Identification of Maintenance and Equipment Needs of Rural Road Agencies

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A limited questionnaire was used to gather data about maintenance activities and costs and maintenance equipment for cities, counties, and townships in Minnesota and North Dakota. Information was gathered on winter road maintenance, and maintenance of gravel and paved roads and material costs. The results of the questionnaire were compared with a 1981 North Dakota survey and limited Montana and South Dakota estimated costs. Comparisons were also made between Minnesota and North Dakota. Because of the limited sample size of all survey sources, the results are not statistically valid, but the average values are considered representative for the rural agencies in the upper Midwest. Because of the typical response of unknown, maintenance data can only be considered to be an estimate. Typical results indicating maintenance needs is that respondents believed that a seal coat job would have an estimated life of 5 years but the actual resealing period was more than 8 years, with some agencies reporting up to 15 years. Similarly for gravel roads, the roads were typically regraveled at 6 years, but the estimated period needed was 4 years. Maintenance costs for a low-volume rural gravel road for three states was about $225 per year. Salt usage was prevalent for all agencies, as was the minimal usage of contracting out any winter road maintenance activities.

Identification of maintenance needs and equipment needs for low-volume roads is of interest to rural road agencies. Maintenance costs and productivity measures allow agency personnel to compare their performance to others. The major drawback is lack of data regarding costs, materials, equipment, and procedures used by others. This lack of information is confounded by the lack of maintenance management systems or equipment management systems for rural road agencies.

Several studies have been reported on maintenance costs and practices of rural road agencies. Two recent surveys were reported for rural road agencies in Indiana and Iowa (*1*, *2*). These were rural roads but not low-volume roads. There was a study completed by the University of Illinois (*3*) that considered the administration and operation of township roads in Illinois, Iowa, and Minnesota. The study described state policy differences but not maintenance practices and costs.

This paper addresses the maintenance activities and costs of low-volume rural road agencies in the upper Midwest. The states covered in detail are Minnesota and North Dakota. Limited comparisons are made to cost data for Montana and South Dakota. The types of agencies compared are townships, counties, and cities. The cities were small and rural. The majority of the roads were unpaved.

The Iowa county roads study (*2*) will be used to show comparisons. There are no portland cement concrete (PCC) roads in North Dakota and limited mileage of PCC roads for low-volume situations in Minnesota. Iowa, on the average, has 100 mi of PCC roads per county. Iowa has five counties over 100,000 in population and only 16 counties under 10,000 in population out of 87 counties reporting. North Dakota has no counties over 100,000 in population and only 13 urbanized counties over 10,000 in population out of 53 counties. The same situation occurs for counties outside of the Twin Cities and urbanized areas of Minnesota. Therefore, in this paper, even the city data are for low volume roads.

OBJECTIVE

The objective of this project was to compile typical data for low-volume roads to allow rural road agency personnel to compare operational and maintenance practices and costs.

CATEGORIES

The information gathered was limited to three categories: winter road maintenance, gravel road maintenance, and paved road maintenance. While this information was desired for all three agency types in both Minnesota and North Dakota, only county data were sufficient to make any meaningful comparisons. City data were extremely limited and township data were nearly nonexistent. However, respondents estimated some of these costs in order to develop comparison values. They gave their best estimates in many cases without benefit of actual cost breakdowns. Also, the sample size in some cases was very small. For the average mileage cost data, the typical response was no answer or unknown. With these caveats, however, it is believed that the data give acceptable values for certain operations and are comparable to other study results.

The range of information gathered reflects the range of winter conditions, moisture, climate and environment conditions, material and subgrade differences, and traffic volume differences over a wide area of the upper Midwest. The range of coverage is from the sparsely populated western extreme of North Dakota to the farmost northern area of Minnesota to the southern area of Minnesota to the Red River Valley. All the information gathered is from nonurbanized areas of both states.

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The following table provides a breakdown of the agencies for each state:

	Minnesota	*North Dakota*
Cities	928	253
Counties	82	53
Townships	1,800	950

For both states, there is a formal township structure that is responsible for roads. The counties are also responsible for roads.

QUESTIONNAIRES

A series of questionnaires was used to gather information on three areas of roadway responsibility: paved road repair, gravel road maintenance, and winter road maintenance.

Two specialty questionnaires were used to gather information on asphalt pavement repair and on materials and geotextiles. These two specialty questionnaires will be covered first.

SPECIALTY AREAS

Asphalt Pavement Repair

A small questionnaire covering asphalt pavement repair practices was administered in North Dakota. The results are as follows:

	Percentage	
Activity	*Yes*	*No*
Crack maintenance	80	20
Pothole repair	100	—
Seal coat	67	33

	Average Life of Repair in Years						
Activity	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Crack seal, %	60	7	—	33	—	—	—
Pothole repair, %	8	11	17	33	30	—	—
Seal coat, %	—	—	17	17	—	33	33

Activity	*Cost* ($)	*Material*
Pothole repair	25/ton	Cold mix

Similar to other reported results (*4*), 80 percent of respondents did crack maintenance. Everyone did pothole repairs. Seal coats were done by 67 percent of the respondents.

Looking at repair life expectancy, respondents believed that a crack sealant was only effective for a 1-year period. The life of a pothole repair ranged from 1 to 7 years, with most respondents estimating the average life was 4 to 5 years. In terms of seal coats, about one-third of the respondents believed the life was 3 to 4 years, one-third believed it was 6 years, and one-third believed it was 7 years. Respondents paid about $25 a ton for cold mix for pothole repairs.

Geotextiles

A questionnaire on materials usage (including geotextiles) covered the border area of North Dakota and Minnesota. The results of this questionnaire are given in Table 1. In terms of fly ash usage, 60 percent of the respondents had used it. Because of the high interest in the use of geotextiles, a series of questions concerning various applications and associated results was asked. Of the respondents, 81 percent indicated geotextile usage. The results for each application area are described next.

In terms of the area of filtration/drainage, two-thirds of the respondents indicated that they used geotextiles for this application. Seventy-one percent indicated that the installations had been successful.

For the application of a geotextile as a silt fence, only 13 percent had used it and 74 percent believed it was successful. Use of geotextile as a slope blanket had been done by about 30 percent of the respondents and 90 percent indicated it was successful.

Use of geotextile for erosion control had been done by only 13 of the respondents, but all believed it was a successful application. For use as a roadway separation device, 55 percent of the respondents had used a geotextile, but only two-thirds said it was a successful application.

About 40 percent of the respondents had used a geotextile for a road reinforcement situation. Only 58 percent believed it was successful. The major design problem was lack of sufficient over burden and users reducing layer thickness because of the geotextile presence.

Only 30 percent had used a geotextile as part of an asphalt overlay and had received negative results. Only one-sixth of the respondents had used a geotextile in an embankment, and the majority believed it was a successful application. Only a few had used geotextiles in a retaining wall, but these indicated it was a successful application.

As part of this questionnaire, questions were asked concerning the use of geotextile specifications in the design and construction process. Eighty percent had specifications on geotextile characteristics, 62 percent had specifications on test results, and only 29 percent used performance specifications for geotextiles. The number of respondents using specifications was a little higher than expected but showed coming trends.

WINTER ROAD MAINTENANCE

An extensive survey of winter road maintenance was conducted of cities and townships. Data collected from cities in Minnesota covered major equipment, miles of road, budget for new equipment, and amount of salt used in a year. The survey contained questions on use of salt, other chemicals, sand enclosures, and contracting out. The range of the number of each type of equipment, average number, and the percentage of agencies that own a particular piece of equipment are shown.

Minnesota Cities

Most Minnesota cities had at least one of each major type of equipment. The results are given in Table 2. The typical city had 55 mi of urban roads and 16 mi of rural (open) roads that they maintained. Only 8 percent had any rural mileage. As an indicator of maintenance activity, the miles per truck mea-

TABLE 1 MATERIALS QUESTIONNAIRE

	PERCENTAGE				
	YES	NO	NO REPLY	SUCCESSFUL YES	**NO
Fly Ash Usage	61	39			
Geotextile Usage	81	19			
Filtration/Drainage	67	3	30	71	--
Silt Fence	13	32	55	74	--
Slope Blanket	29	29	42	89	11
Erosion Control	13	29	58	100	--
Roadway Separation	55	10	35	65	--
Roadway Reinforcement	39	19	42	58	8
Asphalt Overlay	29	26	45	--	78
Embankment	16	32	52	80	--
Retaining Wall	3	39	58	100	--
Geotextile Specifications On*					
Characteristics	80	20			
Test Results	62	38			
Performance	29	71			

* of those responding

** of those indicating usage

sure were calculated. For Minnesota cities, this was an average of 15 mi per truck, with a range of 5 to 35 mi. The average yearly budget for new equipment was believed to be $38,000. A typical city used 168 tons of salt; the usual response was chlorides. The usage rate is as follows:

	Percentage	
Activity	*Yes*	*No*
Salt usage	100	0
Other chemicals	10	90
Sand enclosure	14	86
Contract out any activities	20	80

All respondents used salt. Only 10 percent used other chemicals in addition to salt. A somewhat surprising finding was that only 14 percent had a sand enclosure. In terms of privatization, only 20 percent had contracted out any portion of their winter road maintenance activities (this was typically snow hauling).

Minnesota Counties

Almost all Minnesota counties had each type of major equipment (Table 3). The typical county respondent had 26 mi of urban road and 450 mi of rural road that they maintained. Only 31 percent had any urban roads to maintain, with a range of from 1 to 120 mi of road. The miles of rural roads maintained ranged from 54 to 900. As an indicator of maintenance activity, there was an average of 56 mi per truck; the range was from 15 to 133 mi. The average yearly budget for new equipment ranged from $10,000 to $250,000, but was believed to be $134,000. The typical county used 334 tons of salt per year. Extra major equipment was typically a blower.

All respondents used salt; only 41 percent used other chemicals, as shown in the following table:

	Percentage	
Activity	*Yes*	*No*
Salt usage	100	0
Other chemicals	41	59
Sand enclosure	26	74
Contract out any activities	23	77

Again somewhat surprising is that only one-fourth of the respondents had a sand enclosure. Twenty-three percent had contracted out a portion of their winter road maintenance activities. It should be noted that in Minnesota, counties are responsible for secondary roads.

Minnesota Townships

A small number of Minnesota townships were sampled. Winter road maintenance was performed either by the county, private contractors, or the townships' own operators (Ta-

TABLE 2 MAJOR TYPES OF EQUIPMENT USED FOR WINTER ROAD MAINTENANCE IN MINNESOTA CITIES

Major Types of Equipment	Number		
	Range	Average	Percent Having
Truck	1-13	5.1	100%
Motor Graders	1-4	1.7	84%
Sanders	1-12	3.5	92%
Plows	2-15	5.2	86%
Loaders	1-6	2.0	88%
Other *	1-3	1.3	24%
Miles of Roads			
Urban	15-142	55	100%
Rural	0-25	16	8%
Miles per Truck	5-35	15	
Budget of New Equipment in $1000	4-140	38	
Amount of Salts Used (tons per year	2-600	168	

* Typical response was small loaders

ble 4). The results of the survey appear to be representative for a township carrying out their own winter road maintenance. Not every township had every piece of major equipment, but they all had a motor grader. The typical respondent maintained 18 mi of urban road and 57 mi of rural road. Only 19 percent had any urban roads. It should be mentioned that Minnesota does have urbanized townships; the respondents to the questionnaire were from rural areas. The average mileage per truck was 35, which appears to be a representative value. The budget for new equipment was $8,000/year (small sample), which would be considered representative. Respondents used on the average 25 tons of salt.

TABLE 3 WINTER ROAD MAINTENANCE IN MINNESOTA COUNTIES

Major Types of Equipment	Number		
	Range	Average	Percent Having
Truck	2-14	8.7	100%
Motor Graders	1-20	5.5	100%
Sanders	2-14	7.5	100%
Plows	3-22	13	90%
Loaders	1-4	1.9	92%
Other*	1-4	2.2	36%
Miles of Road			
Urban	1-120	26	31%
Rural	54-900	450	100%
Miles per Truck	14-133	56	
Budget for New Equipment in $1000	10-250	134	
Amount of Salt Use (Tons per Year)	11-2000	334	

* Typical response was blower

TABLE 4 WINTER ROAD MAINTENANCE IN MINNESOTA TOWNSHIPS

Major Types of Equipment	Number Range	Average	Percent Having
Truck	1-3	1.7	80%
Motor Graders	1-2	1.1	100%
Sanders	1-2	1.4	65%
Plows	1-5	2.5	60%
Loaders	1-2	1.1	65%
Other	1	1	10%
Miles of Roads			
Urban	0-35	18.5	19%
Rural	26-90	57	81%
Miles per truck	3-78	35	
Budget for New Equipment in $1000	8-10	8*	
Amount of Salt Used (Tons Per Year)	1-75	25*	

Small sample size

As observed from the following table, 70 percent of the respondents used salt, 10 percent used other chemicals, and 15 percent had a sand enclosure. Also, 12 percent indicated that they contracted out maintenance activities, typically to the county or driveways to a private firm. Townships generally performed their own maintenance activities.

	Percentage	
Activity	*Yes*	*No*
Salt usage	70	30
Other chemicals	10	90
Sand enclosure	15	85
Contract out any activities	12	88

North Dakota Cities and Townships

A very small number of North Dakota cities were sampled that are rural in nature. As an indication of the size of the cities, respondents had no paved roads to maintain. The results of the questionnaire are summarized in Table 5, and the usage rates are as follows:

	Percentage	
Activity	*Yes*	*No*
Salt usage	50	50
Other chemicals	0	100
Sand enclosure	0	100
Contract out any activities	0	100

There were no respondents from North Dakota Townships. Only one township owns road equipment; the remainder contract with the county or private contractors for maintenance.

North Dakota Counties

Three-fourths of the counties in North Dakota had a major piece of each type of equipment, and all respondents had a motor grader. The results of the survey are summarized in Table 6. The counties had an average of 2 mi of urban road (only 6 percent of counties maintained urban roads and 576 mi of rural). The range of rural road mileage maintained was from 80 to 900 mi. As an indicator of maintenance activities, the average miles of road per truck was 152 mi.

The average budget for new equipment was $157,000; however, this figure is not believed to be representative, but is probably the result of a county buying a major piece of equipment the previous year. The amount of salt used was 24 tons per year. Again the sample size was small.

As observed from the following table, 88 of the responding counties used salt; no county used other chemicals. Somewhat surprisingly, 82 percent of the respondents had a sand enclosure. No county contracted out winter maintenance activity.

	Percentage	
Activity	*Yes*	*No*
Salt usage	88	12
Other chemicals	0	100
Sand enclosure	82	18
Contract out any activities	0	100

NOTE: Only one township owns winter road maintenance equipment. The remainder contract with the county for maintenance activities or private contractors.

TABLE 5 WINTER ROAD MAINTENANCE IN NORTH DAKOTA CITIES

Major Types of Equipment	Number Range	Number Average	Percent Having
Truck	2	2	100
Motor Graders	1	1	100
Sanders	1	1	100
Plows	---	---	---
Loaders	1	1	100
Other	1-2	1.5	100
Miles of Roads			
Urban	15	15	100
Rural	0	0	0
Budget for New Equipment in $1000	---	---	
Amount of Salt Used (Tons per year)	50	50	

Very small sample

Comparison of Winter Road Maintenance in Minnesota and North Dakota

The only meaningful comparison, although not statistically significant, can be made between North Dakota and Minnesota counties. Again the results are for the respondents and are not statewide averages.

Each of the Minnesota counties surveyed had every piece of major equipment; whereas only three-fourths of the North Dakota counties had every major piece of equipment. Thus it would appear that some North Dakota counties depended only on motor graders to keep their roads open during the winter.

Minnesota maintained more urban roads in winter than North Dakota. Although the range of rural road mileage maintained is nearly the same for both states, on the average,

TABLE 6 WINTER ROAD MAINTENANCE IN NORTH DAKOTA COUNTIES

Major Types of Equipment	Number Range	Number Average	Percent Having
Truck	1-9	3.8	76
Motor Graders	1-12	6.6	100
Sanders	2-3	2.6	76
Plows	1-24	8.3	71
Loaders	2-3	3.0	76
Other	3	3	12
Miles of Road			
Urban	2	2	6
Rural	80-900	576	
Miles per Truck	80-180	152	
Budget for New Equipment* in $1000	100-256**	152**	
Amount of Salt Used* (Tons per year)	10-50	24	

* Very small sample

** Not considered representative

North Dakota had more mileage to cover (576 versus 450 mi). Using miles per truck as an indicator, North Dakota averaged 152 mi per truck, whereas Minnesota averaged 56 mi per truck. Because only three-fourths of North Dakota respondents used trucks, looking at miles of road per motor grader, on a county basis, both states averaged about 90 mi per motor grader. Taking a single type of equipment, these results could be misleading; a combination of severe types of equipment would provide a more accurate comparison. The results do suggest, however, that North Dakota counties depend more heavily on motor graders and use less sand and salt probably because the majority of county roads are gravel and the use of salt is not a typical approach.

Minnesota counties have on average more of a mixture of paved and unpaved roads. Also, county needs vary because of the wider range of winter conditions. Southern Minnesota typically receives the heaviest concentration of snow, but open Northern Minnesota has more forests. North Dakota and Western Minnesota are subject to lower snowfalls but blowing and drifting snow is more common. Thus the amount of snow and the ground movement of the snow are the determining factors in selecting the size and type of equipment used versus the mileage of road. Most of the larger cities and counties in both states own a piece of blower equipment.

All agencies in Minnesota use salt, and a portion used other chemicals; not every county in North Dakota used salt, and no county used other chemicals. In comparing the counties in the two states the surprising result was that only one-fourth of the Minnesota counties had a sand enclosure compared with 82 percent of North Dakota counties.

ROAD MAINTENANCE

Introduction

A questionnaire was used to gather information on road characteristics and the agencies' road maintenance activities in both states. A limited survey was conducted in 1981 by the North Dakota State Highway Department to gather similar data on the counties. Only a portion of the total counties in the states responded to the questionnaire and the 1981 survey. For North Dakota counties, results of both the questionnaire and the survey are compared. Counties were asked about the frequency of blading gravel roads, regraveling roads, and mileage of roads by type. Also, the use of dust control liquids, gradation specifications, and a pavement management system were determined. Comparative data are only available for counties.

North Dakota Counties

The questionnaire results and the 1981 survey results are summarized as follows:

	Percentage				
Number	*3*	*4*	*5*	*6*	*>10*	
Frequency of blading gravel road	15	15	23	15	31	
Weeks	*1*	*2*	*>3*	*Rain*		
In Summer, average time period between bladings	24	28	20	28	(questionnaire)	
	53	47	0	0	(summary)	

	Percentage							
Years	*2*	*3*	*4*	*5*	*6*	*7*	*>7*	
On the average, how are roads regraveled?	10	10	13	33	7	6	20	(questionnaire)
	7	10	4	7	0	14	57	(summary)

	County		
Miles of Road	*Range*	*Avg.*	*Percentage*
Gravel	85 to 1,100	406	100
PC concrete	0	0	0
Asphalt surface treatment	0 to 100	8	14
Bituminous 1 to 2 in.	0	0	0
Bituminous >2 in.	0 to 350	93	50

In terms of frequency of reblading gravel roads, the range was from 3 to more than 10 times per year. The distribution was fairly uniform across the number, but the highest frequency was more than 10 times. The response to the time interval between rebladings in the summer was fairly uniform, ranging from 1 week to more than 4 weeks. Interestingly, in the 1981 survey, respondents indicated that only 1 or 2 weeks elapsed between reblading. The responses were more dispersed for the questionnaire.

The questionnaire responses indicated a fairly wide dispersion for the regraveling interval from 2 to more than 7 years, with the highest frequency between 2 to 5 years. In the 1981 survey, the same dispersion range occurred but the most frequent time interval was more than 7 years. In the intervening 5 years, it is difficult to believe that the frequency of regraveling has increased. Notwithstanding the differences, it would appear that regraveling occurs on the average at a frequency of at least 5 years. These results would indicate that adequate maintenance of gravel roads probably is not as frequent as it should be.

To determine the type of road maintenance needed, the counties were asked to indicate their mileage of roads by type. The types indicated were gravel, portland cement concrete, asphalt surface treatment, a bituminous surface of between 1 to 2 in. thick, and a bituminous surface of more than 2 in.

As expected, all North Dakota counties have gravel roads; the mileage ranges from 85 to 1,100 mi. The respondents indicated no portland cement concrete, or thin bituminous pavements. About one-seventh of roads in North Dakota have some asphalt surface treatment. Bituminous surface roads (greater than 2 in.) range from 0 to 350 mi; the average is 93 mi. Only one-half of the counties have a paved road, which would indicate that the counties predominantly have gravel roads. The average county has more than 500 mi of road to maintain, 80 percent of which is gravel.

In responding to the question, "How often are roads sealed?" counties estimated that a road would be sealed on the average every 7 years; the range was from 3 to 10 years. This would indicate some maintenance deficiency between seal life and actual seal coat interval. Responses to additional questions are as follows:

	Percentage	
	Yes	*No*
Do you use oil sprays or chemicals	18	82
Do you use gradation specifications for gravel?	36	64
Do you have a pavement management (repair) system?	24	76

About one-third of the counties indicated that they used a

TABLE 7 ROAD MAINTENANCE IN NORTH DAKOTA CITIES

Miles of Road	Range	Average	Percent Having
Gravel	0-65	12.6	100%
PC Concrete	0-3	0.6	29%
Asphalt Surface Treatment	2-50	8.9	71%
Bituminous 1"-2"	0-100	19.7	71%
Bituminous >2"	0-65	9.3	14%

Township roads in North Dakota are all gravel or dirt, except for a few urbanized townships.

graduation specification for gravel. The North Dakota practice may be a little unique because many of the smaller counties, cities, and townships buy directly from a small gravel pit operator, and personal reputation is used to assure quality. Although this works well in most cases, the agency still has to recognize the type of material characteristics it wants.

North Dakota Cities and Townships

The sample was inadequate to draw meaningful results from the road maintenance questionnaire for cities and townships in North Dakota. As indicated for winter road maintenance, only one township has road equipment; all other townships contract with the county for maintenance activities. Questionnaire results are summarized in Table 7.

Rural characteristics appear in the city mileage. All the respondent cities have gravel roads ranging is from 0 to 665 mi, with an average mileage of 12.6. It should be noted that dirt roads were excluded from the questionnaire. Only 30 percent had PCC roads, which were a very small mileage. Seventy percent had an average of 9 mi asphalt surface treatment roads. Seventy percent had a thin (1 to 2 in.) bituminous road, averaging 20 mi. Only 15 percent had a bituminous surface (2 in.) road, and the average mileage was 10. This would indicate that the typical city had low-volume roads. Overall they were responsible for more than 50 mi of road, 40 percent of which were surface treated, 20 percent had a bituminous surface, and 25 percent of roads were gravel; PCC roads were nonexistent.

MAINTENANCE NEEDS

North Dakota Counties

The following questions were asked about maintenance needs:

Question: What is your greatest need for maintenance?
Response: Training, 6 percent; money, 21 percent; management system, 20 percent; personnel, 16 percent; materials, 13 percent; and equipment, 24 percent.

Question: What do you think is the most common cause of pavement failures?
Response: Lack of maintenance, 4 percent; freeze thaw, 60 percent; moisture, 6 percent; weak base, 12 percent; inadequate construction, 14 percent; and drainage, 4 percent.

Question: What are your bridge concerns?
Response: Railing, 7 percent; inspection, 7 percent; safety, 23 percent; funding, 3 percent; maintenance, 27 percent; age, 27 percent; and des/construction, 7 percent.

Question: How often should roads be regraveled?

	Years	
	Range	*Avg.*
Questionnaire	1 to 10	3.6
Survey	1 to 10	4.1

Question: How often are roads regraveled?

	Years	
	Range	*Avg.*
Questionnaire	2 to 10	5.1
Survey	2 to 15	6.8

The response to the question about the greatest need for maintenance was about equally divided among equipment, a management system, or money. Personnel and materials were also indicated. When asked what they believed to be the most common cause of pavement failure, the majority indicated freeze-thaw; related responses were inadequate construction and weak bases. To get an idea of bridge concerns or county roads, the question "What are your bridge concerns?" was asked. The respondents indicated about equally the related concerns of age, maintenance, and safety.

To get some comparative maintenance needs assessment, a series of questions was asked about actual practice and needed practice. First, the question was asked about the regraveling interval. Respondents to the questionnaire indicated a range of 1 to 10 years with an average of 3.6 years. The 1981 survey results also indicated a range of from 1 to 10 years and an average of 4 years.

On the actual practice of regraveling, respondents to the questionnaire indicated 2 to 10 years with an average of 5 years. The 1981 survey respondents indicated a range of 2 to 15 years with an average of just under 7 years. This would indicate that the respondents do not believe that actual regraveling practices satisfy road maintenance needs. It would also indicate that the 5-year regraveling frequency is about one-third longer than it should be.

The next set of questions is summarized as follows:

Question: What determines the blading interval?
Response: Moisture, 5 percent; schedule, 5 percent; experi-

ence, 7 percent; money, 4 percent; condition, 53 percent; and complaints, 26 percent.

Question: What determines regraveling interval?
Response: Funds, 9 percent; condition, 85 percent; and complaints, 6 percent.

Question: What determines when a gravel road should be paved?
Response: Funding, 57 percent; public demand, 6 percent; and traffic volume, 37 percent.

A follow-on question about regraveling indicated that the regraveling interval was determined by road condition. Although this is expected, it would indicate that if regraveling was not being accomplished as often as it should that road condition was probably less than desired.

A similar question was asked about the reblading interval. The respondents indicated condition and complaints were the main determinants of reblading. However, the low frequency of reblading would indicate the likelihood of poor road condition.

Because the vast majority of agencies in North Dakota do not change surface type because of funding constraints, a correlated question was asked: "What determines when a gravel roads should be paved?" The majority indicated funding followed by traffic volume.

Maintenance Costs

To obtain an estimate of maintenance costs, a series of questions was asked.

The results for North Dakota counties are summarized as follows:

What is the average cost for a cubic yard of gravel?

	Purchased Range	*Avg.*	*In Place Range*	*Avg.*
Questionnaire	.40–11.00	3.71	2.25–12.50	5.59
Survey			2.50–14.70	5.30

What is the average cost for a ton of patching mix?

Range	*Avg.*
20–50	34.50

What is the yearly average cost for regular maintenance of one mile of gravel road?

	Actual Range	*Avg.*	*Adequate Range*	*Avg.*
Questionnaire	20–900	324	40–7,000	1,718
Survey	180–1,920	800	500–7,000	2,204

What is the yearly average cost for regular maintenance of one mile of paved road?

	Actual Range	*Avg.*	*Adequate Range*	*Avg.*
Questionnaire	30–4,200	1,330	850–8,000	3,270
Survey	150–5,500	1,135		

The 1981 survey results were similar with a range of $2.50 to $14.70 and an average cost of $5.30. The price of gravel varies with material suitability, availability, and specifications. The next question concerned the cost of a ton of patching mix. The respondent range was $20 to $50 with an average of $34.50.

The next series of questions dealt with annual maintenance costs. As would be expected, there is a wide range of respondent estimates. It should be noted that the typical response to these questions was "unknown," which would indicate the lack of knowledge of actual expenditures for a specific road or cost allocation to roads. It would emphasize the interest in maintenance management systems and the difficulty of estimating allocated costs.

First response to the question "What is the yearly average cost for regular maintenance of a one mile gravel road?" was actual expenditure and the second response was for an adequate maintenance level expenditure.

The questionnaire yielded a range of costs from $20 to $900/mi with an average of $324/mi. The 1981 survey results indicated a range of $180 to $1,920/mi with an average of $800/mi. The diversity of response is troublesome. It could have arisen from the lack of maintenance expenditure or use of an inaccurate estimate. However, both average values are lower than other values of gravel road maintenance reported in the literature. The results for an adequate maintenance expenditure level were somewhat more consistent and would indicate some misestimations of gravel road maintenance costs. The questionnaire results indicated a range of $40 to $7,000/mi for an adequate maintenance level with an average of $1,718. The 1981 survey results indicated a range of $500 to $7,000 and an average of $2,204. The low range of the questionnaire estimates are questionable. The 1981 survey results in this case are better representation of agency views.

The response to the question "What is the yearly average cost for regular maintenance of one mile of paved road?" indicated actual activity from $30 to $4,200/year with an average of $1,330/mi. The 1981 survey results indicated a range from $150 to $5,500 with an average value of $1,135/mi. Although the low range values are extremely low, the overall sample average appears representative.

Responses to the question on maintenance expenditure estimates for paved roads indicated a range of from $8,500 to $800/mi with an average estimate of $3,270/mi for adequate maintenance level. The paved maintenance cost estimates appears to be typical of recognized maintenance cost.

The maintenance issue is highlighted in the following table:

Seal Coating Years	*Range*	*Avg.*
Estimated life	1 to 7	5.69
Actual resealing period		
Questionnaire	3 to 10	7.1
Survey	3 to 15	9.9

In terms of seal coating frequency, respondents estimated a seal coat life ranged from 1 to 7 years with an average life expectancy of 5.7 years. The average result would appear to be near the typical accepted life expectancy of 3 to 7 years (*5*). However, looking at actual frequency of seal coating, the questionnaire results have a range of between 3 to 10 years between resealings with an average of 7 years. The 1981 survey had even higher frequencies with a range of 3 to 15 years and an average of 10 years. Both of these estimates exceed the predicted life expectancy, indicating a maintenance deficiency in terms of paved roads.

These road maintenance activity summaries highlight the inadequacy of maintenance on low-volume roads in rural

counties. This means that road condition and deterioration fall below an acceptable value, and deficiencies typically will occur and persist on these low-volume roads. The summary also indicates that the low-volume roads are typically gravel (and probably dirt) and that a rural agency is only responsible for some moderate-volume paved roads.

ROAD MAINTENANCE

Minnesota Counties

Similar data were part of a limited questionnaire on road maintenance activities sent to Minnesota counties. Results are summarized as follows:

	Percentage			
	<9	10 to 24	26	>26
Frequency of blading gravel road per year	25	17	25	25

	Percentage				
	1	1.5	2	3	>3
In summer, average time period between bladings, weeks	27	18	27	9	18

	Years			
	1	2	3	>4
On the average, how often are roads regraveled? ([a]includes as needed)	50[a]	13	12	25

	County		
Miles of road	Range	Avg.	Percent having
Gravel	44 to 500	181.7	100
PC concrete	0 to 10	2	22
Asphalt surface treatment	0	0	0
Bituminous 1 to 2 in.	1 to 310	53.4	44
Bituminous >2 in.	0 to 150	43	67

In terms of the number of times a gravel road is bladed each year, Minnesota respondents showed a wide diversity. Twenty-five percent bladed less than 10 times per year and 50 percent bladed 26 or more times per year. During the summer, respondents were equally likely to blade once a week or every 2 weeks, or once every 3 weeks or more. Reblading a gravel road during the summer appeared to be a frequent maintenance activity.

One-half of the respondents regraveled annually; one-fourth regraveled at a 2- to 3-year frequency, and one-fourth regraveled at greater than 4-year interval. One reason for the range of regraveling intervals is how it is done. Several respondents indicated spot regraveling on an annual basis and regraveling lifts being done at 4-year intervals, which would explain the diversity of ranges indicated.

The miles of gravel road ranged from 44 to 500 mi with an average of 180 mi. Only 22 percent of the counties had any PCC roads, and the average amount was very small. It should be noted that southern Minnesota counties have the higher preponderance of PCC roads whereas Northern and Western Minnesota counties have no PCC roads.

Minnesota county respondents indicated that they had no asphalt-surface treatment roads. One-half of the counties had light bituminous-surfaced roads ranging from 1 to 310 mi with an average of slightly more than 50 mi. Bituminous surfaced roads were present in two-thirds of the counties. The range was from 0 to 150 mi with an average mileage of 43 mi.

The typical county respondent had 280 mi of roads, two-thirds of which were gravel, 20 percent light bituminous, 15 percent bituminous, and less than 1 percent PCC.

The results of maintenance practices are summarized as follows:

Activity, years	Range	Avg.	Percent having
How often are roads sealed?	8 to 10	9	75

	Percentage	
	Yes	No
Do you use oil sprays or chemicals for dust control?	33	67
Do you use gradation specifications for gravel	91	9
Do you have a pavement management (repair) system?	12	88

The respondents believed that roads were resealed every 9 years. One-third of the respondents used oil sprays or chemicals for dust control. More than 90 percent used gradation specifications for gravel. The typical specification was Minnesota Department of Transportation Class V material. Only one-eighth of the respondents had a pavement management system.

MAINTENANCE NEEDS

Minnesota Costs

Responses to questions about various maintenance activities are summarized as follows:

Question: What is the greatest need for maintenance?
Response: Training, 6 percent; money, 81 percent; personnel, 17 percent; and equipment, 6 percent.

Question: What do you think is the most common cause of pavement failure?
Response: Lack of maintenance, 0 percent; freeze thaw, 35 percent; moisture, 20 percent; weak base, 30 percent; drainage, 5 percent; and heavy trucks, 10 percent.

Question: What are your bridge concerns (small sample size)?
Response: Age, 50 percent; and maintenance costs, 50 percent.
Question: How often should roads be regraveled? (assume 3-in. lift)

Years	
Range	Avg.
1 to 10	4.6

Question: How often are roads regraveled? (minor and soft spots)

Years	
Range	Avg.
1 to 5	2.4

Question: What determines the blading interval?
Response: Moisture, 9 percent; schedule, 13 percent; expe-

rience, 17 percent; money, 3 percent; condition, 46 percent; and complaints, 12 percent.

Question: What determines regraveling interval?
Response: Condition, 94 percent; and traffic volume, 6 percent.

Question: What determines when a gravel road should be paved?
Response: Funding, 10 percent; public demand, 20 percent; and traffic volume, 70 percent.

The first question dealt with the greatest need for maintenance. The biggest concern was money followed by personnel. The second question concerned the most common causes of pavement failure, which were listed as freeze thaw, weak base, and moisture.

The responses to the bridge concern question, age and maintenance costs, were related. The frequency of road regraveling was believed to be an average of 4.6 years with a range of 1 to 10 years. The roads are typically regraveled (minor and soft spots) at 2.5-year intervals with a range of 1 to 5 years.

About one-half of the respondents believed that road condition determined the blading interval. The regraveling interval was also believed to be determined by road condition.

Traffic demand determined when a gravel road should be paved. The responses concerning maintenance costs are given in the following table:

What is average cost for a cubic yard of gravel?

Purchased		*In Place*	
Range	*Avg.*	*Range*	*Avg.*
1.5 to 8.00	2.99	3.50 to 11.00	5.67

What is average cost for a ton of patching mix?

Range	*Avg.*
15 to 30	22.50

What is yearly average cost for regular maintenance of one mile of gravel road (small sample)?

Actual		*Adequate*	
Range	*Avg.*	*Range*	*Avg.*
50 to 2,500	848	350 to 3,500	1,281

What is yearly average cost for regular maintenance of one mile of paved road (very small sample)?

Actual		*Adequate*	
Range	*Avg.*	*Range*	*Avg.*
1,400 to 2,700	1,867	1,800 to 3,500	2,433

The average cost for a cubic yard of gravel purchased ranged from \$1.50 to \$8.00 with an average of \$2.99. The in-place cost ranged from \$3.50 to \$11.00 with an average cost of \$5.67. The respondents indicated a range of \$15 to \$30 for a ton of patching mix with an average cost of \$22.50.

From the responses to the questions related to the annual maintenance cost for rural roads, it would appear that rural agencies do not have good cost data. The average cost for regular maintenance of a mile of gravel road was believed to be \$848 in terms of actual operations with a range of from \$50 to \$2,500. The low range value is somewhat surprising. The needed expenditure level for adequate maintenance was believed to be \$1,283 with a range of \$350 to \$3,500. The cost for actual maintenance practices for a paved road is believed to average \$1,867 with a range of \$1,400 to \$2,800. Adequate maintenance was believed to cost an average of \$2,433 with a range of \$1,800 to \$3,500.

The estimates of gravel road maintenance costs (for a typical annual maintenance budget) for a city and township are \$2,750 and \$225, respectively.

COMPARISONS

A comparison of the maintenance costs and activities are summarized in the following tables.

Average cost for regular maintenance of one mile gravel road (state)

MN	*MT*	*ND*	*SD*
—	1,317	—	1,226

Average cost for regular maintenance of one mile paved road (state)

MN	*MT*	*ND*	*SD*
1,238	3,029	—	—

Average cost for regular maintenance of county road

MN	*MN*	*N*	*SD*
230 (gravel road)	1,643 (paved road)	178 (gravel road)	275 (gravel road)

Comparison data on both estimated state and county gravel road maintenance costs are given. North Dakota counties had an estimated maintenance cost of \$178 for gravel roads, Minnesota estimates were \$230, and a comparative South Dakota estimate was \$275. It would appear that these costs are comparable.

The following table compares North Dakota and South Dakota regraveling practices; in South Dakota the average is 7.6 years, whereas it is 10 years in North Dakota.

How often are roads regraveled?

	Years	
	Range	*Avg.*
MN	—	—
MT	—	—
ND	3 to 15	9.9
SD	4 to 15	7.6

Material costs are compared in the following table:

Average cost cubic yard of gravel

	MN	*MT*	*ND*	*SD*
Purchase	2.99		3.71	
In place	5.67		5.45	

Average cost per ton of patching mix

	MN	*MT*	*ND*	*SD*
Purchase	22.50		34.50	

TABLE 8 COMPARISON OF WINTER ROAD MAINTENANCE IN MINNESOTA AND NORTH DAKOTA COUNTIES

	MN	ND
Annual Budget New Equipment		
	134,000	--
Average Miles per Truck		
	56	152
Salt Usage (%)		
YES	100	88
NO	0	12
Other Chemicals (%)		
YES	41	0
NO	59	100
Sand Enclosure (%)		
YES	26	82
NO	74	18
Contract Out Any (%)		
YES	23	0
NO	77	100

The cost of a cubic yard of gravel purchased is slightly higher in North Dakota, but the in-place cost is about the same. Patching mix cost is higher in North Dakota.

Some of the maintenance usages are compared in Table 8. Although the miles per truck are different between North Dakota and Minnesota, the miles per motor grader is the same. Thus North Dakota counties depend on the motor grader solely for snow removal more than do Minnesota counties. Not every county in North Dakota uses salt. None use other chemicals.

One surprising observation is that North Dakota counties predominantly had a sand enclosure, whereas Minnesota counties predominantly do not. North Dakota counties do not contract out any maintenance activities; a small number of Minnesota counties contract out.

SUMMARY

The obvious conclusion to be drawn is the lack of reliable data on maintenance costs, which is indicated by the interest in maintenance management and equipment management systems. The range of maintenance costs for North Dakota townships is wide. Maintenance is carried out by the counties, and an extremely wide range of costs exist. As extreme values, one township pays a county $35/mi for all annual maintenance, whereas a second township pays $35/hr for all maintenance activities. Obviously actual costs are not known. In the upper great plains, salt is still used, sometimes with other chemicals. For rural agencies with low-volume roads, the motor grader is the predominant winter road maintenance equipment. It appears that 90 mi of road are maintained in winter with each motor grader. An annual cost of gravel road maintenance is around $200 to $225. Very few agencies contract out any maintenance activity.

CONCERNS

Although the respondents did not get an opportunity to list their critical concerns, their general concerns can be seen in their replies to the various questions. Their concern of obtaining sufficient funds is obvious, but the questionnaire sought to identify other issues. In comparison to responses to a survey sent to state agencies in the early 1980s to identify low-volume road agency concerns, which showed design standards and regulations as critical concerns (5), the questionnaire respondents were more concerned with maintenance operations. They ranked much higher than the Cornell study indicated. The Cornell study ranked concerns as follows:

1. Finance
2. Public relations and communications
3. Materials and pavements
4. Bureaucracy and red tape
5. Personnel
6. Management
7. Safety
8. Liability and litigation
9. Traffic
10. Maintenance
11. Equipment

The questionnaire respondents indicated that personnel and management, which were ranked in the middle of the Cornell study, ranked much higher. Also the lower ranked concerns in the Cornell study were the higher concerns in the questionnaire. Rural agencies believed that maintenance and equipment operations were most important. As several respondents indicated, building new roads to design standards was not a problem because they did not build new roads.

CONCLUSIONS

There is a need for better defined maintenance costs. Variability in costs arise from materials, traffic, environment, and climate differences. Maintenance management and equipment management systems are of interest to rural agencies.

DISCLAIMER

The data obtained for this paper are limited in scope and provided only approximate estimates of costs and frequencies.

Because of the small number of respondents and questionnaire interpretation, the data cannot be considered statistically reliable. However, it is believed that many of the average values provide representative estimates. The values obtained do not represent the overall statistics for any state. Only very generic comparisons are possible. The views and interpretations expressed in this paper are those of the authors.

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