

Effects of County Highway Management Practices on Maintenance Costs for Unpaved Roads in Indiana

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ABSTRACT

Costing highway maintenance for both budgeting and performance reporting is a critical problem, particularly for counties and other local highway agencies. In Indiana, guidelines are available for preparing county highway accounts. However, the success with implementation has varied among counties. Road maintenance costs calculated for four Indiana counties are presented. The effects of management practices and policies such as grading frequency, regravelling, and equipment use on maintenance costs of unpaved roads are discussed. In the analysis presented, traffic volume is found to be an important consideration, especially in determining grading frequencies. However, another important factor, road condition or performance, is seldom routinely measured by Indiana counties. Although the condition of unpaved roads is not discussed in detail in this paper, it is considered important to monitor road condition periodically and relate it to the maintenance strategies adopted. The problems of data collection and accurate maintenance costing are traced to deficiencies in the accounting system, which does not enable costing by activity, road type, or location. An improvement in the maintenance cost accounting system is considered necessary for better cost control as well as accurate life-cycle costing.

The ability to estimate the costs of various construction and maintenance activities is an important element in effective highway planning and management. Cost information is useful for both budgeting and accomplishment reporting. However, costing highway maintenance is a critical problem, particularly for counties and other local highway agencies. Generally, because construction and major capital improvement projects are bid by private contractors, the costs are usually well known. The variations from the original contract costs can usually be monitored and the final costs can be estimated. Because most of the maintenance is performed by an agency's own personnel, the ability to estimate highway maintenance cost depends on the maintenance cost-accounting or management system in operation. In Indiana, county highway departments differ in their approach to management, and some of them are unable to monitor and keep adequate records of their operations for accurate budgeting or for reporting accomplishment.

In this paper the procedure used to determine county highway maintenance costs in Indiana is discussed; this procedure is part of research undertaken by the Highway Extension and Research Project for Indiana Counties and Cities (HERPICC) at Purdue University (1). The costs of maintenance activities for unpaved roads undertaken in 1983 and also some maintenance activities for paved roads are determined from data available from county records or collected specially as part of the study. In addition, the impact of various county highway management practices on maintenance costs, particularly for unpaved road surfaces, is also examined.

METHODS OF DATA COLLECTION

To obtain the required cost information, arrangements were made with engineers and supervisors from five counties--Bartholomew, Huntington, Jasper, Tippecanoe, and Warrick--to monitor and maintain records for maintenance activities on selected unpaved road sections for 1983. The maintenance activities included blading or grading, regravelling or spot regravelling, brush cutting, mowing, side ditching, snow plowing, and sign maintenance. As much as possible, the existing data reporting system used as part of county maintenance cost accounting was used. This data collection approach was aimed at reducing problems likely to arise if new data forms were introduced. The only special requirement was that equipment operators and other personnel working in any activity on the selected roads were to provide detailed information for certain items on the daily work reports. Information reported included labor time, equipment time, and distance traveled as well as material types and quantity and costs for each activity. An example of the daily work report form currently used by Indiana counties is shown in Figure 1. Because maintenance activities are not adequately identified on the form, they were described in the space provided for project or location. These details were discussed with the county highway officials before the special study.

Another approach adopted was to analyze past annual operating reports submitted by the counties, which provide the only reported source of information on county operations. Costs from Mason County, in Washington State (2), which has implemented a maintenance management system, are also presented for comparison with costs estimated for Indiana.

The data collection procedure was implemented fairly successfully by three counties, especially when the highway engineers, supervisors, or clerks became personally involved in monitoring the information. In another case, the information was ex-

Form Prescribed by State Board of Accounts County Highway Form No. 1 (Rev. 1972)

COUNTY HIGHWAY DAILY WORK REPORT

Name of Employee: _____ Date: _____, 19__

PROJECT OR LOCATION: (If work was on two or more construction projects describe each project separately by code "A", "B", etc.)					CONSTRUCTION AND RECONSTRUCTION				MAINTENANCE AND REPAIR			OTHER		
					Project A	Project B	Project C	Project D	Roads	Bridges		County Garage		
LABOR – TOTAL HOURS FOR DAY														
EQUIPMENT NUMBER	Speedometer		Total Miles	Number of Hours										
	Begin	End												

← IN

← OUT

MATERIALS – SUPPLIES – REPAIRS: (Describe and attach delivery or sales tickets, invoices, etc)

FIGURE 1 Indiana county highway daily work report form.

TABLE 1 Breakdown of Annual Maintenance Expenditure by County, 1980-1983

Item	Percent Expenditure by County				
	Bartholomew ^a	Huntington ^b	Jasper ^c	Tippecanoe ^d	Warrick ^e
Administrative and operational overhead	22.1	26.6	25.3	23.0	21.7
Garage and mechanical overhead	9.8	18.6	15.7	9.9	14.6
Equipment	3.4	2.3	6.3	7.5	8.1
Stone and aggregate	9.5	7.0	12.3	8.0	4.7
Bituminous and mixes	13.9	3.6	5.4	13.5	5.3
Culverts and tiles	1.5	1.9	2.1	1.0	—
Road signs	0.4	1.1	1.3	0.4	0.6
Other materials	1.5	3.2	0.2	9.6	15.5
Labor	19.9	23.4	24.4	17.7	25.0
Contractual services	17.9	12.2	7.0	9.6	4.6

Note: The expenditures given are 4-year averages.

^aTotal spent, \$1,137,000.

^bTotal spent, \$1,118,000.

^cTotal spent, \$919,000.

^dTotal spent, \$2,024,000.

^eTotal spent, \$1,399,000.

tracted from the daily work reports and accounting records of 1983 supplemented by interviews with the bookkeepers, the highway supervisor, and the grader operators assigned to the roads in the study. The main problem observed during data collection was that the daily work report form, in spite of the provision for other entries, served in most cases as mainly a labor time card. The extent to which other details were provided depended on the individuals completing the forms within the same county. The success at implementation also varied from county to county. Reporting without the necessary detail on equipment and material use by location was sufficient for annual operating reports. The annual reports showed mainly gross summaries of labor, equipment, and material costs for major budget classifications. These summaries are usually provided from the various accounting ledgers and forms

kept by the counties. However, suggestions were made for modifying the current reporting system to enable maintenance activity costing; these suggestions are described in greater detail by Riverson (1).

UNIT MAINTENANCE COSTS ESTIMATED FROM ANNUAL REPORTS

In general, reasonable estimates can be made of the mix of labor, materials, equipment, and overhead from annual expenditure reports. A breakdown of major cost items for maintenance and repair calculated from annual reports is given in Table 1. Following procedures set out in the county accounting guide (3), the administrative and operational overhead and the garage and mechanical overhead were estimated from annual reports. Items included in overhead are as follows:

1. Administrative and operational overhead
 - a. Personal services and administrative staff
 - b. Office supplies
 - c. Other supplies and charges
 - d. Employee benefits
 - e. Communication and transportation
 - f. Insurance (excluding garage)
 - g. Professional services and other charges
 - h. Capital outlays (properties)
2. Garage and mechanical overhead
 - a. Salaries of garage mechanics and other staff
 - b. Garage and motor supplies
 - c. Insurance premiums (garage only)
 - d. Utilities
 - e. Repairs to garage and service building
 - f. Rents (garage only)

From the foregoing analysis, unit costs of maintenance and repair for all roads independent of surface type ranged from \$990/mi to \$2,310/mi. The variation in costs appears to be more a function of revenue received than mileage maintained. The county with the highest mileage had the least unit cost per mile of road maintained. Comparatively, it also had the second highest mileage of gravel roads. However, this appears to be in line with the findings in an-

other aspect of this research: counties in Indiana with the highest unpaved road mileage also spent less per mile of road (1). Figures 2 and 3 present the relative expenditure by cost category and the percentages of total maintenance and repair expenditure for all counties. The average annual costs for the 4 years, 1980-1983, were used in the plots. The specific cost items plotted are as follows:

1. Administrative and supervision overhead
2. Garage and mechanical overhead
3. Equipment maintenance and rental costs
4. Stone and gravel materials
5. Bituminous materials and mixes
6. Other materials (culverts or tiles, bridge metal, road signs, etc.)
7. Labor (truck drivers, equipment operators, etc.)
8. Contractual services

On the average, over the period 1980-1983, the three highest expenditure categories for all five counties were, in decreasing order, administrative and supervision overhead (item 1) followed by labor (item 7) and garage and mechanical overhead (item 2). Together they represent between 50 and 60 per-

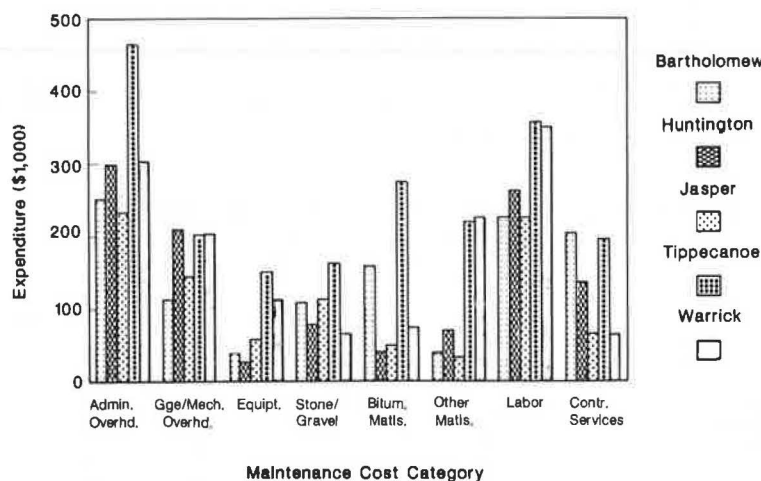


FIGURE 2 County highway maintenance expenditure (1980-1983 average by category).

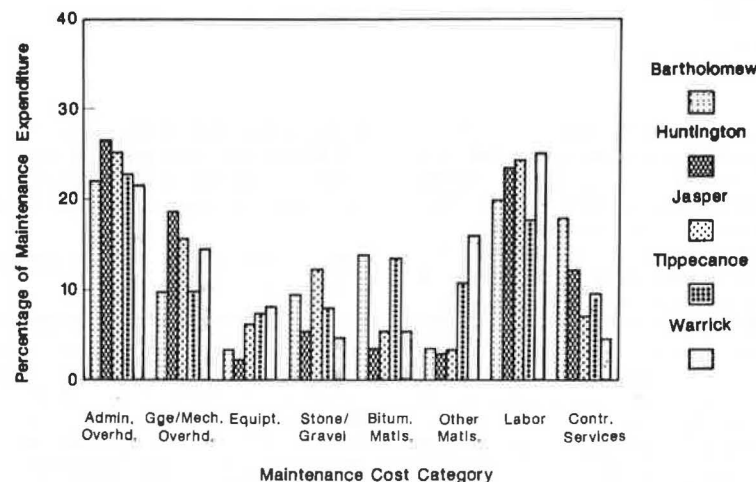


FIGURE 3 Percentage of county highway maintenance expenditure based on average 1980-1983 costs by category.

cent of the annual expenditure on maintenance and repair. Operationally, the control of these categories of expenditure will greatly determine the final costs of individual activities. Because they make up the larger portion of costs, they also affect the relative expenditure on the other items, mainly of materials used, which represents essentially the more variable component of maintenance costs. Average costs of all materials and supplies, if considered together, represents the highest individual cost category, about 26 percent for the five counties, ranging from 17 to 32 percent.

DETERMINING COST OF COUNTY ROAD MAINTENANCE

Data returns from four of the five counties for the selected unpaved road sections in the study provided some indication of relative costs of gravel road maintenance. Information on activity costs for all county roads, paved or unpaved, from Huntington County in Indiana and Mason County in Washington State, both of which implemented some maintenance management procedures, are also presented.

Gravel Road Maintenance Costs

The major activities reported on gravel roads are grading and spot regravelling. Other minor activities included brush cutting or vegetation control, side ditching, and snow plowing. Some of these costs were reported by Huntington and Jasper counties. In the former county, data were obtained from its management information system. Costs for activities common to both gravel and paved roads, such as snow plowing, were usually not separated by surface type.

Bartholomew County

Annual unit costs of gravel road maintenance comprising mainly grading and gravel addition for the

three study roads in Bartholomew County averaged \$259/mi and ranged from \$155/mi to \$480/mi. However, the unit grader cost of \$11.14/hr provided by the county represented labor and grader running costs for fuel and oil and not the total cost for operating the grader including depreciation and other repair costs. The maintenance cost details are presented in Table 2.

Huntington County

The 1983 data for Huntington County gave a unit gravel road grading cost of \$320/mi. With additional data provided by the county engineer, a 3-year (1981-1983) average unit cost for grading of \$365/mi was obtained. There was more blading of unpaved roads in 1981 and 1982; hence the 3-year average unit cost was higher than the unit cost in 1983. The aggregate patching cost for 1983, however, was \$93/mi. On the average in 1983, just for the two major activities of grading and aggregate patching, the unit maintenance cost was estimated at \$409/mi of aggregate road. In Table 3, additional cost calculations were made in consultation with the county engineer for those activities such as vegetation control, sanding and snow plowing, drainage structures, and sign repair that were undertaken irrespective of road type. The percentages of the total expenditure on each activity spent on gravel roads are also shown in Table 3. Including the additional items, annual unit gravel road maintenance cost was \$750/mi.

Jasper County

The annual unit costs in 1983 for the roads studied in Jasper County ranged from \$540/mi to \$6,567/mi, giving an average gravel road maintenance cost of about \$1,360/mi. The rather high estimated unit cost of \$6,567/mi was for a road that serves primarily a private large-scale mint farming project, which gen-

TABLE 2 Gravel Road Maintenance Costs on Study Roads: Bartholomew County

Road	Length (mi)	ADT	Grading Activities			Stone Added		Annual Total Cost (\$)	Annual Cost (\$/mi)
			Frequency ^a (no. x days)	Time (hr)	Cost (\$)	Tons	Cost (\$)		
1	6.5	38	6 x 55	29	323.06 ^b	169	1,049.49	1,372.55	211.
2	1.75	55	5 x 69	7	77.98	31	192.5	270.49	155.
3	3.25	52	6 x 58	10	111.40	156	968.76	1,080.16	480.

^aFrequency is shown as number of gradings recorded during the year and average number of days between gradings.

^bCounty unit grader costs at \$11.14/hr (labor + grader).

TABLE 3 Gravel Road Maintenance Costs on Study Roads: Huntington County

Activity	Expenditure (\$)					Total	Percent of Total
	Labor	Materials	Equipment	Contractual	Overhead		
Grading	18,680	5,765	42,432	-	15,605	82,482	42.3
Aggregate patching	2,391	14,798	5,151	-	1,890	24,230	12.4
Sanding and snow plowing ^a (15, 25)	3,459	10,010	6,434	-	2,872	22,835	11.7
Vegetation control ^a (33)	7,363	-	7,863	-	8,756	23,982	12.3
Drainage structures ^a (33)	4,851	10,481	7,645	-	4,080	27,057	13.9
Side ditching ^a (25)	420	66	922	-	17	1,425	0.1
Sign repair ^a (25)	5,384	2,633	1,422	-	3,703	13,142	6.7
Total						195,154	

^aThese activities were costed irrespective of surface type. Amounts shown in parentheses are proportions assigned to unpaved roads. Sanding, including addition of salt, was estimated as 15 percent compared with 25 percent for snow plowing on gravel roads.

TABLE 4 Gravel Road Maintenance Costs on Study Roads: Jasper County

Road	Length (mi)	ADT	Grading Activities			Stone Added		Brush Cutting (\$)	Side Ditching (\$)	Snow Plowing (\$)	Annual Total (\$)	Annual Cost (\$/mi)
			Frequency ^a (no. x days)	Time (hr)	Cost (\$)	Tons	Cost (\$)					
1	2.5	118	38 x 7.5	330	14,286	380.75	1,092.1	840	—	200	16,418.1	6,567
2	4.5	44	24 x 11.5	72	3,389.2	533.05	1,471.6	840	—	200	5,900.8	1,311
3	2	60	19 x 13.4	21.5	890.7	133.9	435.22	280	—	70	1,675.9	838
4	2.5	149	37 x 7.4	53.5	2,024.6	457.2	1,459.2	560	—	105	4,148.8	1,659
5	4.0	14	19 x 13.4	31.5	1,259.8	181.2	555.93	280	—	70	2,165.5	541
6	2.0	28	20 x 8.0	15	588.5	122.7	398.8	560	—	105	1,652.3	826
7	4.0	28	11 x 12.6	11	655.04	31.95	168.5	70	11.36	140	1,044.93	261
8	4.25	34	17 x 12.6	33.5	1,069.7	—	—	886.5	—	70	2,026.2	477

^aFrequency is shown as number of gradings recorded during the year and average number of days between gradings.

erates high average daily traffic volume mainly of farm vehicles. Maintenance expenditure on that road is borne largely by the private company engaged in the project. Average daily traffic on that road was 118. Excluding that road, average gravel road maintenance cost for 1983 was about \$800/mi. The details of costs for Jasper County are presented in Table 4.

Grading Costs for Tippecanoe County

Consistent monitoring of costs on the study sections was not undertaken by Tippecanoe County. However, information was collected from the county to calculate the cost of grading on the sections under study. The daily work report completed by grader operators and the information on equipment maintenance and fuel use were the main source of data. Grading costs are presented in Table 5. Grading costs in 1983 varied from \$203/mi to \$346/mi for gravel roads in the seven districts of the county. The costs, were, as expected, a function of the frequency of maintenance and the equipment used in the different districts. Equipment operating costs include annual depreciation costs based on a straight-line depreciation over 10 years of estimated life of the grading equipment.

Effect of Different Management Practices

Three management practices that were examined included grading policies, equipment used, and spot regrading. The implementation of such policies in practice may stem from budget limitations; however, detailed examination of their effects is seldom undertaken by the average county.

Grading Policies

Differences in cost between counties are a direct result of policy differences, which also affected

the grading frequencies applied. The lower unit costs for Bartholomew County are due to less frequent grading. Grading frequencies ranged from five times at an average interval of every 69 days (10 weeks, approximately) to six times at an average interval of every 55 days (less than 8 weeks). The range of average daily traffic (ADT) on the roads, however, does not provide a basis for determining the relationship to traffic volumes using the roads.

For Huntington County, the grading frequency ranged from every 14 days to every 54 days on the study sections. Figure 4 is a plot of grading frequency versus traffic volume. A logical pattern is seen in which roads with higher traffic volumes are graded more frequently than roads with lower traffic volumes. A simple linear regression of grading frequency versus traffic volume is shown in Equation 1 (r^2 is 90.4 percent for six data points with an adjusted r^2 of 88 percent):

$$Y = 72.989 - 0.656T \quad (1)$$

where Y is the number of days between gradings and T is the ADT. On the basis of Equation 1, if a maximum frequency of grading of every 7 days is adopted, traffic volume should be at least 100 vehicles per day. A minimum frequency of about once every 73 days is expected for roads carrying little or no traffic.

Figure 5 is a similar plot of grading frequency and ADT for Jasper County. A linear trend is again evident, showing a decrease in days between grading with increasing ADT. The range of grading frequency for this county is, however, smaller. Grading frequencies ranged from approximately every 7 days or weekly to about every 14 days (13.4 days). The linear regression equation obtained for the plot is as follows:

$$Y = 13.119 - 0.039T \quad (2)$$

where the variables are the same as those in Equation 1.

TABLE 5 Unit Costs of Grading Operations: Tippecanoe County

District	Gravel Road (mi)	Year of Purchase	Grader Cost (\$)	Annual Depreciation Cost (\$)	Total Repair Cost ^a (\$)	Number of Bladings a Year ^b	Grader Operating Cost (\$/mi)	Unit Grader Cost (\$/mi)	Annual Grading Cost (\$/mi)
1	56	1973	24,989	2,499	7,223	14	9.6	14.5	203
2	49	1974	28,263	2,826	7,731	18	9.3	14.2	256
3	58	1972	27,227	2,723	6,850	16	7.8	12.7	203
4	42	1973	24,989	2,499	10,053	19	11.9	16.8	319
5	43	1982	111,176	11,118	4,035	14	18.8	23.7	332
6	48	1980	80,615	8,062	8,534	18	14.3	19.2	346
7	47	1983	55,533	5,553	5,275	15	12.1	17.	255

^aTotal grader repair cost for all uses (assumed grading is 75 percent).

^bEquivalent number of complete bladings of all gravel roads in district. Actual blading may differ from road to road.

^cIncludes operator wages estimated at \$6.59/hr. Assumes 1-mi grading takes 0.75 hr of operator's time.

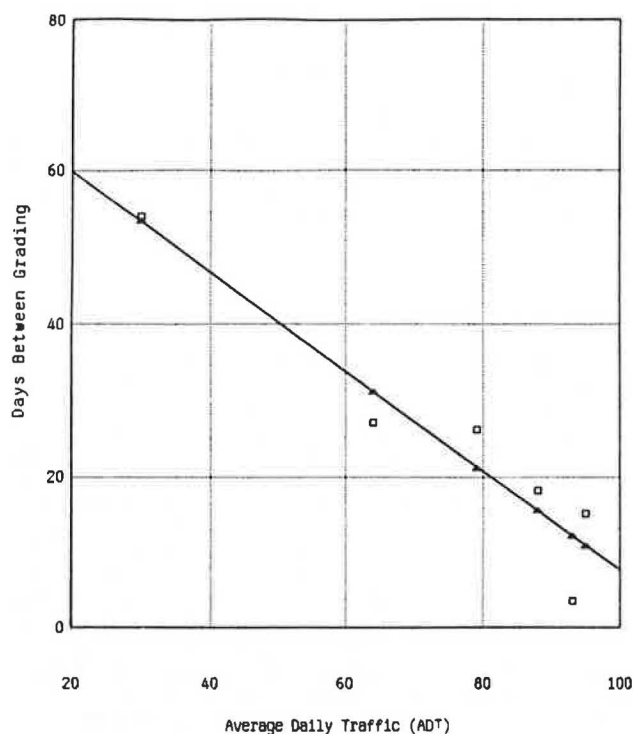


FIGURE 4 Frequency of grading versus traffic volume: Huntington County.

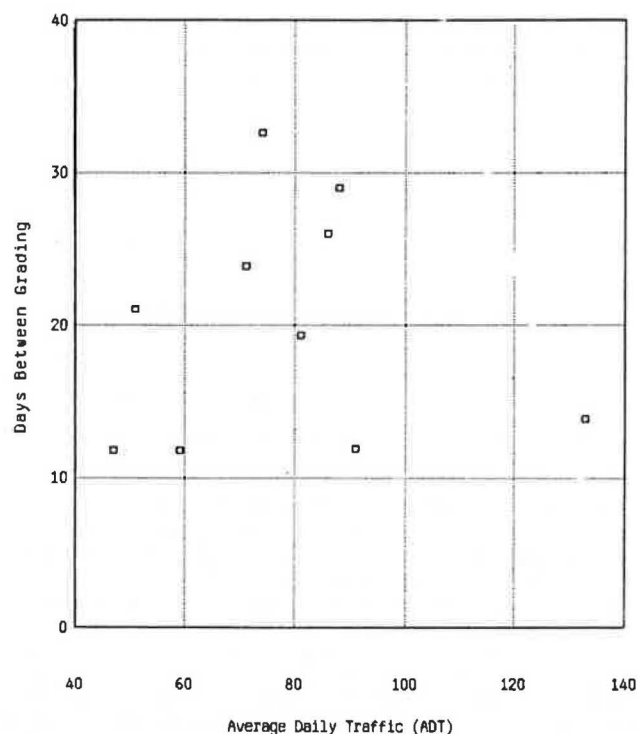


FIGURE 6 Frequency of grading versus traffic volume: Tippecanoe County.

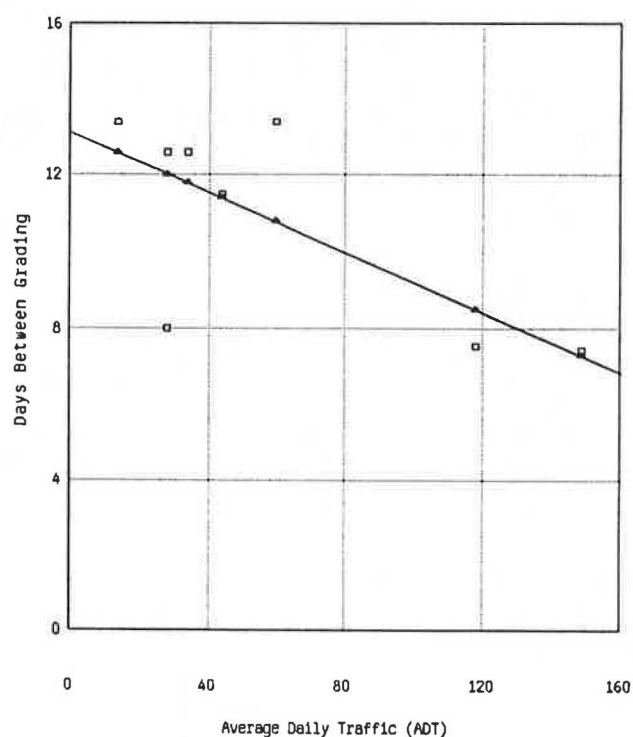


FIGURE 5 Frequency of grading versus traffic volume: Jasper County.

The r^2 is 0.49 and the adjusted r^2 is 0.407. One or two outliers are evident in the plot. From Equation 2, a road should carry a traffic volume of at least 157 vehicles a day for it to receive the maximum frequency of grading every 7 days. The higher frequencies in Jasper County appear to be the

result of generally poor subgrades in several parts of the county. High water tables and prevalence of "muck" soils create a need for frequent addition of gravel on some roads. The county highway department also grades the roads frequently in order to re-spread surface gravel.

Grading frequency plots for the gravel road sections in Tippecanoe County are presented in Figure 6. Regression analysis resulted in a very low r^2 -value of less than 1 percent for the relationship between grading frequency and ADT. The grading policy in the county is that every road be graded at least once a week. Grader operators in the seven grading districts attempt to meet the schedule. However, graders use personal judgment and knowledge of the area, and some differentiation is made in the frequency of maintaining individual unpaved roads in their care. No definite equation was determined for this plot because it appears that traffic volume had little influence on the frequency of grading in that county.

The various grading policies identified have had an influence on the local unit costs of unpaved road maintenance in each county. In general, traffic volume appears to be an important consideration in determining grading policies for counties. Applying appropriate differences in traffic volumes could ensure that money is spent where the need is greatest. Unpaved road distresses such as roughness, rut depth, potholes, and corrugations have been found to reduce with grading or blading (1,4-7). However, as a practice, few Indiana counties measure road distresses or monitor road condition routinely as part of maintenance management (8).

The equations for Huntington and Jasper counties provide first estimates of possible relationships. Because grading frequency in Jasper County is influenced greatly by the poor existing subgrade material, the curve for Huntington County was used to develop possible grading frequency for various ranges of ADT. Riverson (1) also found in a separate

TABLE 6 Suggested Traffic Volume Groups, Grading Frequency, and Other Considerations for Unpaved-Road Maintenance

Traffic Volume (vehicles/day)	Grading Frequency		Annual Cost (\$/mi)	Remarks
	Days Between	Times/Yr		
<50	40-60	7-5	150-108	Roads with steep grades; frequent corrugation may require minimum days
50-100	21-40	13-7	280-150	Same as above, including locations with frequent driveways
100-200	7-20	40-13	860-280	Same as above; some dust control may be required
>200	7 or less	>40	>860	Same as above; stabilization or paving

study of unpaved road roughness that Huntington County roads had on average the lowest roughness number values compared with those of the other counties. Although the values were also influenced by the material gradation characteristics in the various counties, the curve for Huntington County was used as a reasonable basis, initially, for establishing grading frequencies for Indiana counties. Table 6 shows the grading frequencies for various ADT ranges and the variation in grading as a result of terrain and other condition factors such as the rate of corrugation development.

Equipment Used

Another aspect of importance for maintenance management is the type of equipment frequently used for grading unpaved roads. Huntington County, for example, uses mainly trucks with mounted underbody blades for grading gravel roads. Routine blading usually required to maintain a gravel road in good condition is adequately provided by the trucks. In addition, gravel or stone required for spot regravelling can be transported to the road site on the truck, which enables material to be dumped and spread by the same unit of equipment. Annual unit cost of equipment maintenance using 1983 equipment cost data is about \$163 per year per mile of road maintained (261 mi of unpaved roads). Unit cost in 1983 of using the truck-mounted blade maintainer is \$13.42/hr compared with \$28.69/hr for using the motor grader.

Thus, the choice of equipment affects unit costs of grading and hence gravel road maintenance. This choice is usually the prerogative of the particular

county engineer or supervisor. Actual road performance such as roughness after blading or relative deterioration of roads that have been maintained by any piece of equipment is also an important consideration. Nevertheless, it is expected that continued use of any particular piece of equipment by any county would be an indication of the satisfactory road performance experienced previously in any particular county as well as better production rates.

Spot Regraveling

The amount of spot or total regravelling undertaken by any county could increase or lower the unit maintenance costs for gravel roads. A minimal amount of spot regravelling was undertaken by Huntington County, for example, in 1983. It was estimated by the county that to bring existing roads to standard, the average gravel road in the county requires a coating of 1,000 yd³ of gravel (1,500 tons), about 3 in. of gravel over an average width of 20 ft. The unit cost is estimated as \$4,255/mi of gravel road. Such a program can, however, only be sustained on a periodic basis. The 260 mi of unpaved roads in Huntington County will require an annual budget of over \$1.1 million for regravelling alone. As expected, because of the poor subgrade conditions prevailing in Jasper County, spot regravelling costs there, shown in Table 4, are much higher than those estimated for Huntington County.

Total regravelling should thus be considered like paving of the gravel surface, as a periodic maintenance activity. In the absence of adequate funds, spot regravelling could continue to be undertaken as a routine maintenance activity. With a properly developed unpaved surface crust, as was evident on several roads in Huntington County, a minimal amount of spot regravelling would usually be necessary. The unit cost of gravel road maintenance for Mason County is about \$1,000/mi for grading and regravelling. However, this results from undertaking regravelling every year on selected roads, which in turn has led to a reduction in grading. Gravel roads are graded at a frequency of six times per year (2).

Costing Other Activities

Huntington County in Indiana and Mason County in Washington State both provided information to determine the relative costs of other maintenance activities at the county level. On the basis of their different reporting procedures, the top 10 activities in 1983 on which each county spent the most money are indicated in Table 7. Although the actual amounts spent on different activities differ between

TABLE 7 Comparison of the Top 10 Expense Items in Huntington and Mason Counties

Huntington County, Indiana				Mason County, Washington			
Rank	Activity	Amount (\$000s)	Percent of Total	Activity	Amount (\$000s)	Percent of Total	
1	Ice control and snow removal	142.4	17.1	Seal coating	418.5	26.2	
2	Bituminous patching	133.8	16.0	Bituminous patching	256.7	16.0	
3	Administrative ^a	114.1	13.7	Ditching and minor maintenance	208.8	13.1	
4	Sealing	98.2	11.7	Traffic control and striping	156.	9.8	
5	Grading	82.5	9.8	Administrative	114.4	7.2	
6	Storm drainage structures	82.4	9.8	Vegetation control	104.4	6.5	
7	Vegetation control	69.2	8.2	Storm drainage structures	92.08	5.8	
8	Traffic sign repair	52.6	6.3	Aggregate patching	80.4	5.0	
9	Aggregate patching	24.2	2.9	Miscellaneous (including road cleaning)	66.4	4.2	
10	Shoulder maintenance	21.3	2.5	Grading	63.2	4.0	
Total		820.7	98.0		1,560.9	97.8	

^aIncludes office and field engineering, training, county survey, garage, grounds, parking area, and vehicle maintenance.

TABLE 8 Comparison of Maintenance Expenditure in Two Counties by Roadway and Environmentally Related Activities

Item	Percent of Total Expenditure	
	Huntington County	Mason County
Pavement and shoulder		
Paved	30.2	42.3
Unpaved	12.7	9.0
Winter maintenance	17.1	2.3
Roadside drainage	0.8	13.1
Vegetation control	8.2	6.5
Sewer and storm drainage	9.8	5.8
Traffic control and services	6.3	9.8
Total	84.3	88.8

the two counties, it is clear that ice control and snow removal constituted a major cost item in Huntington County and not in Mason County. The differences in weather effects on expenditure in the two counties are highlighted. Bituminous patching and seal coating were among the top four activities with the highest expenditure levels in both counties. Administrative costs, however, may not have been defined in the same way in the two counties. Huntington County, for example, accounts for administrative overhead in each activity.

An alternative breakdown of maintenance and repair expenditure is presented in Table 8. The cost items covered include pavement and shoulder maintenance for paved and unpaved roads. Winter maintenance, vegetation control, roadside drainage, sewer and storm drainage, structure maintenance, and traffic control accounted for over 80 percent of the 1983 expenditure on maintenance and repair in both counties. Pavement and shoulder maintenance activities on paved roads were the highest expenditure items in both counties compared with similar expenditure on unpaved roads.

EFFECT OF ROAD CONDITION

Ultimately, the management effects mentioned earlier would affect the condition of gravel roads. However, in most counties in Indiana, no formal procedures based on quantitative measurements are used to determine the condition of roads in the network (8). Road condition is determined subjectively from inspections conducted by grader operators, foremen, supervisors, or engineers. Considerable weight is also given to complaints by local residents in determining the need for maintenance or major repairs. However, unless care is taken to ensure some rationality in planning maintenance activities, unnecessarily high costs of maintenance may result. For unpaved roads, typical distresses include rutting, corrugation, potholes, dust generation, and loss of surface gravel or stone. The results of other parts of the research by HERPICC concerning unpaved road condition parameters such as roughness, rut depth, material characteristics, and so on are presented by Riverson (1). For management purposes, it is important to note that the condition of unpaved roads changes more rapidly than that of paved roads and it is influenced by factors like material characteristics, traffic volume, weather, and drainage, including surface crown or cross slope, as well as the frequency and type of maintenance. Hence, a "one-time" condition measurement may not be sufficient, and any periodic monitoring of unpaved road condition should be related to the strategies adopted for maintenance as well as the desired level of service and the budget limitations.

CONCLUSIONS

The attempt to isolate gravel road maintenance costs from county highway accounts has thrown some light on specific maintenance management needs of most counties in Indiana. Continuing the present system of accounting will only provide annual summaries of labor, equipment, and materials costs for various budget classifications. Proposals have been made for a maintenance management system to fulfill these needs (1). The system adopts current accounting procedures with some modifications to improve county maintenance management.

Maintenance management of unpaved roads, even if based simply on annual accounts, will be enhanced if adequate consideration is given to traffic volume, road condition, and performance in its planning and implementation. Proper allocation and control of county maintenance funds for specific activities will ensure the best use of funds for the revenue received. Each county will need to take its peculiarities into consideration. However, proper reporting by activity will greatly aid cost accounting and improve maintenance management, which depends on good estimates of maintenance costs of roads of all surface types. As maintenance activity costing is improved in the counties, adequate life-cycle costing procedures can be implemented as the ability to monitor road performance is also enhanced. For some counties, however, the procedure may have to be implemented on a step-by-step basis.

REFERENCES

1. J.D.N. Riverson. Unpaved Road Maintenance Management in Local Highway Systems. Ph.D. dissertation. School of Civil Engineering, Purdue University, West Lafayette, Ind., Dec. 1985.
2. M.L. Young. Maintenance Management Program. Mason County Department of Public Works, Washington, March 1982.
3. J.E. Hittle. Guide Manual: Records and Reports for Indiana County Highway Departments. Highway Extension and Research Project for Indiana Counties, Purdue University, West Lafayette, Ind., June 1981.
4. R.F. Carmichael III, W.R. Hudson, and F.C. Sologuren. Evaluation of Highway Roughness in Bolivia. In Transportation Research Record 702, TRB, National Research Council, Washington, D.C., 1979, pp. 238-248.
5. T.E. Jones. Maintenance Strategies for Unpaved Roads in Developing Countries with Particular Reference to Grading and Dragging. MSc. thesis. University of Birmingham, United Kingdom, May 1983.
6. P.W.D.H. Roberts. Performance of Unsealed Roads in Ghana. TRRL Laboratory Report 1093. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1983.
7. A.T. Visser. An Evaluation of Unpaved Road Performance and Maintenance. Ph.D. dissertation. University of Texas, Austin, May 1981.
8. J.D.N. Riverson, K.C. Sinha, and C.F. Scholer. County Maintenance of Unpaved Roads. In Transportation Research Record 985, TRB, National Research Council, Washington, D.C., 1984, pp. 34-40.