Gravel Shortage Options

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ABSTRACT

Some North Dakota counties are facing a shortage in quality gravel. Other counties may experience the same problem in the near future. Gravel pits in the state are scarce and counties consume substantial amounts of gravel for a large portion of their roads. Obtaining gravel from distant sources leaves counties with considerable transportation and additional maintenance costs to repair damage caused by trucks hauling gravel. There are several alternatives to overcoming gravel shortages and increased cost for hauling gravel, including the following: paving roads with higher traffic volumes, closing roads with little or no traffic, or assigning minimum maintenance status to roads with minimal or seasonal traffic. The selection of an appropriate alternative should be based on appropriate legal, political, and economic analyses. Legal factors arise when closing roads or reducing the level of maintenance to a minimum. Political factors arise because elected officials have to consider how the public views the alternatives. Elected officials also have to be concerned about re-election and may be swayed by public opinion rather than long-term economic impacts. Economic factors will ultimately determine which alternative is more cost effective. A life-cycle cost analysis is used in this study to weigh the benefits and costs of alternative strategies over the life of the structures. In particular, Cass County participated in a case study analysis to illustrate a life-cycle cost analysis between graveling or paving specific road segments with different traffic levels.

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CHAPTER 1

INTRODUCTION

North Dakota has more than 106,000 miles of roads, of which more than 50 percent are gravel. Given the large number of gravel road miles, adequate supplies of quality gravel are necessary to maintain the extensive system in an acceptable condition. The roads of North Dakota, particularly the gravel roads, have been experiencing changes in travel patterns. Changes in the agricultural industry and increased commuter traffic are redistributing traffic in several counties. The trend toward larger farms reduces the need for multiple access roads to each farm. Reducing the number of multiple access roads also reduces the need for gravel and maintenance on specific roads. Further, with the increased farm size there has been an increase in equipment size. The larger and heavier equipment requires wider and stronger rural roads. In addition, several farm families earn off-farm income either seasonally or all year-round, thus increasing commuter traffic on rural roads. As the purpose of rural trips changes, the demands for improved maintenance increase.

Adjustments in road maintenance strategies are necessary to accommodate the shifts in traffic patterns. Roads with increased traffic volumes will require additional maintenance, i.e., more frequent graveling and blading, while roads with decreased traffic may require less maintenance. Counties in North Dakota face two primary problems with increasing road maintenance. First, counties have budget constraints, which make increasing maintenance expenditures extremely difficult if not impossible. Second, several counties in North Dakota are experiencing a gravel shortage. County road officials have indicated that good quality gravel supplies are low in many counties and therefore cannot support the required maintenance activities.

The purpose of this study is to assess the gravel shortage in North Dakota and to examine alternative strategies that could reduce gravel use. Methods used to generate additional revenue to ease the constrained budgets are beyond the scope of this study.[1]

Description of the Study

The methodology used to assess the shortage was based upon a mail survey and a telephone survey. First, the amount of gravel used within each county was identified through a mail survey of county engineers or road superintendents to determine the overall gravel usage within the state. Second, the North Dakota Department of Transportation (NDDOT) secondary roads division conducted a telephone survey of consulting engineers and road superintendents to identify their perceptions of the gravel supply available for county use. Third, gravel inventory data were collected from the counties in surrounding states within a 50-mile radius of North Dakota.

Essentially, there are two major strategies that can be used to deal with a gravel shortage. Counties can either find new gravel supplies or reduce the demand and/or use of gravel. Finding new gravel supplies from external sources and hauling them to the demand location may be economical, depending upon transportation costs. However, in addition to the transportation costs, counties will experience additional wear and tear on the roads as a result of moving gravel by truck over more miles. Counties with access to rail transportation, especially short line railroads, may be able to ship gravel supplies by rail and reduce the additional wear and tear on the roads. However, there are a few deterrents to using rail service such as the need for specialized equipment and limited backhauls, which makes hauling gravel less attractive to the railroad.

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[1] The Upper Great Plains Transportation Institute is currently conducting a study, *Innovative Rural Road Financing Methods for the Midwest and Mountain-Plains states,* which describes potential revenue generating methods for counties to implement.

To reduce the demand for gravel, it may be economical to convert the gravel surface roads with high traffic volumes to pavement. Closing or reducing maintenance on gravel roads also would reduce the demand for gravel. Each option must be considered carefully and evaluated using detailed analysis by accurate and adequate data. Furthermore, legal issues must be addressed before any of the alternatives are implemented. The options and the legal issues are discussed in more detail in Chapter 3.

OBJECTIVES OF STUDY

The primary objective of this study is to examine the extent of gravel shortage in North Dakota and to identify and evaluate plausible alternatives. The specific objectives covered in this report are to:

1. Assess the severity of the gravel shortage in North Dakota.
2. Identify common gravel sources in North Dakota and the surrounding states.
3. Consider gravel road alternatives, e.g., paving, closure, etc., and the costs associated with these methods.
4. Apply life-cycle cost analysis to a case study to demonstrate an alternative evaluation.

REPORT ORGANIZATION

The remainder of this report is divided into four parts. An assessment of the gravel shortage in North Dakota is addressed in Chapter 2. Gravel shortage alternative strategies are presented in Chapter 3. A case study using life-cycle cost analysis as applied to Cass County is presented in Chapter 4. Finally, the summary, conclusions, and need for further study are presented in Chapter 5.

CHAPTER 2

GRAVEL SHORTAGE ASSESSMENT

The status of the gravel supply and shortage is uncertain within North Dakota. Some county officials are concerned about the gravel supply within their counties and are looking for alternatives, while other counties are less concerned. The North Dakota Department of Transportation was not certain about the extent of the gravel shortage and supported the efforts of this study. In this chapter, the data collected and used to assess the gravel shortage in North Dakota are explained.

Gravel Inventory Data

Currently there is not a single comprehensive database with information about all of the gravel pits in North Dakota. Several sources were used in this study to assess the gravel shortage. First, annual gravel-usage data were collected from county road offices to determine if the current gravel inventories were adequate to meet the county gravel demands. County road engineers or superintendents completed a questionnaire during the winter of 1995, which described the amount of gravel used within each county. The costs associated with transporting and applying gravel for road maintaining were obtained through phone interviews with a sample of county engineers and road supervisors. Second, gravel inventory data were collected for counties in a 50-mile radius of North Dakota's bordering states including Minnesota, Montana, and South Dakota. Third, perceptions of the gravel supply status were identified through a telephone survey of road professionals, including consulting engineers and county road superintendents.

North Dakota Gravel Inventories

North Dakota has approximately 14,000 miles of county roads. Of these, 60 percent are gravel. The more metropolitan counties have a smaller percentage of gravel roads than the more rural counties. For example, Cass County has 468 miles of county roads, only 35 percent of these are gravel. Whereas, Grant County has approximately 150 miles of county roads and 98 percent are gravel. Naturally, the counties with the most miles of gravel roads would be more concerned about locating quality gravel.

Road superintendents' and consultants' perceptions of gravel supplies were key in assessing the gravel shortage in North Dakota. Road superintendents and consulting engineers in North Dakota counties based their responses on the approximate number of years of gravel supplies remaining in the counties they are most familiar with. Respondents rated the supplies as an "immediate shortage" if there is 0-2 years supply remaining; "short-term shortage" if there is 3-5 years supply; and "adequate supply" for over five years supply remaining. In addition, they indicated their perception of the quality of gravel remaining as poor, fair, or excellent.

Results from the telephone survey revealed that 17 counties are experiencing an immediate gravel shortage. These 17 counties contain 52 percent (4,306 miles) of North Dakota's county gravel road miles. Furthermore, the majority of gravel available in these counties is of poor quality (Figure 2.1). These counties face serious future difficulties if additional gravel sources are not identified.

It was found that about eight counties are experiencing a short-term shortage. These counties account for about 10 percent of the gravel road miles in the state. Unfortunately, only one of these counties has excellent quality gravel, while the remaining counties have fair gravel supplies. These counties should be looking for alternative gravel supplies because in the next couple of years their supplies will be depleted.

Consultants and road superintendents perceived that 24 counties in North Dakota have an adequate supply of gravel. This perception may be somewhat misleading, particularly for the western counties of North Dakota identified to have an adequate supply. The counties located in the badlands of North Dakota (Golden Valley, Billings, Slope, and a portion of Mckenzie) have large amounts of scoria, but little gravel. Scoria is not located in all parts of these counties but is in an abundant supply in many areas. Scoria is less expensive than gravel, but it is quite hard on tires the first year or two (Schulte). Golden Valley has substituted scoria for gravel for many years on their county roads (Schulte).

The data clearly illustrate that gravel supplies in North Dakota are not evenly distributed across the state, likewise, neither is the demand. Naturally, counties with fewer gravel road miles demand less gravel than counties with more gravel road miles. For example, all of the county roads in Pembina County are paved, therefore the quantity of gravel remaining in this county is less of an issue than it is in counties with a large number of gravel road miles. Some of these counties have virtually no gravel remaining and are left with the option to import gravel from other counties and other states.

Even though there is not a comprehensive database of gravel supplies for each county, the district Department of Transportation (DOT) offices have lists of gravel pits within their district. County road officials searching for gravel should contact their district DOT office to locate good quality gravel within a reasonable distance. The contact person in each office is listed in the table below.

Table 2.1. Department of Transportation District Office Gravel Contact Person

District	Contact Person	Telephone Number
Williston	Mel Knudsvig	(701) 774-4352
Minot	Robert Allen	(701) 857-7625
Devils Lake	Glenn Salisbury	(701) 662-4082
Grand Forks	Jake Dvorak	(701) 795-3800
Fargo	Willie Schacher	(701) 239-8900
Valley City	Ken Jewett	(701) 845-8600
Bismarck	Jim Glick	(701) 328-6950
Dickinson	Ron Tessier	(701) 227-7400

Source: North Dakota Department of Transportation, Materials and Research Department, Bismarck, North Dakota, 1996.

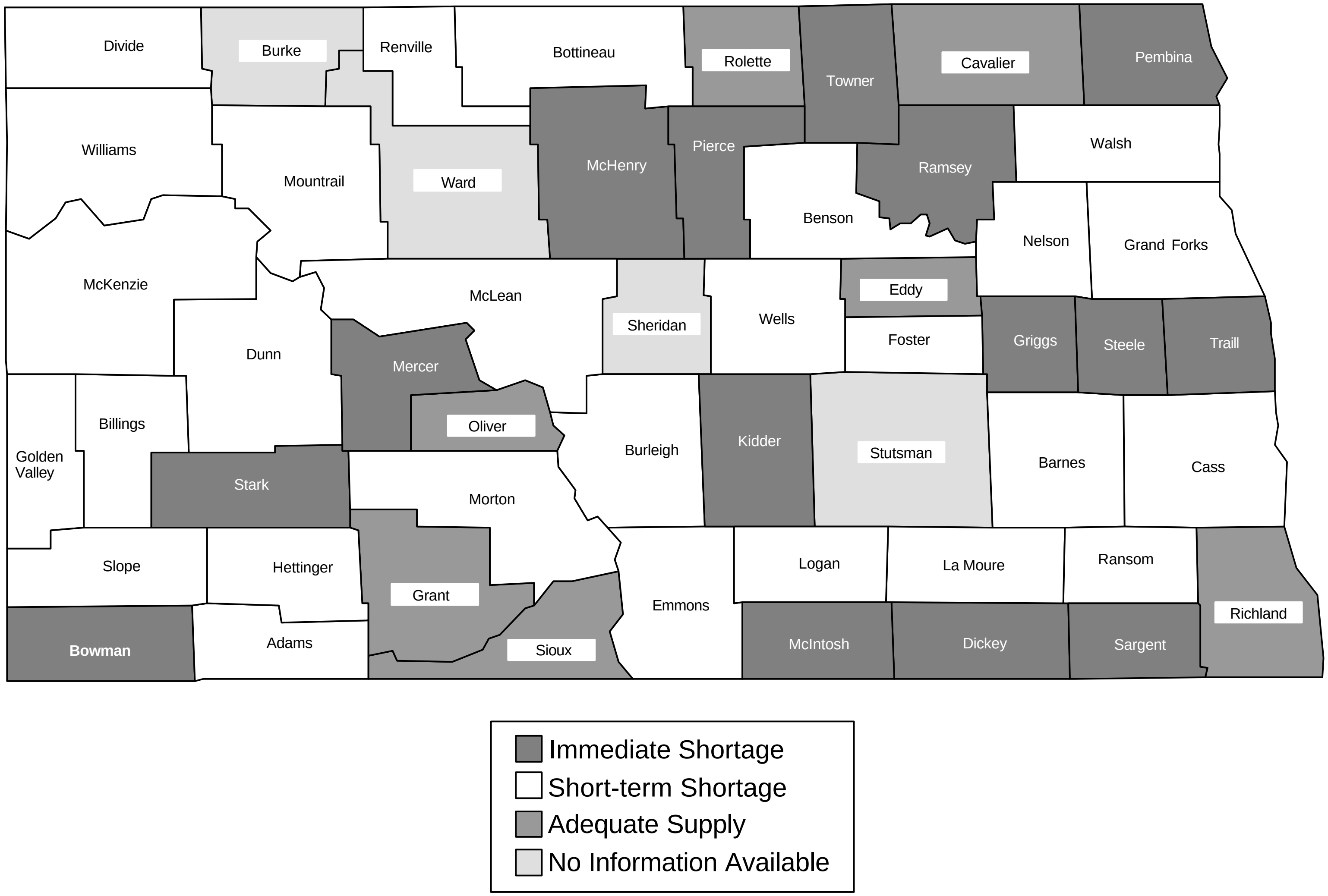


Figure 2.1 Perceptions of the Gravel Shortage Status in North Dakota, 1996.
Developed from: Survey of Consulting Engineers and Road Superintendents.

Surrounding State Gravel Inventories

Data regarding the gravel pits in selected regions of Minnesota, Montana, and South Dakota were collected. A few Canadian trucking companies were contacted to inquire about shipments of gravel from Canada into the United States. Those contacted did not transport gravel into the U.S., however, data from the Department of Commerce reveals that the U.S. does import gravel from Canada, but it could not be determined where the gravel was imported or used. Furthermore, the data did not identify the quality of gravel. North Dakota counties could most likely tap into these sources if the costs of the aggregate and transportation are economical.

Minnesota appears to have a large supply of gravel, particularly along its western boarder. Road officials in Montana indicated they too are experiencing a gravel shortage, although the extent of that shortage has not been documented. Likewise, South Dakota indicated it is experiencing a gravel shortage. One state engineer explained that the shortage is so extensive that the state has resorted to crushing rocks from farmers' fields to increase gravel supply. It appears that presently, Minnesota is the only reliable gravel source for North Dakota to pursue when purchasing out of state supplies.

Gravel Usage Survey

To gather information about the quantities of gravel North Dakota counties use annually for road maintenance, a one-page questionnaire was developed and mailed to each of the 53 counties. Fifty-one counties returned the survey, yielding a 96 percent response rate. This section contains a description of the survey instrument used and an analysis of the survey.

The survey contained 12 questions pertaining to gravel usage and acquisition and purchasing practices.[2] Questions were asked relating to the amount (quantity) of gravel counties purchase and use

[2] See Appendix A for copy of the questionnaire.

annually, their annual gravel cost (expenditures), where counties purchase their gravel, the frequency of the purchases, and if coordinated efforts are made to purchase gravel with other counties in an attempt to reduce costs. Furthermore, questions were asked about transportation modes used to move gravel and the storage facilities used for excess supplies purchased. Finally, questions also were asked about gravel and pavement recycling practices within each county.

Gravel Purchases

North Dakota counties reported they use nearly 2.2 million tons (three million cubic yards) of gravel annually. Approximately 1.79 million tons is used for gravel roads and the remaining 0.41 million tons of gravel is used for other purposes in their counties, i.e., paving. The data indicate North Dakota counties spend more than $6 million on gravel, annually. Nearly 85 percent of county officials indicated they purchase gravel from private landowners on an “as needed basis.” Therefore, the frequency of purchases depends on project and maintenance schedules.

When asked about what factors they require when selecting gravel, road officials indicated the following: binding material, rock content, clay content, and length of haul. They also were asked what classification of gravel they prefer to purchase. Gravel classifications are determined by the amount of rock the soil sample may pass through a set of sieves with progressively smaller openings. According to the responses, road officials most frequently purchase and blend gravel to meet Class 5, 8, or 13 specifications.

When asked about coordination with other counties that would take advantage of group purchase discounts, county road officials indicated little coordination. Only 14.9 percent of the counties do coordinate gravel purchases with other counties. No counties reported any discounts due to larger coordinated gravel purchase efforts. Coordinated purchases may be low because so many county officials purchase gravel as needed, based on road maintenance needs. These demands may vary among counties.

Road officials indicated that once gravel is purchased it is usually stored at county gravel pits. Interestingly, Cass county, which has low gravel supplies, purchases a given quantity of gravel in the fall and stores the gravel in locations throughout the county to be spread on roads in the spring. This may be an excellent solution to counties needing large quantities of gravel and having the cash reserve to make advance purchases. If adjacent counties can make joint purchases and transport gravel together, they may be able to receive savings from bulk purchases and transport.

Recycling Practices

Some counties may be able to reduce the amount of gravel they purchase through recycling efforts. Road officials were asked if they recycle pavement and if they recycle gravel by “cutting the shoulder” on gravel roads. Forty percent of the counties indicated they recycle their pavement. There may have been some misunderstanding in the question referring to “cutting the shoulder.” Some counties may use specialized equipment to “cut the shoulder” while other may simply refer to blading as “cutting the shoulder.” Responses ranged from twice a year to every six years. The average response was once every 3.5 years. The frequency of “cutting the shoulder” is related to the level of traffic on the road as well as the funds available for this maintenance task.

Transporting Gravel

County officials were asked how they transport gravel purchases from the supply source. All (but one) counties use trucks to haul gravel. Cass County uses rail transportation. Gravel trucks haul about 15 tons or 10-11 cubic yards of gravel. Gravel is hauled between eight and 40 miles by truck in North Dakota. The reported average length of haul was 15 miles. The average transportation cost for moving gravel by truck for each mile was $1.33 per cubic yard for the first three miles and $0.30 per cubic yard per additional mile. These were just averages since some counties pay up to $5.25 per cubic yard miles regardless of the length of haul.

Gravel transported by rail is hauled primarily in hopper cars. Each hopper car can hold up to 70 yards of gravel. Cass is the only county currently using rail service to move gravel. Their rail movements are approximately 50 miles. Cass County is served by a shortline railroad, the Red River Valley & Western Railroad. The county and the railroad have been in a service contract since 1995. Contract rates vary between parties, as rates must be negotiated. Cass County has negotiated rates, which vary by season and by year and receives between eight and 15 cars of gravel per shipment. Counties should investigate the possibility of using rail for transporting gravel to increase potential supplies and reduce gravel handling costs.

Transportation Concerns

Gravel transportation costs from supply locations to storage and use can be a measurable cost to a county's budget. However, counties and road users experience two additional costs. These costs are related directly to transporting gravel and the need for increased road maintenance. Because of the additional truck traffic hauling gravel over roads, there would be an increased deterioration of the highway infrastructure and increased road user costs. Past rail abandonment studies have measured these costs with respect to impacts of rail abandonment. Some of their findings regarding road deterioration apply to this study.

There are two methods for measuring or estimating the highway deterioration costs resulting from damage by trucks. These measurements include: 1) incremental pavement damage model, which estimates the additional pavement damage resulting from an occurrence (such as abandonment) given the present infrastructure and 2) average pavement damage model, which calculates an average cost imposed on the highway system for each equivalent single axle load (ESAL) generated per mile.[3]

Highway user costs increase due to increased vehicle operating costs and opportunity costs. The increase in vehicle operating costs is the result of increased vehicle wear and tear, and increased fuel costs due to poor pavement conditions and lower operating speeds. The increase in opportunity costs is the result of additional time spent traveling (Bitzan et al., 1996). These concepts are illustrated in the case study application in Chapter 4.

[3] Each type of vehicle is classified in terms of the amount of equivalent single axle loads (ESALS) per mile they impose on the highway. Thus, all vehicles impose a certain amount of damage on the highway on a per ESAL basis.

CHAPTER 3

GRAVEL SHORTAGE ALTERNATIVE STRATEGIES

There are a number of alternatives that could potentially ease the gravel shortage problem in North Dakota counties. These alternatives can generally be classified into two major strategies: 1) find new gravel supplies and 2) reduce the demand and/or use of gravel. For example, by using rail to transport gravel, counties can access supplies that would have been uneconomical (because of prohibitive trucking cost). On the demand reduction side, one option would be to convert the surface of gravel roads with high traffic volumes to pavement. It is presumed that any decisions of this nature are supported by detailed economic analysis and that these decisions meet legal requirements in state and county laws. Another option to reduce demand is to minimize maintenance or close roads. The following sections discuss some of the most plausible and practical strategies and some of the potential implications and issues that are related to their implementation.

Strategies for Additional Gravel Supplies

Counties usually obtain gravel from local gravel pits in the same county or in adjacent counties. In many cases, however, not all of these gravel pits have the required grades or acceptable quality of gravel, leaving the county with limited supply choices. Counties with limited supplies of gravel in their local pits may have to look elsewhere for new supplies. The price of gravel has been considerably low however, with a rising gravel shortage, the price may increase in the future. Presently, the transportation cost for hauling gravel can be a significant portion of the delivered or total cost. The survey indicated that all North Dakota counties, except Cass, depend on trucks to transport gravel from gravel pits. As a result, only gravel pits located within a certain distance can be accessed by each county. This distance represents the average length of haul that trucks are used to transport gravel. Results from the survey indicated that about 70 percent of the counties haul gravel from pits within a 15-mile radius. The most common length of haul was 10-15 miles.

To acquire gravel from pits that are located beyond truck haul limits, several options may be explored, which include transporting gravel by rail. Figure 3.1 graphically depicts this concept and shows the economically feasible zone for accessing available gravel supplies by truck and rail. However, there are a number of factors that have to be considered for transporting gravel by rail. Further, not all counties have viable access to rail transportation.

There are a few deterrents to using rail service. First, there is a need for specialized equipment to move the gravel. Open top hopper cars can be used to move this high density product, but few other commodities can be hauled in the same cars carrying gravel. Therefore, finding a product to move as a backhaul is difficult. Second, railroads typically move unit trains or multiple-car trains (26 or more cars) to be cost effective. Since counties do not purchase large quantities of gravel at a time, the haul becomes less attractive to the railroads. However, counties may be able to coordinate with one another and purchase large quantities of gravel and receive volume discounts from the railroads. This would make gravel purchases more attractive to the railroads, which in turn could offer lower rates to the counties. Third, moving gravel by rail does not alleviate the need to move gravel by truck. The location of the demand for the gravel may be several miles from the rail track, and would require unloading and reloading of the gravel into trucks to haul it to the desired location.

When counties are making their transportation choices, they must consider the costs. There is a need for a detailed analysis with accurate data on transportation rates and handling costs. These costs can be obtained by contacting local trucking firms and area rail service providers.

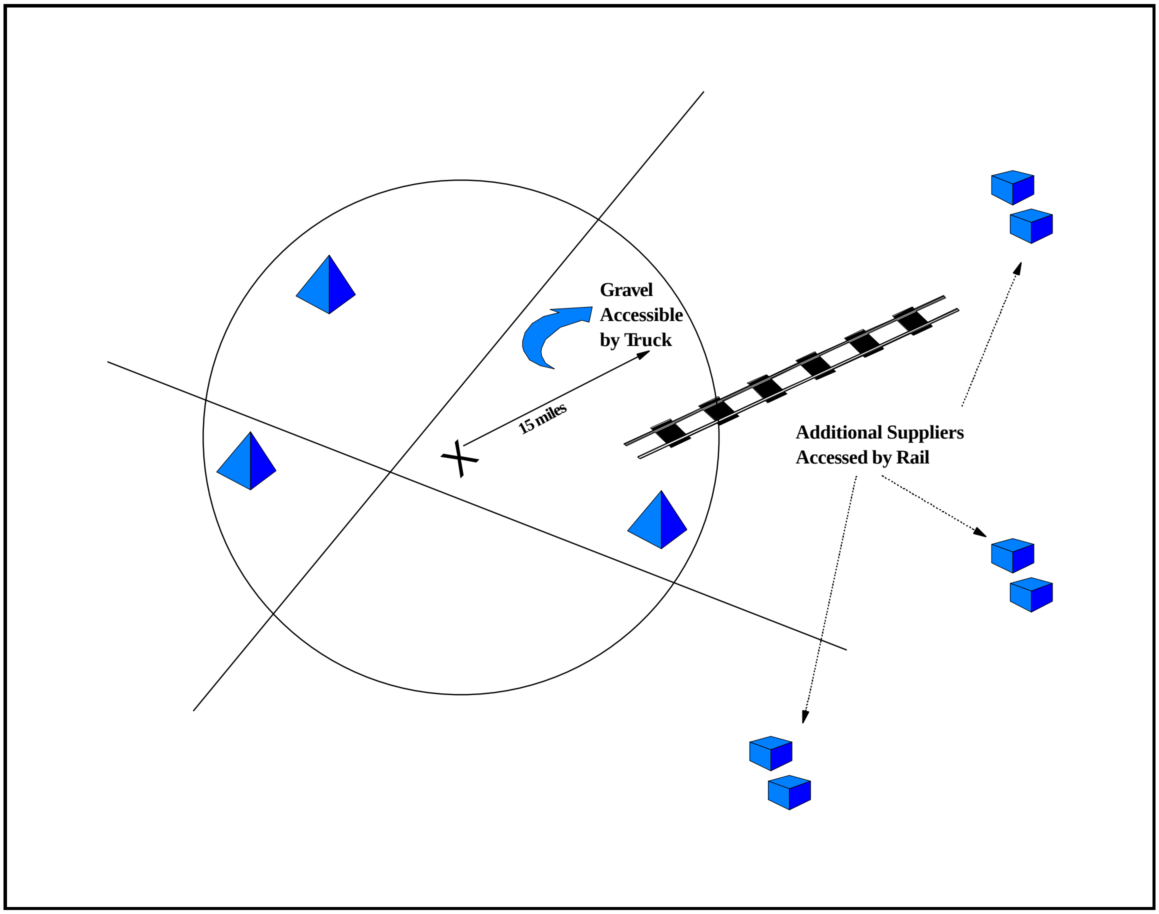


Figure 3.1 Feasible Zone for Accessing Available Gravel Supplies by Truck and Rail

Reducing Demand for Gravel

There are a number of alternatives road officials can consider to reduce gravel use, including: 1) reducing the level of maintenance on some gravel roads, 2) reducing gravel road miles by closing low traffic roads, and 3) paving high traffic volume gravel roads. The suitability and feasibility of these alternatives will vary by specific situation, therefore, it is hard to establish general rules for implementing these strategies. In general, the level of traffic on the gravel road will be the determining factor in the required economic and legal analysis.

Reducing Maintenance Activities

The level and frequency of maintenance on any road is directly related to its traffic levels. For instance, gravel roads with higher traffic levels require more routine maintenance such as blading and adding gravel. However, there are some gravel roads that handle little traffic and are used only seasonally by intermittent traffic. To cut back on gravel use and to reduce maintenance expenditures, maintenance activities on these roads could be scaled back significantly. As a result, these roads would be designated as "minimum maintenance" either seasonally or throughout the year.

Such a designation involves several economic and legal issues. In general, the savings in maintenance expenditures on these roads must justify any increased travel times and/or costs to road users. In addition, there are other considerations such as emergency vehicle, farm, school bus, and mail operations. The process of implementing reduced maintenance must conform to legal requirements set forth in the state code. The county or township making the designation also should follow legal precautions to minimize any tort liability that could arise due to the minimum maintenance designation.

Roads providing essential service for mail delivery or school bus routes may not be declared as minimum maintenance roads. Although the North Dakota Century Code (N.D.C.C.) does not clearly define a minimum maintenance road, it does clearly describe when a road can be minimally maintained. The procedure to follow when declaring a minimum maintenance road is described in Figure 3.2.

The N.D.C.C. Section 32-12.1-03(7) refers to minimum maintenance roads and the tort liability of counties for assigning such a designation. The section states that a county or township is not liable in tort for a claim based upon the designation, repair, operation or maintenance of a minimum maintenance road if the county or township follows the procedural requirements of the North Dakota Century Code when the county or township designates the road as a minimum maintenance road and if the road is maintained well enough to serve occasional or intermittent traffic.

There are potential problems with this reduced maintenance option. The main problem is that the road would be downgraded over time. If the road is to remain open, substantial local government investments would eventually be required to upgrade the roads to an acceptable condition, particularly those containing bridges.

The economic analysis of minimum maintenance roads is straightforward. Although there is not a model per se to analyze this option, a simple comparison of maintenance costs reduction can substantiate this decision. After determining if a road can be legally designated as a minimum maintenance road, the simple economic analysis can consist of summing up all of the maintenance costs spent on a road throughout the year. Then determine what amount of maintenance will continue on the road, i.e., gravel every few years, blading, etc. Subtract the costs of reduced maintenance from the original maintenance costs. There may be an added cost of sign maintenance if "minimum maintenance" signs are placed along the roadway. The signs themselves will cost approximately $50. The cost of placing and maintaining the signs must be calculated before determining the cost savings of declaring a minimum maintenance road.

Closing Low-Use Gravel Roads

Roads with an extremely low traffic volume may be considered for closure. First, road officials must determine if the road is eligible for closure. Roads used for mail delivery or a school bus route may not be closed. In addition, any road providing the only access to a residence may not be closed. On the other hand, if the road has not been used for the past 10 years, it is not necessary to formally close the road, it is considered statutorily vacant (N.D. C.C. Section 24-07-31). The North Dakota Century Code has provided detailed statutory procedures for closing roads. These procedures are illustrated in Figure

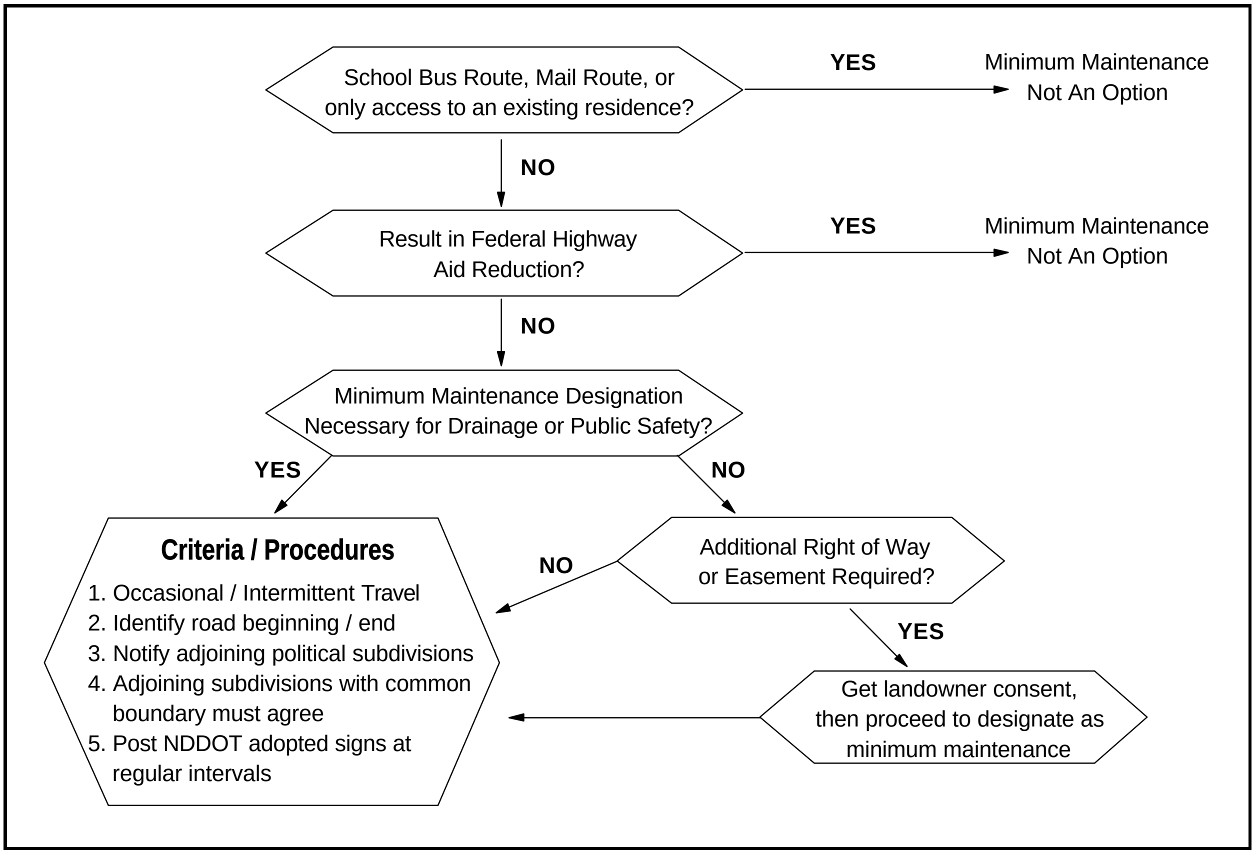


Figure 3.2 Procedure for Declaring a Minimum Maintenance Road

SOURCE: Welte, Peter; Jill Hough; and Ayman Smadi. *Legal Implications to Closing or Reducing Maintenance on Low Volume Roads in North Dakota.* Mountain-Plains Consortium report 97-69. Upper Great Plains Transportation Institute, North Dakota State University, Fargo, ND. Forthcoming.

3.3.[4] Following the proper procedures greatly reduces the possibility of tort liability when closing a road. If a bridge is located on the road considered for closure, the procedure is more complicated and an attorney should be consulted before the procedure begins.

[4] For a more detailed discussion of closing roads, see Welte, Hough, and Smadi. *Legal Implications to Closing or Reducing Maintenance on Low-volume Rural Roads in North Dakota.* Mountain Plains Consortium Report 96-69, North Dakota State University, Fargo, 1996.

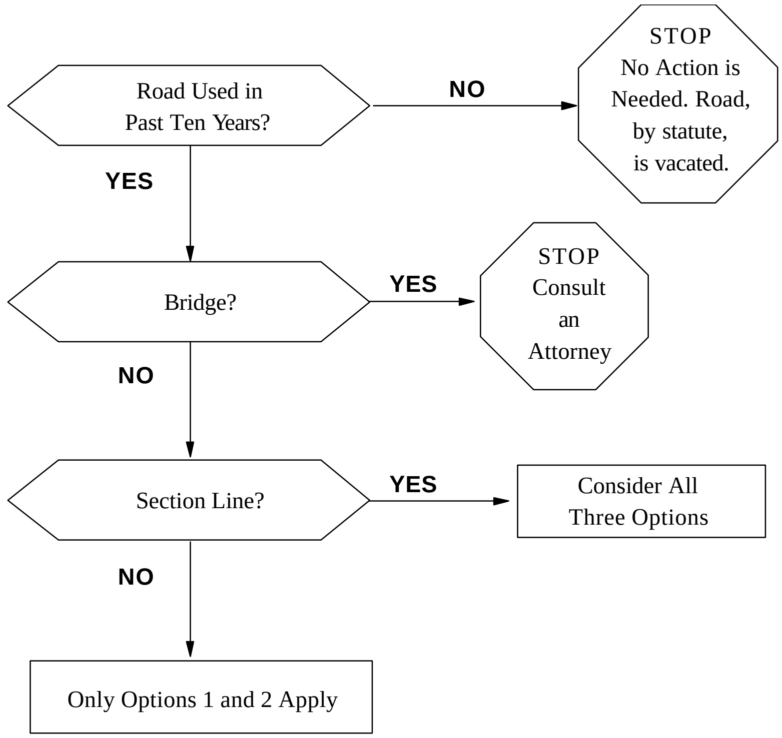
Closing a road is generally an economic decision. Maintaining roads with low use can be expensive, particularly when there are other routes available to reach the same destination. The rectangular grid layout of the road system often allows property owners to have up to access points to their homes. Most homes, farms, and fields would still have at least one access if some of the local roads were eliminated.

Eliminating some roads would result in higher travel costs to some of the road users because they would have a longer distance to travel because of re-routing. Closing a road must be evaluated carefully so that the cost savings is greater than the cost incurred to re-route traffic. The roads that inherit additional traffic also must be factored into this evaluation. These roads will require additional maintenance and resurfacing costs because of the increased traffic. Furthermore, closing a road requires an investment to prevent unplanned entry. There is a cost to install and maintain proper barriers.

Paving High Traffic Volume Gravel Roads

Roads with an extremely high traffic volume may be considered for paving. Economics plays a crucial role when determining whether to pave a road. To determine if justification is warranted, several costs must be considered for the duration of the life of the surface including the initial costs, the maintenance costs and the user costs. Paving a road requires high initial costs. The subgrade preparation, thickness of the pavement, and the materials used determine the cost per mile of the pavement structure. Some counties may find it difficult to raise the needed revenue for paving additional roads and they may want to consider investigating innovative methods to raise the needed dollars.[5]

[5] The Upper Great Plains Transportation Institute is conducting a study to investigate the innovative financing methods used at the county level within eight states. This report is forthcoming.



Option 1

1. Petition from 6 electors, with legal description of road.
2. Post petition in three most public places for 20 days.
3. After #2, set meeting in 10 days.
4. Ten days prior to meeting, personally notify landowners, and post in three most public places.
5. Hold hearing, make decision. Refusal is final for one year.
6. File materials in five days, wait for auditor/clerk to record.
7. File recorded order in 20 days. Notify overseer of highways.

Option 2

1. Petition from 70 percent of qualified electors.
2. Personal notice to qualified electors who didn't sign petition in #1.
3. Continue with #5 of Option #1.

Option 3

1. Petition by any person with an interest in adjoining land.
2. Public hearing.
3. Find "public benefit."
4. Closing okay if:
   a. No use for 10 years; or
   b. No travel due to obstacles/ terrain; or
   c. Not required due to readily accessible alternate route of travel; or
   d. Interstate intersection causes dead end.

Figure 3.3 Procedures and Options for Closing a Road

Source: Welte, Peter; Jill Hough; and Ayman Smadi. *Legal Implications to Closing or Reducing Maintenance on Low Volume Roads in North Dakota.* Mountain-Plains Consortium Report 97-69, Upper Great Plains Transportation Institute, North Dakota State University, Fargo, ND. Forthcoming.

The costs of maintaining gravel and paved roads are influenced by several factors including weather, topography, traffic levels, policies, jurisdictional size, and surface type. In North Dakota, the weather and topography do not differ much within each county. Traffic levels mainly will impact the maintenance costs between the two types of surfaces. High use roads do need more maintenance to remain in safe operating conditions. Gravel road maintenance costs include blading, snow removal, signing, and periodic regraveling. Paved road maintenance costs include signing, repairs, crack sealing, overlays, and patching. These costs must be calculated for the entire life of the surface and compared between the two surface types.

User costs also must be calculated and compared when determining the costs of paving or graveling a road. User costs generally include vehicle operating costs and opportunity costs. The vehicle operating costs primarily include the wear and tear on the vehicle due to the road surface and fuel consumption. Vehicles cost more to operate on gravel roads than on paved roads for three main reasons: the rolling resistance and less traction increase fuel consumption, the roughness of the road increases tire wear and other maintenance costs, and dust causes extra engine wear.

Opportunity costs measure the cost of delays, or additional travel time, as opposed to using that time for productive purposes. These costs are important because the time passengers spend in vehicles reduces the time they could spend in productive events such as employment. Travel speeds, which differ between surface types, influence opportunity costs the most. The average operating speed on gravel roads is only 40 mph whereas the average operating speed on a paved road is 50 mph or higher. The difference in operating speeds constitute additional travel time that could be converted to dollar cost based on hourly wage estimates.

Measuring and comparing user costs and opportunity costs can be difficult and controversial. Road management agencies do not directly benefit from reduced user costs. Also, it is questionable whether the user even notices any savings or added income as a result of more efficient highways (Bremner).

Economic analysis does require detailed data to perform an accurate assessment of the costs and benefits of paving a road. Each road must be considered on a case-by-case basis. In the next chapter, a case study analysis is presented that illustrates the costs of paving a road in Cass County.

Feasibility Factors

Reducing maintenance, closing, or paving roads are three alternatives counties may consider when evaluating how to reduce the demand for gravel. The feasibility of each alternative will vary between roads. Even though traffic levels may be high enough on a gravel road to justify paving the road, the initial cost may be too high for a county to afford the paving process.

There could be local opposition to reducing maintenance or closing a road. First, either option may be politically unpopular for the decision makers because of the major inconveniences some residents may experience. The inconveniences of re-routing traffic greatly limits the cooperation from road users or nearby residence. However, the more county officials can work with other local agencies/groups, i.e., mail carriers, school systems, to educate them about developing a smaller road system with a higher level of service, residence may be more accepting of the road options.

CHAPTER 4

CASE STUDY APPLICATION

The purpose of this chapter is to demonstrate a methodology that could be used to investigate the feasibility of paving gravel roads with higher traffic levels. Paving was identified as a potential alternative to reduce the demand for gravel as identified in chapter 3. However, it should be emphasized that any decision to pave gravel road segments must be based on sound and detailed economic and engineering analysis of the financial and operational implications of such a decision. The methodology in this chapter was developed for the specific issues and using available data from the case study location. Therefore, counties wishing to conduct similar analysis may be required to modify the methodology to reflect their counties applicable issues and data.

The first section of this chapter describes the case study location and the road sections used. The second section outlines a general framework for the methodology followed to conduct the analysis and identifies data requirements and some of the assumptions used in the analysis. The third section documents the calculations used to conduct benefit-cost analysis for the sample road sections. Finally, the fourth section illustrates the use of the results of benefit-cost analysis to evaluate the paving alternative.

Scope of the Case Study

Cass County was selected to participate in the case study analysis because of its depleted gravel inventory and increasing traffic volumes. Cass County has the largest population within the state of North Dakota. In addition, Cass County ranks first in overall total miles and paved miles, but ranks fifth in the state for miles of gravel roads. Due to the extensive miles of roads in the county, the demand placed on road segments varies greatly. As a result, more maintenance is required on road segments with higher traffic levels to provide an adequate level of service.

To conduct the analysis, five segments of roads were selected in Cass County with the assistance of the county engineer, Keith Berndt. Each of the segments represented five miles of road with homogeneous surface and traffic characteristics. Traffic levels on these segments were 100, 150, 175, 250, and 325 Average Daily Traffic (ADT). Traffic levels are used to develop appropriate design parameters (layer thickness) and eventually used to estimate construction and maintenance costs for the life of the structure. Maintenance costs were obtained for these segments for the current gravel surface and estimated for the pavement surface from Cass County. Naturally, road maintenance costs would vary by traffic levels. However, available maintenance data could not be used to develop any meaningful expressions of maintenance costs in terms of traffic levels (ADT). Therefore, the study team relied on county officials to provide estimates of maintenance costs on different road segments with various traffic levels.

General Methodology

The methodology presented in this section is intended to provide an evaluation tool to examine the feasibility of paving gravel roads. The impetus of the methodology is that gravel roads with higher ADT volumes may justify paving to reduce maintenance and user costs. However, there is no “magic” number at which paving can be justified for all gravel roads. A detailed economic analysis, using life-cycle costs (LCC) must be used to determine the ADT level at which paving could be justifiable. That ADT level will represent a minimum threshold for considering gravel roads for paving. Gravel roads with traffic levels higher than a specified threshold may show that the benefits of paving, reduced maintenance and user costs, exceed the additional costs of paving.

The LCC used in this study compares the costs of existing gravel roads with the costs of the same roads converted into paved structures over a projected life of 20 years. The costs used in the LCC analysis are maintenance costs, vehicle operating costs, and opportunity (user) costs. It is imperative to understand that the results found in this study are specific to the data obtained from Cass County. The calculated values should not be used by other counties as the “magical” point at which to pave. However, the analysis may serve as a general methodology that could be modified to suit a county’s specific needs. The general steps for the methodology can be described as follows (see Figure 4.1):

1. Select gravel road sections for evaluation. Generally, sections with higher traffic volumes will have a higher potential for passing the feasibility test.

2. Collect adequate data for each of the candidate sections. The data typically would include section attributes (route number or name, length), surface characteristics (width, type, depth), traffic data (ADT, percentage growth, percentage commercial vehicle), and annual maintenance costs (blading, graveling).

3. Develop typical pavement designs to meet current and future demands using appropriate design standards. Cass County design policies were used in the case study whenever applicable. However, the design process meets AASHTO Flexible Pavement Design guidelines. The output of this step is the makeup and depth of the section layers.

4. Estimate LCC for the two cases: existing gravel surface and paved surface.
    - Pavement costs:
        - Initial construction costs
        - Annual maintenance costs
    - Gravel surface costs:
        - Annual maintenance costs
    - Reductions in user costs:
        - Reduction in annual user costs due to paving
        - Reduction in opportunity costs due to paving
    - Total LCC:
        - Sum of initial, maintenance, and user costs over the life of the section (20 years)

5. Select surface alternative.
    - Sections with LCC_{paved} less than LCC_{gravel} show initial feasibility for paving

6. Examine other factors (legal, political, budgetary, etc.).

It must be noted that the economic analysis will provide the basis for a decision. The final decision to pave a road section is ultimately a management decision. Further, the economic evaluation itself has no relationship to financing a project. That is, if economic analysis shows paving a gravel road section would yield savings, the funds for the initial costs of paving may be hard to come by. As a result, financial constraints will greatly impact the decision to pave a gravel road.

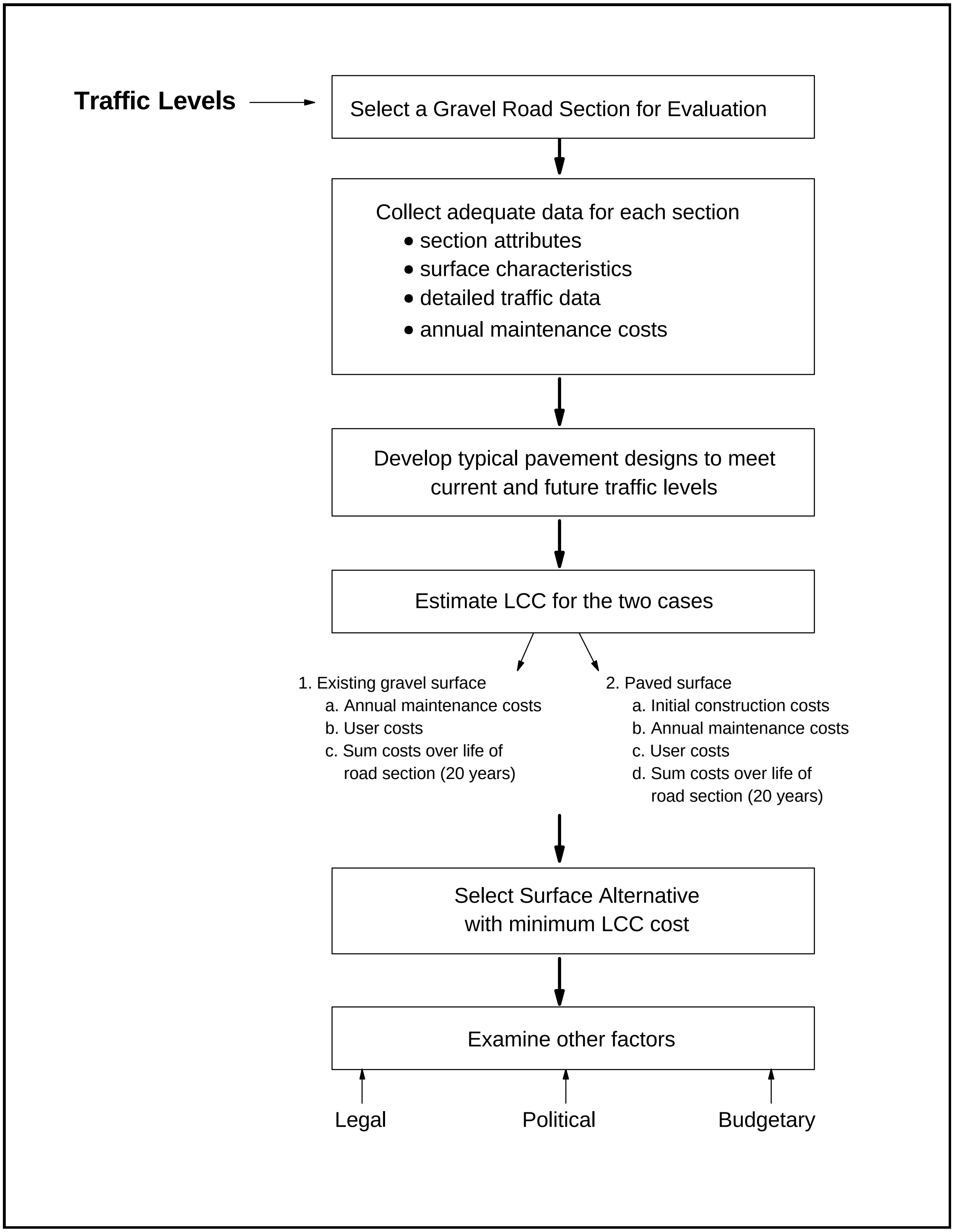


Figure 4.1 General Methodology to Select Surface Alternative

Pavement Design

Pavement design is an important factor in the LCC analysis. Pavement design determines the appropriate depth of layers needed to support the expected traffic using the road over its design life. The information on the depth of layers is used to calculate the pavement construction and maintenance costs. In order to determine the depth and costs, some general data must be collected and a Structural Number (SN) must be calculated. The SN may be calculated using the American Association of State Highway and Transportation Officials (AASHTO) flexible pavement design formula:

$$\log_{10}W_{18} = Z_R S_o + 9.36\log_{10}(SN + 1) - 0.20 + \frac{\log_{10}[\Delta PSI/(4.2 - 1.5)]}{0.40 + [1094/(SN + 1)^{5.19}]} + 2.32\log_{10}M_r - 8.07 \qquad \textbf{(1)}$$

where:

W_{18} = predicted number of 18,000 lb single-axle load applications
Z_R = standard normal deviation for a given reliability
S_o = overall standard deviation
SN = structural number indicative of the total pavement thickness
ΔPSI = p_i - p_t
p_i = initial serviceability index
p_t = terminal serviceability index
M_r = resilient module in lb/in.^{2}

The data needed to calculate the SN were obtained from Cass County Vehicle Classification Study.[6] The following information was used in the design calculations:

Z_R = -0.3885
S_o = 0.45
p_i = 4.5
p_t = 2.0
M_r = 31,000 psi for granular base, and 7,500 psi for sub-base

[6] Fargo-Moorhead Metropolitan Council of Governments, *Cass County Vehicle Classification Study*, Fargo, ND, October, 1995.

Once the SN is estimated from the first AASHTO formula (equation 1 above), a second formula is used to determine the thickness of the structural layers. Generally, flexible pavements consist of three layers, an asphalt concrete surface layer, a base layer, and a sub-base layer. The following AASHTO formula is used to calculate the depth variables (D's):

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3 \qquad \textbf{(2)}$$

where m_i = drainage coefficient for layer *I*

a_1, a_2, a_3 = layer coefficients representative of surface, base, and sub-base respectively

D_1, D_2, D_3 = actual thickness in inches of surface, base, and sub-base respectively

The values for a_1 ,a_2, and a_3 were estimated from the AASHTO *Guide for Design of Pavement Structures* handbook. Values for a_1 and a_2 were 0.44 and 0.14 respectively. The value for a_3 was not determined since sub-base material for structures of this strength already exist.

Equations 1 and 2, were used to calculate structural numbers for each of the five road segments. The SN increase as the ADT levels increase (Table 4.1). The SN values ranged between 1.919 to 2.264. These values were placed in equation 2 to calculate the depths of asphalt and gravel.

Table 4.1. Structural Number Values, by Road Segments in Cass County

Segment	ADT (vehicles/day)	SN	Asphalt (Inches)	Gravel (Inches)
1	100	1.919	2.5	6.5
2	150	2.045	2.5	7.5
3	175	2.076	3.0	6.0
4	250	2.202	3.0	7.0
5	325	2.265	3.0	7.5

Calculation of Life-Cycle Costs

This section documents the calculation of the cost items that will be included in the economic evaluation analysis. Generally, there are several types of costs: initial costs of construction and preparing the road structure for use, maintenance costs, and user costs over the life of the structure. Since the analysis evaluates paving as an alternative to gravel surfaces, initial costs are only considered in the pavement costs (i.e., gravel roads have zero initial cost). Maintenance costs were obtained for both gravel and paved surface types from county officials and private contractors.

Pavement Costs

Once the thicknesses of each of the three layers are calculated for the gravel road segments, it is possible to calculate the paving cost of each segment. These costs were estimated using prices obtained from Cass County and a local paving company (Border States Paving, Inc.). Paving costs ranged from $95,000 per mile for a two-inch pavement depth to $645,000 per mile for a six-inch pavement depth.

Maintenance costs were estimated based on average maintenance activities for similar structures in Cass County. Typical maintenance activities of flexible pavements include chip seal, seal crack, and striping and marking. On the average, a chip seal is done on a seven-year cycle,. A seal crack is done on a five-year cycle, and striping and marking of centerline and sidelines are done on a three-year cycle. The following maintenance costs were used: chip seal at $9,850 per mile, crack seal at $880 per mile, striping at $206 per mile, and marking at $1,305 per mile. These costs were discounted back from point of time they are incurred to present value.

Gravel Maintenance Costs

All gravel maintenance costs were estimated from Cass County data. The data showed cost information for various maintenance activities on the selected gravel road sections during 1993. The costs included labor, equipment, and material. These figures were divided by the length of each case study sections to obtain an annual maintenance cost per mile. These costs are summarized in Table 4.2.

Table 4.2. Estimated Gravel Maintenance Costs for Case Study Sections

Section	ADT	Gravel Application	Smoothing/ Blading	Labor and Equipment	Cost/mile (1993)	20-year life cost
1	100	12.74	289.56	273.64	302.30	2,574
2	150	3.63	338.08	324.81	341.71	2,909
3	175	2,077.84	579.51	556.68	2,657.35	22,624
4	250	1,695.28	927.71	787.62	2,623.00	22,331
5	325	2,287.70	6,563.38	691.09	8,851.08	75,354

User Costs

User costs are an integral part to economic evaluation of road projects. Generally, reductions in user costs represent benefits for various alternatives. User costs include vehicle operating costs, opportunity cost due to travel time and delays, and accident costs. User costs are typically used in pavement management analysis to reflect additional costs of deteriorating pavements. Pavement condition is generally measured in terms of a serviceability, for example, the Pavement Serviceability Rating (PSR), as shown in Table 4.3.

Table 4.3. Pavement Serviceability Rating

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.

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

Vehicle Operating Costs

A drop in PSR results in additional travel times and vehicle operating costs that can be estimated using several methods. The Highway Performance Monitoring System (HPMS)[1] provides some analytical tools that could be used to measure these costs. The HPMS uses travel speeds at a near perfect PSR value of 4.5 to calculate vehicle operating costs in dollars per 1,000 vehicle miles. These costs include costs of fuel, lubricating oil, tires, maintenance and repairs, and use-related depreciation. The following formula is provided in the HPMS to account for drops in PSR values in vehicle cost calculations:

$$VCAF = 0.9818182 + (5.0 - PSR)/(20.0 + (5.0 * (PSR - 3.0))) \quad \textbf{(3)}$$

where: VCAF = vehicle operating cost adjustment factor
PSR = Pavement Serviceability Rating

When a value of 4.5 is used for the PSR index, the equation produces a value of 1.0. When values below 4.5 are used for the PSR index, the equation will yield vehicle operating costs adjustment factor (VCAF) values greater than 1.0.

To estimate user cost differences between paved and gravel services, it was necessary to assign gravel road surfaces an equivalent PSR. A value of 1.5 was arbitrarily used in this study (1.8 was reported in some studies). All gravel road sections were assumed to have the same PSR value. Adjustment factors were then calculated using the HPMS formula and applied to initial operating cost values using HPMS vehicle operating costs tables. Average operating speeds were assumed to be 40 mph for gravel roads, and 50 mph for paved roads. In addition, the HPMS tables break the costs by vehicle class requiring vehicle classification data. A Cass County Vehicle Classification study was used to estimate percentages of particular vehicle classes of the over all ADT. These percentages may be described as follows: 1) Medium/large autos (68 percent), 2) Pickup truck (15 percent), and 3) single unit and other combination trucks (17 percent).

Opportunity Costs

Gravel roads require more travel time because of the slower traveling speeds. Using speeds of 40 mph on gravel roads and 50 mph on paved roads, additional travel times were calculated and converted to opportunity costs. These costs represent lost time that the road user could have spent in productive events such as employment. For the case study analysis, opportunity costs were based on a North Dakota average hourly wages of $10.02 per hour. The difference of 0.3 minutes per mile or 0.005 hours per mile. The average North Dakota wage is $10.02 per hour. An average vehicle occupancy of 1.3 was used to convert the opportunity costs to dollars per vehicle basis[7].

[7] United States Department of Transportation, Bureau of Transportation Statistics, *National Transportation Public Survey*, Washington, D.C., 1990.

Summary of Total Costs

Initial and maintenance costs for each of the five case study sections were converted to net present value using an interest rate of 8 percent. The rate was selected to represent current prime rate, which is used in public works projects and account for inflation. Other interest rates could be used by different counties. A traffic growth rate was assumed at 2 percent per year over the 20-year design life of the pavement structure. The results are summarized in Table 4.4.

Table 4.4. Maintenance and Road User Costs Over a 20-year Period

Section	ADT	Gravel Maintenance Costs	Operating Costs	Opportunity Costs	Total Gravel Costs	Total Paved Costs*
1	100	2,968	44,594	3,165	50,727	168,242
2	150	3,355	66,891	4,747	74,993	169,122
3	175	26,090	78,040	3,641	107,771	211,294
4	250	25,753	111,485	7,912	145,150	212,174
5	325	86,901	144,931	286	232,118	212,614

* Total pavement costs include initial construction costs.

Interpretation of Results

The costs summarized for each of the gravel road sections in Table 4.4 above indicate the costs of keeping the surfaces as gravel and the cost of paving over a 20 year period. The total pavement cost is a function of the pavement thickness and maintenance activities necessary to support the predicted traffic. A quick glance on Table 4.4 shows that the cost of paving the gravel road sections exceed the total maintenance and user costs except for section with the highest ADT. In fact, the result indicate that only gravel roads with traffic levels as high as 300 ADT will have merit for paving. The 300 ADT threshold could be used for selecting gravel road sections for further evaluation.

The maintenance costs for each gravel road segment varied significantly. The total maintenance costs per mile for a gravel road over a 20-year life design ranged from $2,968 for a segment with 100 ADT to $86,901 for the segment with 325 ADT. The large variation in the cost per mile is due to high levels of maintenance on high use gravel roads. However, gravel road maintenance costs were still significantly less than pavement costs. Only when user costs are added to gravel road costs did paving become a favorable option. Further, when opportunity costs were added to gravel road costs, paving became more favorable. It is important to explain the validity of user costs consideration to the decision makers before they can be used effectively in the economic evaluation. Table 4.5 provides a summary of the cost differences of paving vs. Gravel for each road section.

Table 4.5. Benefit Cost Analysis of Paving a Road

Segment	ADT	Benefits	Costs	Net Benefits
1	100	47,759	165,274	-117,515
2	150	71,638	165,757	-94,129
3	175	81,681	185,204	-103,523
4	250	119,397	186,421	-67,024
5	325	145,217	125,713	19,504

In conclusion, as counties are experiencing a gravel shortage, paving may become a viable alternative for roads with a high ADT level. An analysis with detailed data must be conducted before any decision should be made. Even though the data may verify that benefits outweigh the costs and paving is justifiable, counties may not have the revenue to absorb the initial investment of paving. In which case alternative sources and methods to generate revenue become increasingly important.

CHAPTER 5

CONCLUSIONS

The findings to this study indicate that about 75 percent of North Dakota counties are experiencing an immediate or a short-term gravel shortage. The counties with an immediate shortage have less than a three-year supply of gravel remaining while those counties experiencing a short-term shortage have less than five years of gravel supplies remaining. These counties must make some difficult choices. Essentially, the county officials have two strategies they can use to remedy the gravel shortage. They may try to 1) find new gravel supplies and/or 2) reduce the demand and/or use of gravel.

To find new gravel supplies, counties can try to locate and purchase gravel from other counties or other states that have adequate supplies. Montana and South Dakota road officials indicated they too are experiencing a gravel shortage, however, some counties with an adequate supply may sell quantities of gravel. Minnesota appears to have an adequate gravel supply, particularly along the west-central border.

Transportation plays a crucial role when counties choose to import gravel from other counties or states. Presently, the average length of haul for gravel is 15 miles. In the future, counties will most likely have to haul gravel from further distances. The mode of transportation selected for hauling gravel will become more important as the length of haul increases. Most counties move gravel by truck with the exception of Cass County, which also utilizes rail transportation. Not all counties have access to rail service, but those that do should contact the rail service provider to investigate the rail rates for gravel shipments. Since the location of the demand for the gravel may be several miles from the rail track, moving gravel by rail will not alleviate the need for truck movements. However, using rail service can help reduce the wear and tear on the roads.

Counties experiencing a gravel shortage that are located within a close proximity to one another may want to consider purchasing gravel in bulk quantities. Bulk gravel prices may be lower and transportation rates may be lower. Rail rates are negotiable and larger bulk shipments (26 cars or more) are less expensive on a per car basis. These counties may want to try an approach similar to practices used by Cass County. Each fall Cass County purchases the gravel supplies needed for the following spring. The supplies are disbursed throughout the county in locations where they will be needed after the winter thaw. This tactic enables the county to spread gravel along roads particularly vulnerable to the spring thaw.

To reduce the demand for gravel, road officials may consider three alternatives, 1) reducing the level of maintenance on some gravel roads, 2) reducing gravel road miles by closing low traffic roads, and 3) paving high traffic volume gravel roads. The first two alternatives apply to gravel roads with low traffic volumes. Alternative three applies to gravel roads with high average daily traffic levels.

Each alternative has legal and economic considerations. The legal issues involved in reducing maintenance and closing a road must be recognized by the county road officials so the proper procedures are followed if implementing these solutions. The procedures were outlined in Chapter 3. It is imperative for counties to maintain detailed cost data and traffic volume data when evaluating if these solutions are economically justifiable. Both alternatives may require the rerouting of traffic, an added cost to road users. The cost savings due to reducing maintenance must be greater than the costs involved in rerouting traffic. Closing roads or reducing the maintenance may be politically unpopular in a county. Therefore, informing the public of the potential savings may satisfy angry citizens.

Although citizens prefer paved roads, this solution is frequently not economically justifiable for most gravel roads. A life-cycle cost analysis, which compares the initial costs and maintenance costs between gravel roads and paved roads for a 20-year life cycle, was conducted for a case study analysis. Five homogeneous segments of five-mile stretches of gravel roads with low, medium, and high traffic volumes in Cass County were used to demonstrate the LCC analysis. Only when opportunity costs and user costs are considered, paving was found to be justifiable on the high traffic volume gravel road segment at the 325 ADT level. Because counties do not receive any of the cost savings reflected by user and opportunity costs, they may not find it justifiable to pave a road. However, the findings do suggest that ADT levels of 325 may be a good "rule of thumb" for counties to consider paving a road. An analysis is warranted and detailed data are paramount to the success and use fullness of determining the level at which to pave a road.

LIMITATIONS

The main limitation to this study was the lack of data. There was not enough data to conduct an appropriate analysis to justify reducing maintenance or closing low-use gravel roads. Re-routing traffic would be necessary if one of these options were implemented, however, no data were available to conduct such analysis. The lack of data constrained the analysis of this report to evaluating the traffic levels at which paving a road may be justified on a road by road basis. Furthermore, the life-cycle cost analysis conducted was based on data for one year. Since costs may vary from year to year due to events such as flooding, it is important for counties to maintain several years of data. Furthermore, counties must be consistent in their accounting practices to have data that can be compared from year to year.

NEED FOR FURTHER STUDY

The gravel shortage is a problem that will not go away unless more supplies of gravel are found or demand is reduced. One method to extend the life of gravel roads that was not addressed in this study is the use of chemical additives. Chemical additives may be applied to road surfaces to reduce dust and stabilize the soil therefore reducing the quantity of gravel applications required to maintain adequate gravel roads. A study is underway at the Upper Great Plains Transportation Institute to investigate the types of chemical additives available on the market and how they would perform on North Dakota soils.

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APPENDIX A

GRAVEL USE QUESTIONNAIRE

County Gravel Use per Year

COUNTY__________________

GENERAL GRAVEL USE

1. On average, how much gravel is used in your county?
   Total Use (tons, cu. yd.)________________________________
   For Gravel Road use only (tons, cu. yd) ___________________
   For Paving & all other uses (tons, cu. yd)__________________

2. Where do you usually purchase the gravel?

3. How are purchases made, i.e., planned, as needed?

4. After you purchase the gravel, do you store it at the pit or at one or more locations within the county?

5. What is the average length of haul from point of supply to point of use? Do you use truck or rail?

6. Do you coordinate gravel purchases with other counties? If so, which counties?

7. How much do you spend on gravel in one year?

GRAVEL ROAD USE ONLY

8. How many miles of gravel roads are in the county?

9. How do you determine the frequency of applying gravel, i.e., user demand, traffic volume (ADT), seasonal?

10. How frequently do you recycle used gravel, i.e., "cut the shoulder" on roads in your county?

    a. Do you use recycled or crushed pavement in place of gravel as a base for paved roads?

11. On average, what are the typical gravel specifications you use, i.e., sieve size, moisture content?

12. What factors do you consider when selecting gravel type?