (5.0-PSR)/(20.0+(5.0*(PSR-3.0)))$$

where: VCAF = vehicle operating cost adjustment factor
PSR = pavement condition rating

This equation produces a value of 1 at a PSR of 4.5, and increases as PSR decreases. The vehicle operating cost is found by multiplying the vehicle operating cost adjustment factor by a weighted average vehicle operating cost.[28] In 1992 dollars, the

[27]U.S. Department of Labor. *Employment and Earnings.*

[28]The HPMS gives tables that show vehicle operating costs per 1000 vehicle miles for various types of vehicles. 1989 United States rural annual vehicle miles of travel by vehicle classes are used to weight these operating costs. U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics, 1989.*

vehicle operating cost per VMT for a paved road is \$.2555 per mile, while for a gravel road it is \$.2920 per VMT.[29]

Adding up total user costs for each road type, the total user costs per trip for a gravel road are \$.512 per mile (.292 + .220), and the total user costs per trip for a paved road are \$.4615 per mile (.2555 + .206). Thus, the benefit of converting a gravel mile into a paved mile is the total annual trips times \$.0505 (.512 - .4615). When considering the conversion of a paved mile to a gravel mile, this figure becomes the annual cost.

The costs of maintaining gravel and paved roads are a function of several factors as explained previously. These factors include weather, topography, utilization, local official preferences, jurisdictional size, and surface type. In this analysis, we are interested in the difference in costs between gravel and paved roads. Weather and topography will not vary much among counties, since they are all in North Dakota. Utilization, local preferences, and jurisdictional size will vary considerably among counties. However, there is no *a priori* reason to believe that jurisdictional size or local official preferences will influence the difference between gravel and paved maintenance costs. While increases in utilization will probably increase the difference between gravel and paved maintenance costs, any area where utilization is great enough to increase the paved maintenance costs enough to alter a benefit-cost analysis presumably has enough traffic to justify investment in a paved road. Thus, the same cost of converting a gravel road to paved is used for all North Dakota counties.

Gravel road maintenance includes blading, snow removal, signing, mowing, and periodic regraveling. A 1988 study by the North Dakota Department of Transportation estimated the annualized maintenance costs for a gravel road in Mountrail county on a

[29]1980 levels are adjusted to 1992 levels by the CPI for Private Transportation.

weekly blading schedule and a 5 year regraveling schedule to be $1,365 per mile. In 1992 costs, this would be $1,538 per mile.[30]

Paved road maintenance includes mowing, signing, repairs, crack sealing, an overall seal every 7 to 10 years, and patching. The 1988 North Dakota DOT study estimated these costs to be $2,015 per mile for Mountrail County. In 1992, these costs would be $2,271. In addition to the annual paved maintenance expenses, paved roads should receive a two inch overlay every 25 years.[31] The cost of such an overlay according to the NDDOT was $50,000 in 1988, which represents $2,000 per year. In 1992, these costs are $2,254.

For a benefit-cost analysis of converting a mile of gravel road into paved, the annual costs are $2,987, which is the difference between the annualized paved and gravel costs. For a benefit-cost analysis of converting a mile of paved road into a mile of gravel, the annual benefit is $2,987 (cost savings).[32]

The following section of the report presents the results of the benefit-cost analysis for North Dakota Counties.

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[30]Adjusted by the Producer Price Index.

[31]NDDOT.

[32]However, this does not take into account the initial cost of converting the paved road to gravel. The pavement must be destroyed, debris hauled away, and gravel put in place. This is only a one time cost; eventually significant cost savings will occur annually.

CHAPTER 7

BENEFIT-COST RESULTS

Thirty-four North Dakota counties returned surveys with the necessary data to perform the benefit-cost analysis. The benefit-cost analysis is presented on an individual county basis in Appendix A.

The benefit-cost analysis showed several different situations among counties in terms of the optimal mix of road services. Several counties, such as Cass, Grand Forks, and McLean appeared to have an optimal mix of roads. The benefit-cost analysis for these counties showed no apparent gains from converting gravel or paved mileage to the alternative. Very rural counties, such as Eddy, Grant, and Kidder showed significant potential gains from converting all of their roads to gravel. In many cases the low traffic volumes don't appear to justify investment in paved roads. Other counties with high traffic volumes such as Walsh, Oliver, and Nelson, showed benefits from converting a portion of gravel roads to paved. Interestingly, these counties border urban counties, suggesting that the decision regarding existing surface types may have only considered the costs and benefits to those living in the county, whereas much of the traffic is bridge traffic resulting from the bordering county. Finally, there were counties where there were gains from converting gravel to paved and paved to gravel. This phenomena occurred where gravel roads had high traffic volumes and paved roads had low traffic volumes.

The benefit-cost analysis generated reasonable results upon which to make recommendations regarding road mix. The analysis showed that approximately 162 average daily trips are needed on a gravel road in North Dakota before conversion to a paved road is justified in terms of benefits and costs. Such an analysis could easily be applied to the optimal mix of road services in other states.

CHAPTER 8

SUMMARY AND CONCLUSIONS

The first part of this study presented a model of county road expenditures which accounts for differences in county resources and differences in county official behavior. Furthermore, the model presented in this study doesn't require a large data set, and therefore can be applied on an individual state basis.

By accounting for differences in county resources and behavior, the model can be used to identify economies of size in the provision of road services. Previous models developed by Lamb and Pine, Lesher and Mapp, and Deller, Chicoine, and Walzer failed to include important factors in explaining expenditures. Thus, it is likely that the estimates they presented are somewhat biased.

Because of differences in weather, topography, the extent of agricultural activity, and other various factors, economies are likely to vary widely among regions of the country. This necessitates a model that can be applied to individual states with limited data sets. Although the translog function estimated by Deller, et al. can be applied to individual states or regions it requires a large data set. In contrast, the model presented in this paper can be applied with limited data sets; a very important attribute in economic analysis.

In applying the model to county road services in the state of North Dakota, it was shown that factors other than costs are important in determining county road expenditures. In addition, significant economies of size were shown for North Dakota county road services. This suggests that consolidation of county road services in North Dakota may be beneficial.

The second part of the study presented a model for determining the optimal mix of road services at the county level. The model was applied to North Dakota in this study, but it can easily be applied to other states.

The model makes improvements over past benefit-cost analysis in this area, as it accounts for the time costs of travel, accounts for overhead traffic, and doesn't require assumptions about the routes people travel.

In applying the benefit-cost analysis to counties in North Dakota, it was shown that there are improvements that could be made in the mix of road services provided by North Dakota counties. Counties that have very heavy traffic levels may benefit from converting some gravel mileage to paved, while those that have very light traffic levels may benefit from converting some paved mileage to gravel. Further, there are some counties that have close to the optimal amounts of each type of road, but could still benefit from significant conversion (e.g. some counties have gravel roads that have very high traffic levels and at the same time have paved roads that have very low traffic levels). Finally, there are several North Dakota counties which are near their optimal mix of roads.

During the course of this study it became apparent that further research is needed in the area of rural road services. First, additional study is needed to find improved measures of the preferences of county road officials. Improved preference measures will allow rural officials' behavior to be more accurately reflected. Second, data collection and management systems for county governments are in great need. Many county governments had difficulty in collecting the data necessary for this study. Research into the feasibility and usefulness of various data collection and management systems would be beneficial. Finally, more study is needed to find ways to reduce rural road costs.

REFERENCES

Beattie, Bruce R. and C. Robert Taylor. *The Economics of Production.* John Wiley and Sons: New York, 1985.

Boadway, Robin W. and David E. Wildasin. *Public Sector Economics.* (2nd edn) Little, Brown and Company: Boston, 1984.

Chicoine, David L. and Norman Walzer. *Financing Rural Roads and Bridges in the Midwest.* U.S.D.A. Office of Transportation, Washington, D.C., October 1984.

Deller, Steven C., David L. Chicoine, and Norman Walzer. "Economies of Size and Scope in Rural Low-Volume Roads." *The Review of Economics and Statistics*, 459-65, 1988.

Hamlett, Cathy A., Sherry Brennan, and C. Phillip Baumel. "Local Rural Roads: A Policy Analysis." *Journal of the Transportation Research Forum*, 30(1): 1-8, 1989.

Kennedy, Peter. *A Guide to Econometrics.* (2nd edn) The MIT Press: Cambridge, 1985.

Lamb, Steven W., and Wilfred H. Pine. "Influence of Size and Administrative Organization on Costs of Rural Roads," *Southern Journal of Agricultural Economics*, 6: 157-160, December 1974.

Musgrave, Richard A. "Provision For Social Goods," in J. Margolis & M. Guitton (Eds), *Public Economics.* St. Martin's Press: New York, 1969.

Pappas, James L. and Mark Hirschey. *Fundamentals of Managerial Economics.* (2nd edn) The Dryden Press: Chicago, 1985.

Lesher, William G. and Harry P. Mapp. "Economies of Size in Highway Maintenance and Administration: A Preliminary Analysis for the Counties of New York State," *Journal of Northeastern Agricultural Economics*, 3: 90-111, May 1974.

Marathon, Nicholas and Jerry D. Norton. *Rural Highway Finance: Federal Funding for Interstate and Non-Interstate Highways in Rural Areas.* U.S.D.A. Office of Transportation, Washington, D.C., September, 1988.

Miller, Don M. "Reducing Transformation Bias in Curve Fitting," *The American Statistician*, 38(2): 124-26, May 1984.

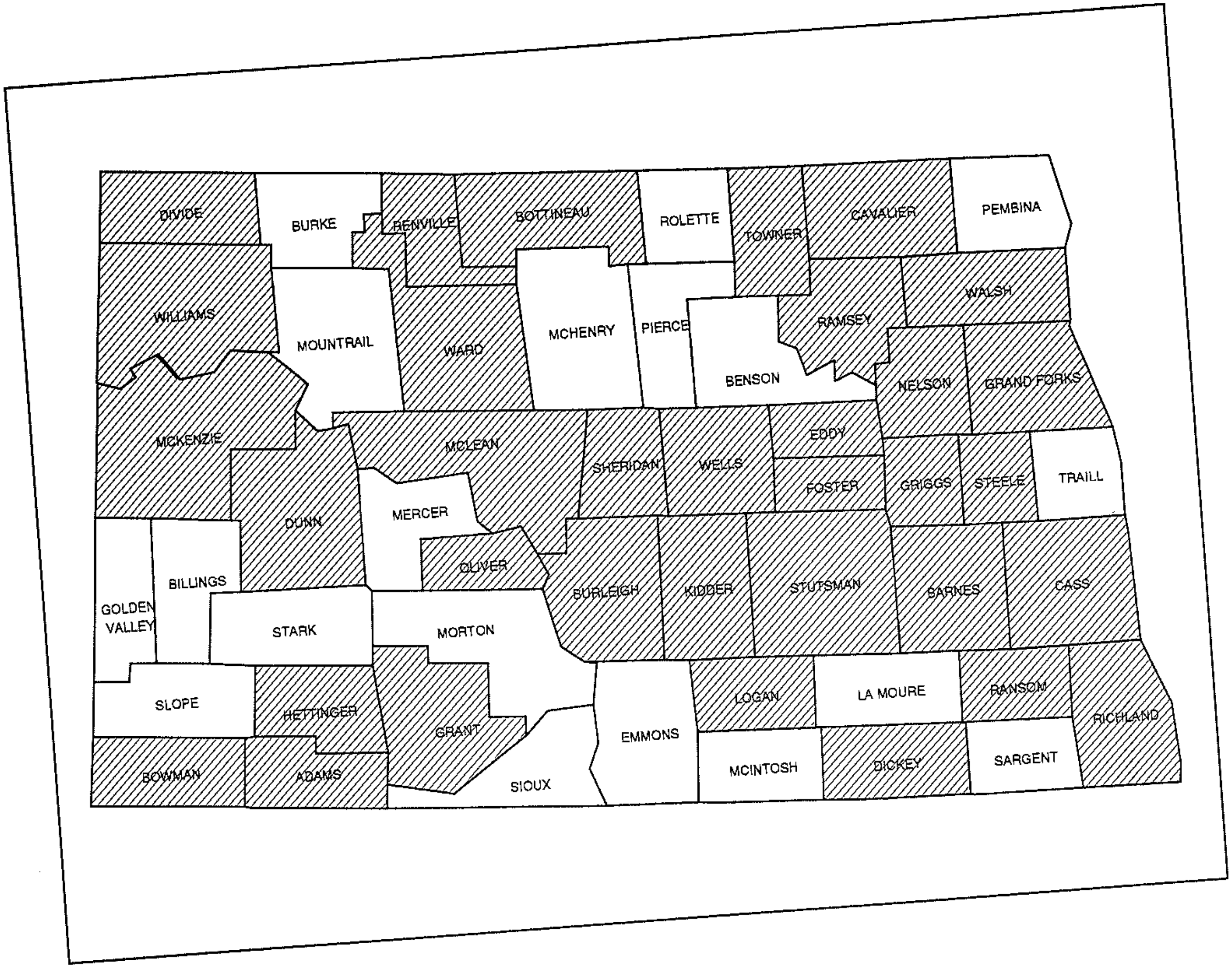
The Road Information Program (TRIP). *1989 State Highway Funding Methods: An Analysis and Update.* Washington, D.C., 1989.

Tolliver, Denver D. *The Impacts of Grain Subterminals on Rural Highways: Volume II.* UGPTI Report No. 75. Upper Great Plains Transportation Institute, North Dakota State University, Fargo, 1989.

Walzer, Norman and David L. Chicoine. *Rural Roads and Bridges: A Dilemma for Local Officials*. U.S.D.A. Office of Transportation, Washington, D.C., April, 1989.

APPENDIX A: BENEFIT-COST ANALYSIS

All North Dakota counties that returned useable surveys are analyzed in terms of the optimal mix of roads in each. The benefit-cost methodology used in this study only measures the benefits to existing traffic from road conversion. A survey of users was not performed for this study, and the change in traffic on road sections resulting from conversion is expected to be small for reasons discussed previously. In this appendix, the benefit-cost analysis is presented on a county by county basis.


DIVIDE
BURKE
RENVILLE
BOTTINEAU
ROLETTE
TOWNER
CAVALIER
PEMBINA
WILLIAMS
MOUNTRAIL
WARD
MCHENRY
PIERCE
BENSON
RAMSEY
WALSH
NELSON
GRAND FORKS
MCKENZIE
MCLEAN
SHERIDAN
WELLS
EDDY
FOSTER
GRIGGS
STEELE
TRAILL
DUNN
MERCER
OLIVER
BURLEIGH
KIDDER
STUTSMAN
BARNES
CASS
GOLDEN VALLEY
BILLINGS
STARK
MORTON
SLOPE
HETTINGER
GRANT
SIOUX
EMMONS
LOGAN
LA MOURE
RANSOM
RICHLAND
BOWMAN
ADAMS
MCINTOSH
DICKEY
SARGENT

Adams

Adams county, located in the southwest part of the state, has a county road system which comprises 310 miles. Of these 310 miles, 277 are gravel and 33 are paved. The first step in the benefit-cost analysis examines possible conversion of gravel roads to paved roads. Adams county has 269 miles of gravel roads with less than 100 average daily trips (ADT), and 8 with between 100 and 150 ADT according to county highway department estimates. In this analysis it is assumed that the traffic levels are at the midpoint of the given range. The traffic estimates, and estimated annual benefits and costs of conversion to paved for the gravel roads are shown in Table A1.

Table A1: Costs and Benefits of Conversion of Gravel Roads Into Paved For Adams County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	102	$23,501	$304,674	($281,173)
26 - 50	122	$85,453	$364,414	($278,961)
51 - 100	45	$62,624	$134,415	($71,791)
101 - 150	8	$18,506	$23,896	($5,390)

Table A1 shows that there are no net benefits to converting any of Adams county's gravel roads to paved. In fact, conversion of any of the roads which have less than 162 trips may be detrimental.

Adams county's paved roads all have traffic volumes exceeding 100 average daily trips. The traffic estimates, and the estimated annual benefits and costs from conversion of paved roads into gravel are shown in Table A2.

Table A2: Costs and Benefits of Conversion of Paved Roads Into Gravel For Adams County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 200	18	$53,766	$49,934	$3,832
201 - 250	15	$44,805	$62,348	($17,543)

Table A2 shows that there may be some net benefits from converting 18 miles of paved roads to gravel in Adams county. However, a more detailed traffic count is required before making this decision, since these 18 miles are assumed to have 150.5 ADT in this analysis. Furthermore, the gains from such a conversion are minimal. The combination of Tables 1 and 2 shows Adams county to be near its optimal mix of roads.

Barnes

Barnes county is located in the eastern part of the state, and borders Cass county - the most urbanized county in the state. Barnes county has a county road system that includes 347 miles of road. A high portion of these county miles are paved (233 miles).

Of the 114 miles of gravel roads in Barnes county, over 40 percent have traffic volumes exceeding 100 ADT. The traffic estimates for the county's gravel mileage, and estimated annual costs and benefits of converting these miles to paved are shown in Table A3.

Table A3: Costs and Benefits of Conversion of Gravel Roads Into Paved For Barnes County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	36	$8,294	$107,532	($99,238)
26 - 50	13	$9,106	$38,831	($29,725)
51 - 100	18	$25,050	$53,766	($28,716)
101 - 200	47	$130,382	$140,389	($10,007)

Table A3 shows that conversion of gravel roads to paved in Barnes county would not be beneficial overall. Similarly to Adams county, a more detailed traffic count of gravel roads exceeding 100 ADT should be performed before deciding whether to convert higher volume gravel roads to paved. The cutoff point of 162 ADT still applies. However, significant increases in utilization resulting from conversion would bring this cutoff point down.

Barnes county's paved road network includes 233 miles; all but 10 of which has more than 100 ADT. Table A4 provides the traffic estimates given by the county official for the paved roads in Barnes county, and the estimated annual benefits and costs of converting paved mileage into gravel.

Table A4: Costs and Benefits of Conversion of Paved Roads Into Gravel For Barnes County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	10	$29,870	$13,917	$15,953
101 - 200	105	$313,635	$291,280	$22,355
201 - 300	63	$188,181	$290,893	($102,712)
301 - 500	33	$98,571	$243,613	($145,042)
501 - 1000	19	$56,753	$262,838	($206,085)
1001 - 2000	3	$8,961	$82,974	($74,013)

Table A4 shows that there are 115 miles of paved road in Barnes county where conversion to gravel may be justified in terms of the annual costs and benefits. However, further traffic counts on 105 of these miles should be performed before conversion, as the costs of conversion are based on the range average. There are 118 miles of paved road in the county where conversion would produce net losses. Tables 3 and 4 show that there may be some benefits to changing the mix of roads in Barnes county.

Bottineau

Bottineau county is located in the north central portion of the state, and has a county road system which is comprised of 253 miles. Nearly 70 percent of this mileage is paved road mileage (176 miles). Of the 77 miles of gravel mileage in the county, only 28 miles have more than 100 ADT. Table A5 presents estimates of traffic volumes on gravel roads in the county, along with estimates of annual benefits and costs of converting these gravel miles to paved miles.

Table A5: Costs and Benefits of Conversion of Gravel Roads Into Paved For Bottineau County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	14	$3,226	$41,818	($38,592)
26 - 50	17	$11,907	$50,779	($38,872)
51 - 100	18	$25,050	$53,766	($28,716)
101 - 200	27	$74,901	$80,649	($5,748)
1000	1	$18,433	$2,987	$15,446

Table A5 shows that there is one mile of gravel road in Bottineau county where conversion to paved roads would definitely be beneficial. A more detailed traffic count on the 27 miles that have between 101 and 200 ADT should be performed before making conversion decisions, since there are annual net benefits from converting gravel roads with more than 162 ADT to paved. Furthermore, any significant increases in the utilization of Bottineau county's roads resulting from conversion would lower the threshold where conversion would be beneficial. The mile of road that has 1000 ADT should definitely be converted to a paved road, as conversion would produce benefits exceeding costs of over $15,000 per year.

There are 176 miles of paved roads in Bottineau county, and 174 of these miles have at least 150 ADT. The paved mileage traffic estimates, and the estimated annual benefits and costs from conversion to gravel miles are shown in Table A6.

Table A6: Costs and Benefits of Conversion of Paved Roads Into Gravel For Bottineau County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	2	$5,974	$1,401	$4,573
150 - 200	15	$44,805	$48,524	($3,719)
201 - 250	149	$445,063	$619,323	($174,260)
400	10	$29,870	$73,730	($43,860)

Table A6 shows that there would be some gains from converting 2 miles of paved roads into gravel roads. Conversion of any other paved mileage into gravel mileage would be detrimental to the county. Tables A5 and A6 show that there are minimal gains in changing the mix of roads in Bottineau county. Bottineau county is close to its optimal mix of roads.

Bowman

Bowman county is located in the southwest corner of the state, bordering South Dakota and Montana. The county maintains 268 miles of road, 162 miles of which are gravel. All of the gravel mileage in Bowman County is sparsely traveled, experiencing less than 100 ADT. Table A7 presents traffic estimates on the gravel roads in Bowman county, along with the estimated benefits and costs of converting these roads to paved roads.

Table A7: Costs and Benefits of Conversion of Gravel Roads Into Paved For Bowman County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	8	$1,843	$23,896	($22,053)
26 - 50	54	$37,824	$161,298	($123,474)
51 - 100	100	$139,165	$298,700	($159,535)

Table A7 shows that conversion of Bowman county's gravel roads to paved should not even be considered. The annual benefits of such a conversion would be far outweighed by the annual costs.

Bowman county's road network also includes 106 miles of paved roads. Table A8 shows the traffic estimates for these paved roads, along with the estimated benefits and costs of converting these miles to gravel miles.

Table A8: Costs and Benefits of Conversion of Paved Roads Into Gravel For Bowman County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	12	$35,844	$8,405	$27,439
51 - 100	32	$95,584	$44,533	$51,051
101 - 150	62	$185,194	$143,423	$41,771

Table A8 shows that there are substantial potential gains from converting paved roads to gravel in Bowman county. If all paved roads in Bowman county are converted to gravel, the county could realize net benefits exceeding $120,000 per year. Tables A7 and A8 show that low traffic volumes in Bowman county suggest a strategy for the optimal mix of roads of converting all paved roads to gravel. There are no gravel roads in the county where conversion to paved is warranted.

Burleigh

Burleigh county is located in the central portion of the state, and contains one of the state's few urban centers, Bismarck, which is the state capitol. Burleigh county has a county road system that encompasses 312 miles of road. 185 of these miles are gravel, and the rest are paved. All of Burleigh county's gravel mileage has less than 150 ADT. Table A9 shows the traffic estimates for these gravel roads as given by the county official, and provides estimates of the annual benefits and costs of converting these roads to paved.

Table A9: Costs and Benefits of Conversion of Gravel Roads Into Paved For Burleigh County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	5	$1,152	$14,935	($13,783)
26 - 50	63	$44,127	$188,181	($144,054)
51 - 100	76	$105,766	$227,012	($121,246)
101 - 150	41	$94,844	$122,467	($27,623)

Table A9 shows that there are no net benefits to converting gravel roads to paved in Burleigh county.

There are 127 miles of paved roads in Burleigh county, many of which have fairly high traffic volumes. Table A10 presents traffic estimates on these paved roads, along with estimates of benefits and costs of conversion of paved roads to gravel.

Table A10: Costs and Benefits of Conversion of Paved Roads Into Gravel For Burleigh County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 50	7	$20,909	$3,226	$17,683
51 - 150	11	$32,857	$20,377	$12,480
151 - 350	38	$113,506	$175,459	($61,953)
over 350	71	$212,077	$459,356	($247,279)

Table A10 shows that there would be some annual net benefits from converting some of Burleigh county's lower volume paved roads into gravel roads. Tables 9 and 10 show that there is a potential for net benefits from increasing the portion of roads that are gravel in Burleigh county.

Cass

Cass county is the most urbanized of all North Dakota counties, and is located at the eastern edge of the state. There are 662.15 miles of county road in Cass county, and slightly more than half are gravel miles. Cass county's gravel roads all have between 50 and 150 ADT. Table A11 shows county ADT estimates on gravel roads, along with estimates of benefits and costs from converting these gravel roads to paved roads.

Table A11: Costs and Benefits of Conversion of Gravel Roads Into Paved For Cass County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	163.34	$227,313	$487,897	($260,584)
101 - 150	192.3	$444,844	$574,400	($129,556)

Table A11 shows that there are no net benefits to Cass county converting gravel mileage to paved mileage.

Cass county's paved mileage of 306.51 contains very high traffic levels, as there is no paved mileage in the county with less than 200 ADT. Table A12 gives estimates of traffic levels on Cass county's paved road network, and presents estimates of the costs and benefits of converting Cass county's paved roads to gravel roads.

Table A12: Costs and Benefits of Conversion of Paved Roads Into Gravel For Cass County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
200	76.5	$228,506	$282,017	($53,511)
225	25	$74,675	$103,683	($29,008)
300	161.51	$482,430	$893,110	($410,680)
400	11	$32,857	$81,103	($48,246)
500	11	$32,857	$101,379	($68,522)
700	9.8	$29,273	$126,447	($97,174)
2000	9.7	$28,974	$357,591	($328,617)
3000	2	$5,974	$110,595	($104,621)

Table A12 shows that any conversion of paved roads to gravel in Cass county would produce annual costs that far exceed annual benefits. The high traffic volumes on all of Cass county's paved roads makes the total annual difference between the operating and opportunity costs that would be realized on gravel versus paved very large. Tables A11 and A12 show that Cass county's mix of roads appears to be at its optimum.

Cavalier

Cavalier county is located in the northeast portion of the state, on the Canadian border. The county's road system comprises 343 miles, and over 80 percent of these miles are gravel. Nearly half of Cavalier county's gravel roads have over 100 ADT. Table A13 shows the traffic volume estimates on these gravel roads, along with estimates of the benefits and costs of converting these roads to paved.

Table A13: Costs and Benefits of Conversion of Gravel Roads Into Paved For Cavalier County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	50	$11,520	$149,350	($137,830)
26 - 50	50	$35,022	$149,350	($114,348)
51 - 100	50	$69,583	$149,350	($79,767)
101 - 200	62.5	$173,381	$186,688	($13,307)
301 - 400	50	$323,030	$149,350	$173,680
401 - 500	12.5	$103,798	$37,338	$66,460

Table A13 shows that there are substantial potential benefits from converting some of Cavalier county's gravel road network into paved miles. High traffic volumes on these roads suggests that conversion is warranted.

Cavalier county's paved system is comprised of 68 miles. Table A14 shows estimated traffic volumes on these roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A14: Costs and Benefits of Conversion of Paved Roads Into Gravel For Cavalier County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 200	34	$101,558	$94,319	$7,239
201 - 300	27.2	$81,246	$125,592	($44,346)
301 - 500	6.8	$20,312	$50,199	($29,887)

Table A14 shows that there are potential benefits to converting 34 miles of paved roads to gravel in Cavalier county. However, a more detailed traffic count should be performed before such a conversion. Tables A13 and A14 show that there are potential benefits from changing the mix of roads in Cavalier county.

Dickey

Dickey county, located in the southeastern part of the state, has a county road network which comprises 473 miles. Of these 473 miles, 389 are gravel miles. Table A15 shows the traffic volume estimates on these gravel roads, and shows the estimated benefits and costs from converting these miles to paved.

Table A15: Costs and Benefits of Conversion of Gravel Roads Into Paved For Dickey County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	124	$28,570	$370,388	($341,818)
26 - 50	82	$57,436	$244,934	($187,498)
51 - 100	82	$114,116	$244,934	($130,818)
101 - 150	101	$233,641	$301,687	($68,046)

Table A15 shows that there are no net benefits from converting gravel mileage to paved in Dickey county.

Dickey county also has 84 miles that are paved. Table A16 shows ADT estimates, as well as estimates of the costs and benefits from converting these roads to gravel.

Table A16: Costs and Benefits of Conversion of Paved Roads Into Gravel For Dickey County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	9	$26,883	$2,074	$24,809
26 - 50	9	$26,883	$6,304	$20,579
51 - 100	20	$59,740	$27,883	$31,907
101 - 150	19	$56,753	$43,952	$12,801
301 - 400	27	$80,649	$174,436	($93,787)

Table A16 shows that there would be considerable annual net benefits to converting some of Dickey county's paved mileage to gravel. Tables A15 and A16 show that under optimal conditions Dickey county would have a total of 27 paved miles and the rest gravel.

Divide

Divide county is in the northwest corner of the state, and has a county road network that is made up of 188.6 gravel roads and 23.4 paved roads. All of Divide county's gravel roads have between 50 and 150 ADT. Table A17 shows the traffic volume estimates on Divide county's gravel road network, and shows the estimated costs and benefits of converting these roads to paved.

Table A17: Costs and Benefits of Conversion of Gravel Roads Into Paved For Divide County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
51 - 100	31.1	$43,280	$92,896	($49,616)
101 - 150	157.5	$364,341	$470,453	($106,112)

Table A17 shows that there are no potential benefits to converting Divide county's gravel roads to paved.

Divide county's paved roads all have at least 100 ADT. Table A18 shows the traffic volume estimates for Divide county along with estimates of the costs and benefits of converting these roads to gravel.

Table A18: Costs and Benefits of Conversion of Paved Roads Into Gravel For Divide County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
101 - 180	9	$26,883	$23,308	$3,575
151 - 250	14.4	$43,013	$53,218	($10,205)

Table A18 shows some potential benefits from converting 9 miles of paved roads to gravel in Divide county. However, these potential gains are minimal. Tables A17 and A18 show that Divide county is near its optimal mix of roads.

Dunn

Dunn county is located in the western portion of the state, and is very rural in nature as there are no townships in the county. The county maintains 871 miles of road, 850 of which are gravel. Table A19 presents traffic volume estimates for gravel roads in the county, along with the estimated benefits and costs of converting Dunn county's gravel roads to paved.

Table A19: Costs and Benefits of Conversion of Gravel Roads Into Paved For Dunn County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	50	$11,520	$149,350	($137,830)
26 - 50	600	$420,261	$1,792,200	($1,371,939)
51 - 100	100	$139,165	$298,700	($159,535)
150	100	$276,488	$298,700	($22,212)

Table A19 shows that conversion of any of Dunn county's gravel roads to paved would create annual costs exceeding annual benefits.

There are only 21 paved miles in Dunn county. Table A20 shows the traffic volumes on these roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A20: Costs and Benefits of Conversion of Paved Roads Into Gravel For Dunn County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	21	$62,727	$29,225	$33,502

Table A20 shows that the 21 miles of paved road in Dunn county should all be converted to gravel in order to achieve an optimum. Tables A19 and A20 show that the optimal mix of roads for Dunn county would include all gravel roads.

Eddy

Eddy county, located in the east-central portion of the state, has 150 miles of county roads. Nearly 63 percent of Eddy county's roads are gravel, and all have relatively low traffic volumes. Table A21 shows estimates of traffic volumes on Eddy county's gravel roads, along with estimates of the benefits and costs of converting these roads to paved roads.

Table A21: Costs and Benefits of Conversion of Gravel Roads Into Paved For Eddy County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	94	$65,841	$280,778	($214,937)

Table A21 shows that all of Eddy county's gravel roads should remain as gravel roads. Any switch to paved would produce annual costs far exceeding annual benefits.

Eddy county's paved road network is comprised of 56 miles. These 56 miles of paved roads also have relatively low traffic volumes. Table A22 shows the estimated traffic volumes on Eddy county's paved roads, and shows the estimated benefits and costs of converting these roads to gravel.

Table A22: Costs and Benefits of Conversion of Paved Roads Into Gravel For Eddy County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	8	$23,896	$1,843	$22,053
26 - 50	20	$59,740	$14,009	$45,731
51 - 100	28	$83,636	$38,966	$44,670

Table A22 shows that all of Eddy county's paved roads should be converted to gravel in order to achieve the optimal mix of roads. Because of the low traffic volumes on these roads, the opportunity cost savings and vehicle operating cost savings of a paved road over a gravel road aren't large enough to justify the difference in cost between the two types of roads. Tables A21 and A22 show that the optimal mix of roads in Eddy county would include all gravel roads.

Foster

Foster county is also located in the east-central portion of the state, and is located just south of Eddy county. Foster county has a road network which is made up of 384 miles. 300 of these 384 miles are gravel roads. Table A23 shows the traffic estimates for Foster county's gravel roads, along with estimates of the benefits and costs of converting these miles to paved.

Table A23: Costs and Benefits of Conversion of Gravel Roads Into Paved For Foster County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	180	$126,078	$537,660	($411,582)
51 - 100	108	$150,299	$322,596	($172,297)
101 - 150	12	$27,759	$35,844	($8,085)

Table A23 shows that converting Foster county's gravel roads to paved would produce annual net costs.

Foster county has 84 miles of paved road. Table A24 shows traffic estimates on these paved roads, along with the benefits and costs of converting these roads to gravel.

Table A24: Costs and Benefits of Conversion of Paved Roads Into Gravel For Foster County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	67	$200,129	$93,241	$106,888
101 - 200	17	$50,779	$47,160	$3,619

Table A24 shows that conversion of a large portion of Foster county's paved road network to gravel would produce large net annual benefits. However, detailed traffic counts should be performed on the county's roads that have 101-200 ADT before conversion. Tables A23 and A24 show that the optimal mix of roads for Foster county would include nearly all gravel miles.

Grand Forks

Grand Forks county is located in the northwest portion of the state, and contains the urban center of Grand Forks. The county has a road system comprised of 514.3 miles. Of these 514.3 miles, 252.3 are gravel. Table A25 shows traffic estimates on these gravel roads, along with the costs and benefits of converting them to paved.

Table A25: Costs and Benefits of Conversion of Gravel Roads Into Paved For Grand Forks County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	36.3	$25,426	$108,428	($83,002)
51 - 100	103	$143,340	$307,661	($164,321)
101 - 150[33]	113	$261,401	$337,531	($76,130)

[33]The Grand Forks county official gave an estimated traffic volume for these 113 miles of more than 100 ADT. He could not give any further detail. The range of 101 to 150 was assumed for illustrative purposes.

Table A25 suggests that conversion of Grand Forks county's gravel roads to paved roads would produce large net annual costs. However, detailed traffic estimates should be performed on the 113 miles of road that have more than 100 ADT before decisions regarding conversion are made.

Grand Forks county also has 262 miles of paved roads. These paved roads experience very high traffic levels, due to the urban nature of the county. Traffic estimates, as well as estimates of costs and benefits from converting these miles to gravel are provided in Table A26.

Table A26: Costs and Benefits of Conversion of Paved Roads Into Gravel For Grand Forks County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
206	29.5	$88,117	$112,014	($23,897)
404	36.5	$109,026	$271,806	($162,780)
531	102	$304,674	$998,341	($693,667)
756	94	$280,778	$1,309,887	($1,029,109)

Table A26 shows that any conversion of Grand Forks county's paved roads into gravel roads would be detrimental. Because of the high traffic levels, the benefits of paved mileage far outweigh the costs. Tables A25 and A26 suggest that Grand Forks county is near optimal road mix.

Grant

Grant county is located in the southwest portion of the state, and is very rural in nature, as there are no organized townships in the county. Grant County has 1,038 miles of county roads, and all but 4 miles are gravel. Table A27 shows traffic estimates for

Grant county's gravel roads, along with estimates of the costs and benefits of converting these miles to paved.

Table A27: Costs and Benefits of Conversion of Gravel Roads Into Paved For Grant County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	500	$115,203	$1,493,500	($1,378,297)
26 - 50	314	$219,937	$937,918	($717,981)
51 - 100	200	$278,331	$597,400	($319,069)
110 - 120	20	$42,395	$59,740	($17,345)

Table A27 shows that conversion of any of Grant county's gravel roads into paved roads would produce annual costs that exceed annual benefits. In many cases annual costs would exceed annual benefits by a large amount.

Grant county only has 4 paved roads. Table A28 shows traffic estimates on these paved roads, and the benefits and costs of converting these roads to gravel.

Table A28: Costs and Benefits of Conversion of Paved Roads Into Gravel For Grant County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	4	$11,948	$2,802	$9,146

Table A28 shows that the annual benefits of converting the 4 miles of paved road in Grant county to gravel would exceed the annual costs by more than $9,000. Tables A27 and A28 show that Grant county is near its optimal mix of roads, but the optimal mix should be all gravel roads.

Griggs

Griggs county is located in the east-central portion of the state, and has a county road system that is comprised of 235 miles. Of the 235 miles of county road, 196.5 are gravel. Table A29 provides estimates of traffic volume, along with the benefits and costs of converting these gravel miles to paved.

Table A29: Costs and Benefits of Conversion of Gravel Roads Into Paved For Griggs County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	12	$2,765	$35,844	($33,079)
26 - 50	50	$35,022	$149,350	($114,328)
51 - 100	101.5	$141,253	$303,181	($161,928)
101 - 150	33	$76,338	$98,571	($22,233)

Table A29 shows that any conversion of Griggs county's gravel roads to paved would be detrimental.

Griggs county has 38.5 miles of paved county road. Table A30 shows the traffic estimates on these roads, and the estimated benefits and costs of converting these roads to gravel.

Table A30: Costs and Benefits of Conversion of Paved Roads Into Gravel For Griggs County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	38.5	$115,000	$53,579	$61,421

Table A30 shows that there are significant net annual benefits to converting all of Griggs county's paved roads to gravel. Tables A29 and A30 suggest that the optimal mix of roads for Griggs county would consist of all gravel roads.

Hettinger

Hettinger county is located in the southwest corner of the state, and has a county road system that is comprised of 248 miles. Of the 248 miles of county road, 232 are gravel. Table A31 shows the traffic estimates on these gravel miles, along with estimates of the benefits and costs of converting these miles to paved miles.

Table A31: Costs and Benefits of Conversion of Gravel Roads Into Paved For Hettinger County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	12	$2,765	$35,844	($33,079)
26 - 50	70	$49,031	$209,090	($160,059)
51 - 100	96	$133,599	$286,752	($153,153)
101 - 200	65	$180,316	$194,155	($13,839)
300	5	$27,649	$14,935	$12,714

Table A31 shows that there are potential gains from converting 5 miles of gravel road to paved in Hettinger county. However, a detailed traffic count should be performed on the roads with between 101 and 200 ADT before any conversion decisions are made, since conversion of some of these roads may produce annual net benefits as well.

Hettinger county has only 16 miles of paved roads. Table A32 shows the traffic volumes on these roads, and provides estimates of the benefits and costs of converting these roads to gravel.

Table A32: Costs and Benefits of Conversion of Paved Roads Into Gravel For Hettinger County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	1	$2,987	$1,392	$1,595
101 - 200	15	$44,805	$41,611	$3,194

Table A32 shows that conversion of Hettinger county's paved roads to gravel would be beneficial overall. However, conversion of some roads with between 101 and 200 ADT may not produce net benefits. A more detailed traffic count is needed on these roads. Tables A31 and A32 show that Hettinger county is close to its optimal mix of roads, although there are some potential benefits from converting gravel roads to paved and paved to gravel.

Kidder

Kidder county, which is located in the central portion of the state, has a county road network that is comprised of 315 miles. Of the 315 miles of county road, nearly 90 percent are gravel. Table A33 provides traffic estimates for these gravel roads, along with estimated benefits and costs of converting them to paved.

Table A33: Costs and Benefits of Conversion of Gravel Roads Into Paved For Kidder County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	176	$40,552	$525,712	($485,160)
26 - 50	88	$61,638	$262,856	($201,218)
51 - 100	13	$18,092	$38,831	($20,739)

Table A33 shows that any conversion of gravel roads into paved in Kidder county would increase annual costs substantially more than annual benefits.

There are 38 miles of paved roads in Kidder county. Table A34 provides traffic estimates for these paved roads, as well as estimates of the costs and benefits of converting them to gravel.

Table A34: Costs and Benefits of Conversion of Paved Roads Into Gravel For Kidder County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	10	$29,870	$2,304	$27,566
26 - 50	10	$29,870	$7,004	$22,866
51 - 100	18	$53,766	$25,050	$28,716

Table A34 shows that the annual net benefits from converting all of Kidder county's paved roads to gravel are in excess of $79,000. Tables A33 and A34 show that the optimal mix of roads for Kidder county does not include any paved roads.

Logan

Logan county, which is located in the south-central portion of the state, has a county road system which is comprised of 556 miles. Nearly all of these miles are gravel miles. Table A35 shows traffic estimates, and the benefits and costs of converting these gravel miles to paved.

Table A35: Costs and Benefits of Conversion of Gravel Roads Into Paved For Logan County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	200	$46,081	$597,400	($551,319)
26 - 50	100	$70,044	$298,700	($228,656)
51 - 100	220	$306,164	$657,140	($350,976)
101 - 150	36	$83,278	$107,532	($24,254)

Table A35 shows that there are substantial net losses from converting any of Logan county's gravel mileage to paved.

There are only 10 miles of paved county road in Logan county. Table A36 shows traffic estimates on these roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A36: Costs and Benefits of Conversion of Paved Roads Into Gravel For Logan County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	2	$5,974	$461	$5,513
101 - 200	8	$23,896	$22,193	$1,703

Table A36 shows that the annual benefits of converting the 2 miles of road with 0 to 25 ADT to gravel exceed the annual costs from doing so. There are also potential annual benefits to converting 8 miles of paved road with between 101 and 200 ADT. However, detailed traffic counts should take place prior to converting these 8 miles. The benefits of converting these 8 miles appear minimal. Tables A35 and A36 show Logan county is near its optimal mix roads.

McKenzie

McKenzie county is located on the western border of the state, and has a county road system that contains 770 miles. Nearly 85 percent of these miles are gravel miles. Table A37 shows the traffic volume estimates on these gravel roads, as well as estimates of the benefits and costs of converting these roads to paved.

Table A37: Costs and Benefits of Conversion of Gravel Roads Into Paved For McKenzie County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	475	$109,443	$1,418,825	($1,309,382)
26 - 50	100	$70,044	$298,700	($228,656)
51 - 100	50	$69,583	$149,350	($79,767)
101 - 200	25	$69,352	$74,675	($5,323)

Table A37 shows that there are no apparent gains from converting gravel roads in McKenzie county to paved roads. However, a more detailed traffic count must be performed on roads that have 101-200 ADT before any conversion decision is made.

There are 120 miles of paved road in McKenzie county. Table A38 provides traffic estimates for these paved roads, along with estimates of the benefits and costs of conversion of these roads to gravel.

Table A38: Costs and Benefits of Conversion of Paved Roads Into Gravel For McKenzie County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	30	$89,610	$21,013	$68,597
51 - 100	60	$179,220	$83,499	$95,721
101 - 200	30	$89,610	$83,223	$6,387

Table A38 shows that there are substantial potential benefits from converting 90 miles of McKenzie county's paved roads to gravel. Furthermore, there may be net annual benefits from converting a portion of the remaining 30 to gravel. Detailed traffic estimates are needed on these roads before such a decision. Tables A3 and A38 show that McKenzie county's optimal mix of roads would include almost all gravel roads. However, detailed traffic counts should be performed on all roads that have 101-200 ADT.

McLean

McLean county, which is located in the west-central portion of the state, has a county road network that is comprised of 700 miles. 83 percent of these miles are gravel. Table A39 shows the estimated traffic volumes on these gravel roads, and the estimated benefits and costs from converting these miles to paved.

Table A39: Costs and Benefits of Conversion of Gravel Roads Into Paved For McLean County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	130	$180,915	$388,310	($207,395)
101 - 150	450	$1,040,976	$1,344,150	($303,174)

Table A39 shows that there are no net benefits to McLean county converting gravel roads into paved roads.

There are 120 miles of paved roads in McLean county. Table A40 shows traffic volume estimates on these paved roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A40: Costs and Benefits of Conversion of Paved Roads Into Gravel For McLean County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
200	120	$358,440	$442,380	($83,940)

Table A40 shows that the annual costs of converting McLean county's paved mileage into gravel mileage would far outweigh the benefits of doing so. Tables A39 and A40 suggest that McLean county is at its optimal mix of roads.

Nelson

Nelson county is located in the northeast part of the state, and borders on Grand Forks county. Nelson county's road network includes 426.5 county road miles. 375 of these miles are gravel miles. Table A41 provides traffic volume estimates, along with estimates of the costs and benefits of converting these roads to paved roads.

Table A41: Costs and Benefits of Conversion of Gravel Roads Into Paved For Nelson County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	60	$13,824	$179,220	($165,396)
26 - 50	128	$89,656	$382,336	($292,680)
51 - 100	43	$59,841	$128,441	($68,600)
101 - 130	35	$74,513	$104,545	($30,032)
131 - 160	71.5	$191,758	$213,571	($21,813)
161 - 200	35	$116,447	$104,545	$11,902
575 - 675	2.5	$28,801	$7,468	$21,333

Table A41 shows that there are substantial benefits to converting some of Nelson county's gravel road network to paved roads.

Nelson county has a paved road network that includes 51.5 miles. Table A42 provides traffic estimates on these paved roads, along with estimates of the benefits and costs of converting these paved roads to gravel roads.

Table A42: Costs and Benefits of Conversion of Paved Roads Into Gravel For Nelson County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	9	$26,883	$12,525	$14,358
101	1	$2,987	$1,862	$1,125
101 - 220	12	$35,844	$35,501	$343
180	3	$8,961	$9,954	($993)
120 - 280	17	$50,779	$62,671	($11,892)
160 - 240	8	$23,896	$29,492	($5,596)
575 - 675	1.5	$4,481	$17,281	($12,800)

Table A42 shows that there are potential gains to converting 10 miles of Nelson county's paved roads to gravel. There are another 12 miles where some conversion may be beneficial. However, a more detailed traffic count of these 12 miles is necessary. Tables A41 and A42 show that the optimal mix of roads for Nelson county would include an increase in the number of miles that are paved.

Oliver

Oliver county is located in the west-central portion of the state, and has a county road network that is comprised of 545 miles. There are no township roads in the county. Nearly all of Oliver county's roads are gravel. Table A43 shows traffic estimates on these gravel roads, along with the benefits and costs of converting these roads to paved.

Table A43: Costs and Benefits of Conversion of Gravel Roads Into Paved For Oliver County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	28	$6,451	$83,636	($77,185)
26 - 50	94	$65,841	$280,778	($214,937)
51 - 100	272	$378,530	$812,464	($433,934)
110 - 150	40	$95,849	$119,480	($23,631)
151 - 175	50	$150,225	$149,350	$875
176 - 196	44	$150,852	$131,428	$19,424

Table A43 shows that there are 44 miles of gravel road in Oliver county for which conversion to paved mileage would produce substantial annual net benefits. There are also 50 miles where some conversion is likely to produce benefits. However, a detailed traffic count is needed before making the conversion decisions.

There are only 17 miles of paved county road in Oliver county. Table A44 provides traffic estimates on these roads, along with the benefits and costs of converting these roads to gravel.

Table A44: Costs and Benefits of Conversion of Paved Roads Into Gravel For Oliver County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
150 - 160	7	$20,909	$19,999	$910
190	2	$5,974	$7,004	($1,030)
250	4	$11,948	$18,433	($6,485)
400	4	$11,948	$29,492	($17,544)

Table A44 shows minimal annual net benefits from converting 7 miles to gravel. Slight increases in traffic volumes would nullify these net benefits. Any other conversion of Oliver county's paved mileage into gravel mileage would produce annual costs that exceed annual benefits. Tables A43 and A44 show that the optimal mix of roads for Oliver county would include more paved mileage.

Ramsey

Ramsey county is located in the northeast portion of the state, and has a county road network that includes 180 miles. The majority of these miles are paved, as there are only 37 miles of county gravel roads in Ramsey county. Table A45 provides traffic estimates for these gravel miles, along with estimates of the costs and benefits of converting these gravel roads to paved.

Table A45: Costs and Benefits of Conversion of Gravel Roads Into Paved For Ramsey County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	18	$4,147	$53,766	($49,619)
26 - 50	10	$7,004	$29,870	($22,866)
51 - 100	4	$5,567	$11,948	($6,381)
101 - 150	5	$11,566	$14,935	($3,369)

Table A45 shows that there are no net benefits to converting Ramsey county's gravel mileage to paved mileage.

There are 143 miles of paved county road in Ramsey county. Table A46 shows traffic estimates on these paved roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A46: Costs and Benefits of Conversion of Paved Roads Into Gravel For Ramsey County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	9.5	$28,377	$2,189	$26,188
26 - 50	43	$128,441	$30,119	$98,322
51 - 100	48	$143,376	$66,799	$76,577
101 - 150	37.5	$112,013	$86,748	$25,265
151 - 200	5	$14,935	$16,175	($1,240)

Table A46 shows that there are substantial potential net benefits to Ramsey county converting a good portion of its paved mileage to gravel. Tables A45 and A46 show that Ramsey county's optimal road mix would include a greater proportion of gravel miles.

Ransom

Ransom county is located in the southeast portion of the state, and borders the southern edge of Cass and Barnes counties. The Ransom county road network is comprised of 313.5 miles, most of which is gravel. Table A47 provides traffic estimates on Ransom county's 274 miles of gravel road, along with estimates of the benefits and costs of converting these roads to paved.

Table A47: Costs and Benefits of Conversion of Gravel Roads Into Paved For Ransom County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	7	$1,613	$20,909	($19,296)
26 - 50	93	$65,141	$277,791	($212,650)
51 - 100	93	$129,424	$277,791	($148,367)
101 - 150	81	$187,376	$241,947	($54,571)

Table A47 shows that there are no net benefits to converting Ransom county's gravel roads to paved.

Ransom county has 39.5 miles of paved county road. Table A48 provides traffic estimates on these paved roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A48: Costs and Benefits of Conversion of Paved Roads Into Gravel For Ransom County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 150	20	$59,740	$46,266	$13,474
175	6	$17,922	$19,354	($1,432)
151 - 200	3.5	$10,455	$11,322	($867)
201 - 250	10	$29,870	$41,565	($11,695)

Table A48 shows that there are potential benefits to converting 20 miles of Ransom county's paved roads into gravel. Tables A47 and A48 show that Ransom county's optimal mix of roads would include more gravel mileage.

Renville

Renville county, which is located in the north central portion of the state, has a county road network that is comprised of 140 miles. Of these 140 miles of county road, 65 miles are gravel. Table A49 provides traffic estimates on these gravel roads, along with estimates of the benefits and costs of converting these roads to paved.

Table A49: Costs and Benefits of Conversion of Gravel Roads Into Paved For Renville County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	6	$1,382	$17,922	($16,540)
26 - 50	11	$7,705	$32,857	($25,152)
51 - 100	48	$66,799	$143,376	($76,577)

Table A49 shows that the annual costs of converting Renville county's gravel roads into paved far outweigh the annual benefits.

There are 75 miles of paved roads in Renville county. Table A50 shows traffic estimates on these paved roads, along with the estimated benefits and costs of converting these paved roads to gravel.

Table A50: Costs and Benefits of Conversion of Paved Roads Into Gravel For Renville County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
51 - 100	75	$224,025	$104,374	$119,651

Table A50 shows that there are substantial potential net benefits to converting all of Renville county's paved road mileage to gravel. Tables A49 and A50 show that the optimal mix of county roads for Renville county would be all gravel roads.

Richland

Richland county, located in the southeast corner of the state, has a road network that is comprised of 520 miles. Slightly more than half of these miles are gravel. Table

A51 shows traffic estimates on the 292 miles of gravel roads in Richland county, and provides estimates of the benefits and costs of converting these miles to paved.

Table A51: Costs and Benefits of Conversion of Gravel Roads Into Paved For Richland County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	100	$70,044	$298,700	($228,656)
51 - 100	192	$267,198	$573,504	($306,306)

Table A51 shows that the annual costs of converting Richland county's gravel roads into paved roads outweigh the annual benefits by a great deal.

There are 228 paved county miles in Richland county. Table A52 provides traffic estimates on these roads, as well as estimates of the benefits and costs of converting these miles to gravel.

Table A52: Costs and Benefits of Conversion of Paved Roads Into Gravel For Richland County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	38	$113,506	$8,755	$104,751
26 - 50	85	$253,895	$59,537	$194,358
51 - 100	65	$194,155	$90,458	$103,697
101 - 200	10	$29,870	$27,741	$2,129
151 - 200	28	$83,636	$90,577	($6,941)
1400	2	$5,974	$51,611	($45,637)

Table A52 shows that there are substantial potential benefits from converting 188 miles of Richland county's paved road network into gravel roads. Furthermore, there are another 10 miles where conversion may be beneficial. A more detailed traffic count on these 10 miles is needed. Tables A51 and A52 show that the optimal mix of roads for Richland county would include a high proportion of gravel miles.

Sheridan

Sheridan county is located in the central portion of the state, and has a county road network that is comprised of 140 miles. Most of these road miles are gravel miles. Table A53 provides traffic estimates on Sheridan county's gravel mileage, along with estimated benefits and costs of converting these miles to paved.

Table A53: Costs and Benefits of Conversion of Gravel Roads Into Paved For Sheridan County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	8	$5,604	$23,896	($18,292)
51 - 100	110	$153,082	$328,570	($175,488)

Table A53 shows that any conversion of Sheridan county's gravel roads to paved would be detrimental.

There are 22 miles of paved county roads in Sheridan county. Table A54 provides traffic estimates for these paved roads, along with the estimated benefits and costs of converting these roads to gravel.

Table A54: Costs and Benefits of Conversion of Paved Roads Into Gravel For Sheridan County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	17	$50,779	$23,658	$27,121
101 - 150	5	$14,935	$11,566	$3,369

Table A54 shows that there are potential benefits to converting all of the paved road in Sheridan county to gravel. Tables A53 and A54 show that the optimal mix of roads for Sheridan county would consist of all gravel roads.

Steele

Steele county is located in the east-central portion of the state, and has a road network that is comprised of 240.5 miles. Nearly 70 percent of these road miles are gravel. Table A55 provides estimates of traffic volumes on these gravel roads, along with the estimated benefits and costs of converting these roads to paved.

Table A55: Costs and Benefits of Conversion of Gravel Roads Into Paved For Steele County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	17	$11,907	$50,779	($38,872)
51 - 100	96	$133,598	$286,752	($153,154)
101 - 150	52	$120,291	$155,324	($35,033)

Table A55 shows that there are no gains from converting gravel roads in Steele county to paved.

Steele county has 75.5 miles of paved roads. Table A56 provides traffic estimates on these paved miles, along with estimated benefits and costs of converting these roads to gravel.

Table A56: Costs and Benefits of Conversion of Paved Roads Into Gravel For Steele County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 150	75.5	$225,519	$174,653	$50,866

Table A56 shows that conversion of Steele county's paved roads to gravel would produce substantial net annual benefits. Tables A55 and A56 show that the optimal mix of roads in Steele county would include all gravel roads.

Stutsman

Stutsman county, which is located in the east central portion of the state has a county road network that includes 388 miles. Of these 388 miles, 164.25 are gravel. Table A57 provides estimates of the traffic volumes on these gravel miles, along with the benefits and costs of converting these roads to paved.

Table A57: Costs and Benefits of Conversion of Gravel Roads Into Paved For Stutsman County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 200	158	$438,306	$471,946	($33,640)
201 - 300	6.25	$28,858	$18,669	$10,189

Table A57 shows that there are potential benefits to Stutsman county converting 6.25 miles of gravel road into paved mileage. There also may be benefits to converting some of the roads that have 101-200 ADT to paved. However, a detailed traffic count should first be applied to these roads.

There are 223.75 miles of paved road in Stutsman county. Table A58 provides traffic estimates, along with estimated benefits and costs of converting these paved roads into gravel roads.

Table A58: Costs and Benefits of Conversion of Paved Roads Into Gravel For Stutsman County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
101 - 200	129.75	$387,563	$359,938	$27,625
201 - 300	69	$206,103	$318,597	($112,494)
301 - 500	25	$74,675	$184,555	($109,880)

Table A58 shows that conversion of 94 of Stutsman county's paved roads to gravel would produce significant net costs. However, there may be some net benefits to converting some of the roads that have between 101 and 200 ADT to gravel. More detailed traffic estimates are needed on these roads.

Tables A57 and A58 suggest that detailed traffic counts are necessary on the majority of Stutsman county's roads before deciding the optimal mix of roads.

Towner

Towner county, located in the northeast portion of the state, has 381 miles of county roads. Nearly all of these roads are gravel. Table A59 provides traffic estimates on the 370 miles of gravel roads in Towner county, along with the estimated benefits and costs of converting these roads to paved.

Table A59: Costs and Benefits of Conversion of Gravel Roads Into Paved For Towner County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	210.9	$48,593	$629,958	($581,365)
26 - 50	88.8	$62,199	$265,246	($203,047)
51 - 100	51.8	$72,088	$154,727	($82,639)
175.5	18.5	$59,846	$55,260	$4,586

Table A59 shows that there are 18.5 miles where conversion to paved would produce net annual benefits.

There are only 11 paved county miles in Towner county. Table A60 shows traffic estimates on these 11 miles, as well as the estimated benefits and costs of converting these miles to gravel.

Table A60: Costs and Benefits of Conversion of Paved Roads Into Gravel For Towner County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
0 - 25	11	$32,857	$2,535	$30,322

Table A60 shows that there are a significant amount of potential net annual benefits to converting all of Towner county's current paved system into gravel. Tables A59 and A60 show that the optimal mix is close to the current mix in Towner county, but the paved miles are different miles than the current paved miles.

Walsh

Walsh county is also located in the northeast portion of the state, and has a road network that is comprised of 450 miles. Two-thirds of these miles are gravel miles. Table

A61 provides traffic estimates on these gravel miles, as well as the benefits and costs of converting these miles to paved.

Table A61: Costs and Benefits of Conversion of Gravel Roads Into Paved For Walsh County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	40	$9,216	$119,480	($110,264)
26 - 50	100	$70,044	$298,700	($228,656)
51 - 100	200	$278,331	$597,400	($319,069)
101 - 200	30	$83,223	$89,610	($6,387)
201	30	$111,148	$89,610	$21,538

Table A61 shows that there are potential benefits to converting 30 miles of Walsh county's gravel system to paved. Furthermore, there may be benefits to converting a portion of the 30 miles with 101-200 ADT to paved. However, detailed traffic counts should be performed before conversion.

There are 150 miles of paved roads in Walsh county. Table A62 provides traffic volume estimates, along with estimated benefits and costs of converting these paved roads into gravel roads.

Table A62: Costs and Benefits of Conversion of Paved Roads Into Gravel For Walsh County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
101 - 200	38	$113,506	$105,416	$8,090
231 - 270	2	$5,974	$9,235	($3,261)
251 - 350	22	$65,714	$121,857	($56,143)
301 - 400	71	$212,077	$458,702	($246,625)
351 - 400	13	$38,831	$89,978	($51,147)
601 - 724	4	$11,948	$48,846	($36,898)

Table A62 shows that there are potential benefits from converting a portion of the 38 paved miles with 101-200 ADT to gravel. However, more detailed traffic counts should be performed on these roads before making conversion decisions. Any other conversion of paved roads into gravel in Walsh county will create net costs. Tables A62 and A63 show that the optimal mix of roads for Walsh county may include some conversion of paved and gravel roads.

Ward

Ward county is located in the north central portion of the state, and has a county road network that is comprised of 709 miles. Of the 709 miles in Ward county, 505 are gravel. Table A64 provides traffic estimates on the gravel roads in Ward county, along with the estimated benefits and costs of converting these roads to paved.

Table A63: Costs and Benefits of Conversion of Gravel Roads Into Paved For Ward County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
26 - 50	100	$70,044	$298,700	($228,656)
51 - 100	245	$340,955	$731,815	($390,860)
101 - 200	160	$443,855	$477,920	($34,065)

Table A63 shows that there are no benefits to Ward county converting gravel roads into paved roads, overall. However, there are 160 miles where some conversion may be beneficial. Detailed traffic counts on these 160 miles should be performed before any conversion decisions are made.

There are 204 miles of paved road in Ward county. Table A64 provides traffic estimates on these paved roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A64: Costs and Benefits of Conversion of Paved Roads Into Gravel For Ward County				
Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
201 - 500	184	$549,608	$1,188,749	($639,141)
401 - 500	10	$29,870	$83,038	($53,168)
2000	10	$29,870	$368,650	($338,780)

Table A64 shows that the annual costs exceed the annual benefits for converting paved mileage into gravel mileage in Ward county. Tables A63 and A64 show that Ward county is close to its optimal mix of roads, but may benefit from converting some gravel mileage to paved mileage.

Wells

Wells county, located in the central portion of the state, has a county road network that is comprised of 235 miles. Of these 235 miles, nearly half are gravel. Table A65 provides traffic estimates for these gravel roads, along with estimated benefits and costs of converting them to paved.

Table A65: Costs and Benefits of Conversion of Gravel Roads Into Paved For Wells County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	25	$5,760	$74,675	($68,915)
26 - 50	15	$10,507	$44,805	($34,298)
51 - 100	70	$97,416	$209,090	($111,674)

Table A65 shows that any conversion of Wells county's gravel mileage into paved mileage would produce annual costs greatly exceeding annual benefits.

There are 125 miles of paved mileage in Wells county. Table A66 provides traffic estimates on these roads, along with estimates of the benefits and costs of converting these roads to gravel.

Table A66: Costs and Benefits of Conversion of Paved Roads Into Gravel For Wells County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
51 - 100	109	$325,583	$151,690	$173,893
101 - 200	16	$47,792	$44,386	$3,406

Table A66 shows that there are significant potential annual net benefits to converting a large portion of Wells county's paved roads to gravel. Detailed traffic estimates are needed for the 16 miles that have between 101 and 200 ADT before deciding whether to convert them to gravel. Tables A65 and A66 show that the optimal mix of roads for Wells county would include a higher proportion of gravel miles.

Williams

Williams county, located in the northwest portion of the state, has a road network which is comprised of 763 miles. Of these 763 miles of road, 605 are gravel. Table A67 provides estimates of traffic volumes, along with estimates of the costs and benefits of converting these gravel miles to paved miles.

Table A67: Costs and Benefits of Conversion of Gravel Roads Into Paved For Williams County

Traffic Volume	Mileage	Estimated Annual Benefits	Estimated Annual Costs	Annual Net Benefit
0 - 25	100	$23,041	$298,700	($275,659)
26 - 50	105	$73,546	$313,635	($240,089)
51 - 100	150	$208,748	$448,050	($239,302)
101 - 150	250	$578,320	$746,750	($168,430)

Table A67 shows that there are net costs from converting gravel mileage into paved in Williams county.

There are 158 paved miles in Williams county. Table A68 shows the estimated traffic volumes on these paved miles, along with the benefits and costs of converting these miles to gravel.

Table A68: Costs and Benefits of Conversion of Paved Roads Into Gravel For Williams County				
Traffic Volume	**Mileage**	**Estimated Annual Benefits**	**Estimated Annual Costs**	**Annual Net Benefit**
51 - 100	18	$53,766	$25,050	$28,716
125	6	$17,922	$13,824	$4,098
201 - 225	134	$400,258	$526,100	($125,842)

Table A68 shows that there are potential benefits to converting 24 paved miles to gravel miles in Williams county. Tables A67 and A68 show that the optimal mix of roads in Williams county would include a higher proportion of gravel miles.

APPENDIX B: SURVEY

COUNTY ROAD CONDITIONS IN NORTH DAKOTA

COUNTY NAME ____________________ YOUR NAME ____________________

PHONE NUMBER ____________________ YOUR TITLE ____________________

Instructions: ***Thank you for taking the time to complete this survey. Your efforts will help in research which will benefit the state of North Dakota. Please take your time, and forward the survey to the appropriate people if you are unable to answer some of the questions. Please don't throw this survey away. The information you supply is very important. If the exact numbers are not available to you, your best estimates are fine. If you have any questions call Dan Zink or John Bitzan collect at 701-237-7767. Thank you in advance for your help!***

COUNTY ROAD CONDITIONS

1. Please indicate total county road mileage in your county.

   Paved ____________ miles
   Gravel ____________ miles
   Total ____________ miles

2. In response to question #1 you wrote down the number of county road miles that **currently exist** in your county. **Realistically**, how much gravel vs. paved road mileage **would you <u>like</u>** to have in your county in order to meet the needs of county residents? Total should equal total in Question #1.

   Paved ____________ miles
   Gravel ____________ miles
   Total ____________ miles

GRAVEL ROADS

3. Please estimate the number of **gravel** county road miles in your county that are in each of the following traffic volume categories.

Traffic Volume per Day	Miles in Each Category:
0 through 25 Average Daily Trips (ADT)	____________ miles
26 through 50 ADT	____________ miles
51 through 100 ADT	____________ miles
100 through 200 ADT	____________ miles
Over 200 ADT	____________ miles
	____________ Total County Gravel Miles

4. What percent of the trips on your **gravel** county roads are **truck** trips. ____________ %

5. How often do you perform **complete regraveling** of your county roads in each traffic volume category? (once every year, every 5 years, etc.)

Traffic Volume per Day	Frequency of Regraveling:
0 through 25 Average Daily Trips (ADT)	____________
26 through 50 ADT	____________
51 through 100 ADT	____________
100 through 200 ADT	____________
Over 200 ADT	____________

PAVED ROADS

6. Road surface conditions can be rated as follows:

VERY GOOD - only new (or nearly new) pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavement constructed or resurfaced recently should be rated very good.

GOOD - pavements in this category, although not quite as smooth as those described above, give first-class ride and exhibit few, if any visible signs of surface deterioration. Pavement may be beginning to show evidence of rutting and fine random cracks.

FAIR - The riding qualities of pavement in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of pavements may include rutting, extensive cracking, and more or less extensive patching.

POOR - Pavements that have deteriorated to such an extent that they are in need of resurfacing.

VERY POOR - Pavements which are in an extremely deteriorated condition and may even need complete reconstruction.

Please estimate the number of paved county road miles in your county that are in each of these categories. **Fill out the boxes first and total the paved miles. Then work backwards in each category.**

CONDITION: VERY GOOD

0 through 50 Average Daily Trips (ADT) ________ miles
51 through 100 ADT ________ miles
101 through 200 ADT ________ miles
Over 200 ADT ________ miles

[ ] Total **Very Good** Paved Miles

CONDITION: GOOD

0 through 50 Average Daily Trips (ADT) ________ miles
51 through 100 ADT ________ miles
101 through 200 ADT ________ miles
Over 200 ADT ________ miles

[ ] Total **Good** Paved Miles

CONDITION: FAIR

0 through 50 Average Daily Trips (ADT) ________ miles
51 through 100 ADT ________ miles
101 through 200 ADT ________ miles
Over 200 ADT ________ miles

[ ] Total **Fair** Paved Miles

CONDITION: POOR

0 through 50 Average Daily Trips (ADT) ________ miles
51 through 100 ADT ________ miles
101 through 200 ADT ________ miles
Over 200 ADT ________ miles

[ ] Total **Poor** Paved Miles

CONDITION: VERY POOR

0 through 50 Average Daily Trips (ADT) ________ miles
51 through 100 ADT ________ miles
101 through 200 ADT ________ miles
Over 200 ADT ________ miles

[ ] Total **Very Poor** Paved Miles

The five boxes above should total here → [ ] **TOTAL PAVED MILES**

PAVED ROADS (CONT.)

7. What percent of trips on your **paved** county roads are **truck** trips? ____________ %

8. In answering question #6, you gave the total paved road mileage in various conditions in your county. **Realistically**, how much paved road mileage would you **like** to see in each condition in your county?

CONDITION	
very good	____________ miles
good	____________ miles
fair	____________ miles
poor	____________ miles
very poor	____________ miles
	____________ Total Paved Miles

COUNTY ROAD EXPENDITURES AND REVENUES

9. What was your total county expenditure on roads in the most recently completed fiscal year?

$ ____________

10. What was the **beginning total road fund balance** in the most recently completed fiscal year (add up all of the road fund balances excluding those funds used for bridges) ?

$ ____________

11. Please show the amount of road revenues received from each of the following sources in the most recently completed fiscal year. (approx.)

$ ____________ Property taxes levied specifically for highways and bridges

$ ____________ Property taxes levied for general purposes, but spent on roads/bridges

$ ____________ Other local taxes (please specify) ____________

$ ____________ Local road user taxes

$ ____________ County share of state highway taxes

$ ____________ General state shared revenues

$ ____________ Federal Aid Secondary Funds

$ ____________ Net revenues from contracting to maintain township, or other roads in the county

$ ____________ Other (please specify) ____________

$ ____________ Total

12. In the above questions, you have detailed your county's expenditures and revenues for roads. **Realistically**, what kind of balance would you **like** to see in your road funds at the **end** of the fiscal year? (for emergencies, to match bigger projects in the future, etc.) $ ____________

13. If your road revenues were to decline by $100,000, how much would you reduce each of the following? Road Expenditures $ ____________
Ending Road Fund Balance $ ____________

14. There are several possible strategies for county officials to manage their road system. However, there are two possible extremes: 1) they can spend all of their road funds now, in order to achieve high quality roads, or 2) they can save all of their road funds now, in order to finance future projects or to use in the case of unforeseen expenses. In a typical year, what percent of your total road fund revenues would you like to spend? (in case 1, this would be 100%).

____________ %

Thank you and Have a Happy Holiday Season!!

Township miles **maintained by the county**

Gravel __________ miles

Traffic volume per day on these roads:

0 through 25 Average Daily Trips (ADT)	__________	miles
26 through 50 ADT	__________	miles
51 through 100 ADT	__________	miles
101 through 200 ADT	__________	miles
Over 200 ADT	__________	miles

Percent of trips on these roads that are truck trips __________ %