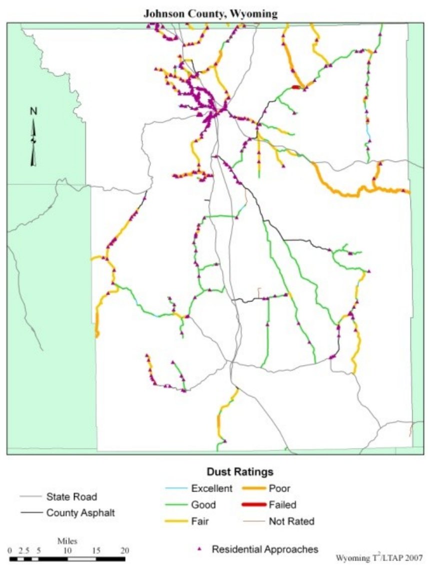
Gravel Roads Management



Wyoming Technology Transfer Center

WY T2 LTAP

Local Technical Assistance Program

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Abstract

This report establishes procedures for managing unsealed dirt and gravel roads, with a primary focus on smaller agencies, such as Wyoming counties, that must manage their roads with very limited resources. To accomplish this, several methodologies and recommendations have been prepared.

A group of experts were consulted, fifty-six of whom participated in one way or another, and their inputs and comments were incorporated into the final recommendations. This report strives, first, to guide and assist smaller agencies with the management of their unsealed roads by implementing asset and pavement management principles, and, second, to encourage and facilitate the development of gravel roads management software.

Several conclusions were drawn from this project:

- The overall effort required to implement a gravel roads management system (GRMS) for local agencies must be minimal.
  - Data collection efforts must be limited.
  - Analysis must be simple and transparent.
- There are four basic steps involved in implementing a GRMS:
  - Assessment
  - Inventory
  - Cost and maintenance history
  - Condition monitoring
- Cyclic maintenance programs may be developed once a network is inventoried and its maintenance history is available.
- Useful performance data are difficult to collect mainly because surface conditions change quickly due to weather, traffic and maintenance.

This report outlines procedures to be followed when creating gravel roads management software and it provides comprehensive advice to those attempting to implement a GRMS.

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Executive Summary

This project was initiated to address the lack of an unsealed dirt and gravel roads management protocol for small local governmental agencies, such as the rural counties of Wyoming. To accomplish this, Wyoming's local technical assistance program, the Wyoming Technology Transfer Center (T^2/LTAP), met with and solicited input from numerous experts in the fields of gravel roads and roadway management, fifty-six of whom participated in this project in one way or another. This report is the culmination of several prior drafts, face-to-face meetings, dozens of emails, a web conference, and numerous conversations.

A review of the published literature revealed a number of efforts to manage unsealed roads in various circumstances. Further investigation revealed other management efforts that were not published in the academic literature. In spite of this, no gravel roads management methods were discovered that are well suited to small, local agencies. Existing methods use considerably more data inputs than are available to or easily obtainable by most counties of the rural west.

Two basic outputs from a gravel roads management system (GRMS) have been identified:

- Provide elected officials with useful information that lets them make good financial decisions;
- Provide road managers with information that helps them maximize the efficiency of unsealed roads' maintenance and rehabilitation.

Two hurdles to addressing these needs have been identified:

- Lack of a suitable methodology for managing unsealed roads;
- Lack of resources needed to collect adequate data.

This report presents ways to deliver the two outputs described above in spite of the potential pitfalls.

Implementation processes are identified and described. These four basic elements should be established:

1) Assessment
2) Inventory
3) Cost and Maintenance Tracking
4) Condition Monitoring

At each of these steps, considerable benefits are realized, though with each step more effort is needed. The following discussions highlight both the process of implementing each step and some of the potential benefits that may be realized.

Assessment

Before beginning the process of implementing or upgrading a GRMS, an agency should assess its current situation, in an effort to answer the following questions:

- How are we collecting, analyzing, and using information about our unsealed roads network?
- What resources do we have to improve the situation?
- What should we do next to improve our unsealed roads management?

The agency should also assess its available resources and assets. Five aspects that should be assessed are:

- Support
- Financial Resources
- Hardware, Software and GPS
- Information
- Personnel

Evaluating their current situation will help agencies identify the next steps in developing a GRMS that will yield the greatest benefit with the least effort.

Inventory

The initial step in developing a GRMS consists of inventorying an agency's unsealed road network. Without an inventory, no other information can be assigned to the proper road section, an essential element of any attempt to manage a road network. Data in an inventory are those properties of each road section that are relatively static.

Any roadway management system must have at least four fundamental pieces of information. They are:

- ✓ Unique Section Identification
- ✓ Location
- ✓ Surface Type
- ✓ Length

Even if no other information is available, this simple inventory will allow an agency to begin implementing a management system. There are a number of other pieces of information that many agencies will find desirable, some of which are listed below:

- ✓ Road Name and Number
- ✓ Top Width
- ✓ Inventory Date
- ✓ Inventory Data Collector
- ✓ Owner
- ✓ Maintenance Intervention Level

- ✓ Functional Class
- ✓ Traffic Volumes
- ✓ Traffic Speeds
- ✓ Utilities
- ✓ Legal Documentation
- ✓ Survey Information
- ✓ Subgrade Type(s)
- ✓ Roadway Prism Height
- ✓ Road Use
- ✓ Land Use
- ✓ Terrain
- ✓ Other Roadway Features

Agencies should determine which of these data are worth collecting based on their situation and needs.

When generating an inventory of an unsealed road network another issue is its division into discrete sections. Ideally, a network would be divided into sections that typically receive the same maintenance treatments. However, many existing systems are subdivided only by road name or number. Guidance is provided as to how to decide where sections should begin and end, considering the trade-off between the additional time it takes to monitor shorter sections and the loss of refinement inherent with longer sections.

Maintenance and Cost Tracking

Once the network inventory is in place, additional information may be collected pertaining to each discrete section. Tracking maintenance and its costs is a fundamental process when trying to manage an unsealed road network. Existing systems such as time cards, work orders, and other field reports may be modified to collect this information.

Many agencies track their costs using systems set up to fulfill accounting needs. Unfortunately, the needs of accountants are not the same as those of road managers. To correct this problem, eight types of work performed on unsealed roads have been identified:

- ➢ Blading
- ➢ Reshaping
- ➢ Drainage Maintenance
- ➢ Regraveling
- ➢ Dust Control
- ➢ Stabilization
- ➢ Isolated Repairs
- ➢ Major Work

Of these, all but the last two should be scheduled as part of a GRMS. 'Isolated Repairs' should be performed on an as-needed basis, while 'Major Work' should be performed as funds become available. Of course, many other activities are performed on unsealed roads, such as sign and culvert maintenance. This project only addressed those management issues that are unique to unsealed roads.

Once historical maintenance information is assembled, it can be used to program and prioritize maintenance tasks using cyclical maintenance schedules.

Cyclical Maintenance Scheduling

One way or another, maintenance activities are always scheduled, even if the schedule is based only on operators' habits. When historical data are assembled and certain assumptions are made about the type and level of maintenance each section should receive, prioritized lists of maintenance tasks can be generated.

Several decisions should be made for each road section in order to implement a cyclic maintenance system. First, the road network must be split into reasonable maintenance management sections, as described in the Inventory section above. Next, the minimum acceptable surface condition should be established for each road section, based on various factors such as traffic volume, road use, and political considerations. This condition should be selected as the 'maintenance intervention level,' the condition in which the road's surface should be improved. An appropriate maintenance strategy should then be assigned to each section, generally based on the agency's typical, current practices. With this information, prioritized lists of maintenance tasks can be generated.

If an optional surface condition evaluation is performed, the timing of maintenance can be adjusted, with better performing roads receiving less maintenance while the poor performers receive maintenance more often.

Condition Monitoring

To most effectively manage any asset, its current condition should be known; unsealed roads are no exception. Unfortunately the surface characteristics of unsealed roads change very quickly, making the collection of useful condition data difficult. However, in order to present decision-makers with an accurate picture of how a road network is performing, one must have some way of measuring that performance.

Issues involved in condition data collection include the timing, the method, and the personnel used to collect the data. All three are potentially problematic.

There are many possible methods for evaluating an unsealed road which are summarized as follows:

- Visual distress surveys
- Measurement-based distress surveys
- Automated roughness measurement

- Gravel thickness measurement
- Photographs

Each method above has its strengths and weaknesses. All are subject to issues of both subjectivity and timing. Both weather and maintenance substantially impact unsealed roads' surface conditions, bringing into question the value of any scheduled condition monitoring. Evaluating road conditions when maintenance is performed is convenient, but data consistency may be an issue. Even measuring gravel thickness may be subject to some interpretation, particularly when subgrade material infiltrates the surfacing gravel from below. In spite of these difficulties and more, performance monitoring is a vital component of any sophisticated management system so some form of condition evaluation should take place.

Triggered Maintenance Scheduling

One great benefit to having reasonable condition data is that maintenance can be performed as needed, rather than on a regular schedule. This will save money by not performing tasks such as regraveling more often than they are really needed.

Automated roughness measurement and gravel thickness measurement seem to have the most promise for instituting triggered maintenance plans. Automated systems may be used to program routine maintenance, while thickness measurement may be used to program regraveling.

Network Level Outputs

Condition, maintenance and cost data can all be used to provide elected officials and other decision-makers with a better understanding of their road agencies' funding needs. If they can better understand the consequences of, for example, cuts in funding, they will be less likely to cut the wrong programs.

Network-wide data may also be useful for road network managers as they decide how to allocate their resources, purchase equipment, supplies and materials, and direct their crews.

Summary

This report strives to provide local government agencies with the guidance and advice needed to implement and sustain a GRMS. There are two basic goals of such a system. First, it should help agencies improve the effectiveness and efficiency of their unsealed dirt and gravel roads maintenance and rehabilitation operations. Second, it should provide decision-makers with better information about their gravel road network. Ultimately such a system should allow these road networks to be managed using economic and engineering principles and practices to provide adequate service at the least possible cost.

Acknowledgments

We would like to thank the Mountain-Plains Consortium and the Wyoming Department of Transportation, particularly Martin Kidner, for supporting this effort. To all those who participated in this project, both those listed and those who participated in less formal ways, you have our thanks and apology if we omitted your name. We extend particular thanks to Ken Skorseth and Gary Berreth without whose encouragement and support this project would not have happened.

Disclaimer

The opinions expressed in this report are the authors' only and do not constitute any endorsement or policy of the Mountain-Plains Consortium, the Wyoming Department of Transportation, or the University of Wyoming.

CHAPTER 1 INTRODUCTION

1.1 Background

This project was initiated in response to discussions at the January 2009 meeting of the Transportation Research Board which identified the lack of an unsealed roads management methodology suitable for small local agencies. Subsequent discussions verified this lack and provided some of the parameters within which such a methodology would need to operate. Fundamental among these parameters is that it must be *simple* and *sustainable*. Agencies which are the target of this effort have very limited resources, and it does not make economic sense to spend a large amount of time or money managing low volume roads.

1.2 Problem Statement

Though there are a number of procedures for managing unsealed roads, none are specifically developed for counties and townships in the rural West and Great Plains. For many agencies, particularly Wyoming counties, the vast majority of their roads are unsealed, so if they are to successfully manage their road networks, they need a gravel road management methodology.

(It is the hope of those supporting this effort that it will be applicable to a variety of entities managing unsealed roads. We will refer to the ultimate users of this methodology as 'agencies' for the sake of simplicity. This effort should generate results that are applicable not only to counties of the rural West, the primary targets of this effort, but also to a variety of political and other entities, such as cities, towns, townships, local agencies in other countries, federal and state governments, and private entities such as oil and gas exploration companies and homeowners' associations.)

The lack of an accepted methodology for managing unsealed roads makes it unfeasible for many counties to initiate or improve a gravel roads management system (GRMS). If such a methodology were available, software developers could justify spending the time to write programs that would execute a gravel roads management program. It is the goal of this effort to recommend methodologies appropriate for counties' and other agencies' gravel roads management.

1.3 Objectives

Preliminary discussions during the inception of this project identified several criteria that a gravel roads management methodology for small agencies should meet. These may be summarized as followed:

- ✓ Minimal additional effort by existing agency forces
- ✓ Minimal additional cost incurred by the agency
- ✓ Simple method easily understood and applied by local elected officials
- ✓ Results applicable by local road and street departments
- ✓ Save the agency money
- ✓ Reduce user costs on the agency's unsealed roads

The success of this effort will be measured by whether it enables counties to *implement* and *sustain* a GRMS. If any of the checkpoints above are not met, it is unlikely that a GRMS will become part of the standard operations of county road and bridge departments, the ultimate goal of this project.

1.4 Report Organization

This report documents and describes the efforts needed to develop a GRMS. Finally two additional documents provide the essential details needed for both road network managers, the 'Implementation Guide,' and for programmers, the 'Programming Guide.'

Chapter 2 Literature Review and State-of-the-Practice, describes some of the previous efforts to develop management systems for unsealed dirt and gravel roads. Chapter 3 Methodology describes the procedures used to generate the procedures described in this report. Chapter 4 Implementation addresses the issues that should be addressed when initiating and sustaining a GRMS. Many of the discussions and processes described will be relevant for the implementation of any type of management system by small local agencies. Chapter 5 Analytical Methods describes procedures that may be used to systematically generate a prioritized list of maintenance tasks that should be performed on an agency's unsealed roads. It also describes the process of generating reports that describe an agency's unsealed road network, primarily for the benefit of elected officials and other decision makers Chapter 6 Summary and Conclusions briefly describes the report and reaches conclusions that represent as concisely and correctly as possible the beliefs of those who participated in this effort. Chapter 7 Recommendations proposes and describes the process of implementing of a pilot project using the methods described in this report.

CHAPTER 2 LITERATURE REVIEW AND STATE-OF-THE-PRACTICE

There has been a wide variety of work done attempting to better manage unsealed roads. One aspect that becomes increasingly apparent as one reviews these efforts is that every system is tailored to the specific issues and situations faced by their organizations. No two organizations have the same problems or the same resources, so each must come up with a different solution. The following discussions investigate some of the work that may help provide guidance in this effort, the development of a gravel roads management methodology suitable for small local governments in the United States, particularly the counties, cities, towns, and townships of the rural Intermountain West and Great Plains.

2.1 Terminology

Many terms describe the types of roads that are the topic of this paper. In the most general terms, this paper reports on means of planning and assessing performance and maintenance of roads which are maintained with a motor grader. Once roads have a surface applied to them that is too rigid to be maintained with a motor grader, they fall into a higher class of roads, the maintenance of which is outside the scope of this paper. The definitions and discussions below are an attempt to synthesize terminology describing these roads throughout the English-speaking world.

Terms used to describe these roads refer to the roads' drainage properties and to the type of materials that comprise the roads' surface and supporting layers. While the definitions below are suggested for common use in the professional community, most should be defined when used due to the ambiguity arising from slightly different definitions.

2.1.1 Gravel Roads Management Systems (GRMS)

When referring to management systems, historically such systems have been referred to as 'gravel roads management systems' or 'gravel roads maintenance systems.' In keeping with this precedent, the term 'gravel roads management or maintenance system' (GRMS) is used to refer to systems designed to plan and program unsealed roads maintenance and improvement processes.

2.1.2 Drainage Terms

When a road is more than simply tracks in the surrounding countryside made by four (or more) wheeled vehicles one should describe it as 'formed' or 'improved.' To some, an 'improved' road merely has ditches and other drainage features, while to others, an 'improved' road also has imported surfacing aggregate.

2.1.3 Surfacing-Type Terms

2.1.3.1 Dirt Roads

Use of this term by roads professionals is discouraged, though it is popular with the general public. Though sometimes synonymous with the term 'earth roads' below, the term 'dirt roads' should not be used due to its multiple meanings.

2.1.3.2 Earth or Native Soil Roads

This term should be used to describe roads surfaced with soil from the immediate vicinity. To some, even a road that has material pulled up from the borrow pit to form the road is no longer an 'earth' road. When using these terms, care should be taken to indicate whether or not the native soil has been moved from its original location to the road.

2.1.3.3 Gravel Roads

This term is problematic due to its widespread use with multiple meanings. To some, a 'gravel' road implies crushed alluvial rock while to others it simply implies that surfacing material has been imported. Roads made with a crushed shale surface may be called a 'shale road' or they may be simply known as a 'gravel road;' the situation is similar for other roads surfaced with a particular type of crushed or processed aggregate. Given these ambiguities, this term should be used with caution, and when it is used, it should be concisely defined.

2.1.3.4 Chemically Treated Roads

A chemically treated unsealed road has had dust suppressant (other than water) or soil stabilizer added to it recently enough to bind together or significantly alter the road's surfacing material from its original, untreated state.

2.1.3.5 Surface Treated Roads

Roads comprised of aggregate topped with a sealant, typically asphalt, cutback asphalt or emulsified asphalt, are referred to as 'surface treated roads.' They may also be referred to as 'bituminous surface treated' or 'BST' roads. When a layer of aggregate chips is placed on top of the asphalt, the road may be referred to as a 'blotter road' or a 'chip seal road.' When no chips are added, the road may be referred to as an 'inverted penetration' ('invert pen') road.

Other terms referring to various surface treatments include 'armoring,' 'armouring,' 'metalling' and 'running course.' These terms are not in widespread use and their use is discouraged. If they are used, they should be concisely defined.

2.1.3.6 Paved Roads

The use of the terms 'paved' and 'unpaved' is discouraged because they have such widely disparate meanings to different people and in different parts of the world. To some, any road with constructed layer(s) to carry traffic is considered a pavement, while in other places any road with a semi-permanent surface is 'paved,' while to still others, the term 'pavement' implies that the road is constructed with hydraulic or asphaltic concrete and is placed with a screed.

2.1.3.7 Sealed Roads

When a road's surface is semi-permanent and water-resistant, the road is said to be 'sealed.' 'Unsealed' roads are those with a granular surface that are or may be maintained on a routine basis with a motor grader, and are the road types whose repair and maintenance is the topic of this paper.

2.1.4 Definitions

Use of the following terms is discouraged, therefore they are not defined except as above, and if they are used, they should always be explicitly defined.

- Dirt roads
- Paved or Unpaved roads
- Armored or Unarmored roads
- Metaled roads or metalling
- Running course

The following definitions are suggested for widespread use within the professional community:

2.1.4.1 Formed Road

Any road with ditches and other drainage features.

2.1.4.2 Unformed Road

Tracks laying on the natural ground surface without drainage features.

2.1.4.3 Improved Road

Any road with ditches and other drainage features and an imported aggregate surface.

2.1.4.4 Unimproved Road

Any road that does not have drainage features and an imported aggregate surface.

2.1.4.5 Earth (or Native Soil) Road

Any road surfaced with material that has not been transported.

2.1.4.6 Gravel Road

Any road surfaced with processed, generally crushed and screened, imported granular aggregate.

2.1.4.7 Chemically Treated Road

Any road with dust suppressant (other than water) or soil stabilizer applied recently enough to bind the surfacing materials or to significantly alter the surfacing material's properties.

2.1.4.8 Surface Treated Road

Any road with a bituminous or other sealant applied on top of a granular aggregate base, forming a semi-permanent, water-resistant top surface which may be topped with additional aggregate.

2.1.4.9 Unsealed Road

Any road that does not have a semi-permanent, water-resistant surface.

2.1.4.10 Sealed Road

Any road with a semi-permanent, water-resistant surface.

2.2 Global Efforts

Depending on who does the counting, somewhere around half to three quarters of the world's roads and streets are surfaced with gravel or dirt. The maintenance of these roads consumes a substantial amount of resources; if they can be managed more efficiently, the potential financial savings and reductions in greenhouse gas emissions are vast. To this end, a number of efforts have been made to manage these roads more efficiently. In each case, the management system is tailored to a particular situation. The following discussions provide some examples from around the world that illustrate how various gravel roads management systems (GRMS) are developed and used.

2.2.1 World Bank Efforts

2.2.1.1 Software

The World Bank has developed a number of software programs *(World Bank 2009)* including the Roads Economic Decisions Model (RED), the Deterioration of Unpaved Roads Model (DETOUR), and Highway Development & Management (HDM-4).

The DETOUR model uses a fairly lengthy list of inputs to predict the deterioration of unsealed roads, including:

- Environment, Geometry, and Traffic
  - Road width
  - Rise and fall
  - Light and heavy vehicle traffic
  - Rainfall
  - Shoulder width
  - Horizontal curvature
  - Traffic growth
- Gravel and Earth Layer Characteristics
  - Thickness
  - Age
  - Mechanical compaction, Y/N
  - International Roughness Index (IRI) – Current, Minimum, Maximum
  - Gradation
  - Plasticity
- Maintenance Policy
  - Grading interval
  - Spot regraveling
  - Regravel thickness
- Material Loss Calibration
  - Gravel Loss Factor
  - Traffic-induced Loss Factor

While this list is quite extensive and beyond the means of most counties to collect, it may be of value if one makes sweeping assumptions about the value of a number of its inputs.

2.2.1.2 Optimal Maintenance Levels in Latin America

Using the World Bank software programs *(World Bank 2009)*, various predictions have been made about the optimum condition in which to maintain roads at various traffic levels using costs and other conditions in Latin America *(Archondo-Callao 2007)*. Though the conditions in Latin America are different from those in the developed world, one can draw some general lessons from some of their projections, especially if one assumes that the differences in maintenance costs are directly proportional to differences in user costs – probably not too bad an assumption.

Table 1 Example Annual Vehicle Fleet Road User Costs

Road Condition	Road User Costs, $/vehicle-mile
Very Good	$0.528
Good	$0.613
Fair	$0.782
Poor	$0.906
Very Poor	$1.028

The Latin American analyses outline the cost assessment method and provide some sample analyses. Though these may not be directly relevant to conditions elsewhere, they provide both a methodology and rough estimates of the ideal way to manage unsealed roads. For example, Table 1 shows annual vehicle costs and Table 2 shows annual maintenance costs. Table 3 shows the cost of upgrading from a lower quality level road to a higher level road.

Table 2 Example Annual Maintenance Costs Needed to Maintain a Road Quality Level

Road Condition	Annual Maintenance Costs, $/mile-
Very Good	$6,437
Good	$4,828
Fair	$2,414
Poor	$1,609
Very Poor	$805

The software and methods developed by the World Bank may provide means for analyzing and applying cost data, both for user costs and maintenance costs, to optimize the maintenance and upgrading of unsealed roads. The software is flexible enough that it may analyze data used to generate inputs to a county's GRMS, but it requires too much data input to be a useful tool for performing routine analyses.

Another table *(Archondo-Callao 2007)* indicates that unsealed roads with 20 or fewer vehicles per day should be maintained in Very Poor condition; roads with 30 to 90 vehicles per day should be maintained in Fair condition, while roads with 100 vehicles per day should be maintained in Good condition. Though these are based on sample data only, they illustrate the general principle that unsealed roads with very low traffic volumes should not have a lot of money spent on them; it doesn't make economic sense.

Table 3 Example Investment Costs ($/mile) Needed to Improve Road Quality Level *(Archondo-Callao 2007)*

	To Road Quality Level			
From Road Quality Level	**Poor**	**Fair**	**Good**	**Very Good**
Very Poor	$8,047	$16,093	$64,374	$144,841
Poor		$8,047	$32,187	$80,467
Fair			$16,093	$48,280
Good				$16,093

2.2.2 South African Efforts

2.2.2.1 Routine Maintenance Schedules

A procedure for scheduling routine maintenance was developed in Western Cape Province (WCP) in South Africa. A pilot study was conducted and algorithms were developed to schedule routine maintenance of unsealed roads *(Burger et al 2007)*.

As part of this effort, they defined five types of blading:

- "Dry blade – blading without a water bowser on site,
- Wet blade – blading with a water bowser on site,
- Rain blade – blading after good rains have fallen,
- Cushioning blade – spreading a thin layer of fine material over the road surface to protect the wearing course, and
- Reshaping – breaking down of the road surface and shaping at the required cross fall to improve drainage on the road (water bowser and, usually, pneumatic tire roller on site)." *(Burger et al 2007)*.

Two algorithms are compared, one of which minimizes the network roughness, while the other minimizes the 'total transportation cost' (TTC) which considers both agency and road user costs. To grossly over-simplify their methods, these two algorithms prioritize the sequence in which road sections need to be bladed based either on their roughness or on the combined agency and user costs. They then try to come up with a geographical route that can be used to efficiently perform routine maintenance on all the unsealed roads within the ward.

They conclude that the network cost, TTC, algorithm is the most efficient, but that either algorithm represents an improvement over the usual way of doing business which consisted of simply maintaining the entire network, then going back to the start of the route and maintaining the entire network again, without regard for surface conditions or user costs.

It is interesting to note that the scale of the unsealed roads maintenance districts in WCP is quite similar to that in Wyoming. WCPs 'District Municipalities' (DM) are comparable in size to Wyoming counties. The five DMs have from 1,905 to 777 miles (3,066 to 1,250 km) of dirt and gravel roads each; each DM is split up into ‘wards’ of very roughly 125 miles (200 km) each that are usually served by a single operator and motor grader, which is similar to how Wyoming’s county road and bridge departments allocate areas to their motor grader operators. Thus, from the point of view of jurisdictional size, equipment, and manpower, gravel roads in WCP are maintained about the same as they are in Wyoming. The fundamental difference seems to be that there is a central authority in WCP, the Provincial Government, which can implement consistent methods throughout, while each Wyoming County is an independent entity, with no standard maintenance prioritization procedures or practices.

2.2.2.2 Visual Assessments and Periodic Maintenance Schedules

For over ten years, Western Cape Province in South Africa has been using visual assessments of road conditions as a primary data source for their gravel roads management system. The assessments are used to assist with programming periodic maintenance projects, which are defined as follows:

- Regraveling (or graveling in the case of earth roads)
- Special maintenance which includes
    - Spot gravel
    - Reshaping
    - Reworking
    - Drainage improvement
- Surfacing to appropriate standards (weatherproofing)

Normally network assessments are carried out by a team of two who examine between 100 km and 200 km (62 and 124 miles) per day *(van der Gryp and van Zyl 2007)*.

An extensive and comprehensive training manual was assembled which defines and describes the various features rated during the visual assessment *(Jones and Paige-Green 2000)*.

Assessors are trained and calibrated on an annual basis. Duplicate assessments are performed on 10% of the road network per year. All assessors evaluate the same road section at annual training. The following information is recorded during the visual assessments *(van der Gryp and van Zyl 2007)*:

- ✓ Defects: Each rated for 5 categories of degree and extent
    - Potholes
    - Corrugations
    - Rutting
    - Loose material
    - Stoniness: fixed
    - Stoniness: loose
    - Erosion: longitudinal
    - Erosion: transverse
- ✓ Material Properties
    - Material type: 10 typical materials

  - Grading classification: Coarse, medium, fine
  - Estimated PI: <6, 6-15, >15
  - Layer thickness: Value (mm) provision for 7 measurements on 5-km [3 mile] segment
  - Layer thickness category: 0-25, 25-50, 50-100, >100 mm [0"-1", 1"-2", 2"-4", >4"]
  - Exposed subgrade: None, isolated, general
  - Maximum size: <13, 13-25, 25-50, >50 mm [<½", ½"-1", 1"-2", >2"]
- ✓ Functional condition
  - Riding quality: 5 categories from very good to very poor
  - Skid resistance: Good, fair, poor
  - Dust: None, minor, severe
  - Drainage: on the road: Good, fair, poor
  - Drainage: side of the road: Good, fair, poor
  - General condition: 5 categories from very good to very poor
- ✓ Segment information
  - Current width: <8 m, 8-10 m, >10 m [<26', 26'-33', >33']
  - Moisture condition at time of assessment: Wet, moist, or dry
  - Traffic: Light, medium, heavy
  - Terrain: Flat, rolling, mountainous

They describe the process whereby assessors are monitored and calibrated – a quality assurance program for visual assessments. The also describe quality control data that shows "…a remarkable compatibility between the assessors and the norm." However, they did identify several data fields that were problematic, specifically:

- Layer thickness: Estimated thickness and category
- Maximum size of material
- Loose stoniness
- Corrugations

In spite of this they concluded that "…concerns regarding the reliability of data are invalid. The high degree of agreement in comparisons of network assessments could be attributed to a standardized documented methodology, training, and effective quality control procedure, and increased experience of assessors." *(van der Gryp and van Zyl 2007)*

2.3 LTAP Centers' Efforts

Several local technical assistance program (LTAP) Centers, notably Utah, Michigan, and New Hampshire, have developed roadway management systems, though none have sophisticated methods for managing unsealed roads. Indeed, it is largely this lack that led the Wyoming T^2/LTAP Center to develop its own analytical procedures as part of its pilot asset management program.

2.3.1 Wyoming LTAP Center's Efforts

The Wyoming T^2/LTAP Center conducted a pilot asset management program for Carbon, Johnson, and Sheridan Counties from 2004 through 2006. More details on this project are available on the Wyoming T^2/LTAP's website *(Wyoming Technology Transfer Center 2007)* and in a summary of this effort *(Huntington and Ksaibati 2005)*. A fundamental lesson learned during this pilot project was that for a management system to be adopted, it must not consume too much of the agency's employees' time, particularly during data collection. Though much was learned by having dedicated data collectors spending much of the summer evaluating the counties' roads, culverts, cattleguards, drainage, and signs, the level of data collection on this pilot project was not sustainable.

One objective of this pilot program was to assess the impacts of oil and gas drilling activities on the three counties' roads. Though these counties have too few sealed roads to draw any conclusions about the impact of drilling traffic on them, considerable evidence was compiled that strongly indicated that the counties' unsealed roads were suffering considerable damage, beyond that which was corrected by the efforts of the drilling companies *(Huntington and Ksaibati 2009a)*. Documenting the impacts of commercial activities is but one of the possible benefits of a roadway management system.

Another function of a gravel roads management system (GRMS) is to evaluate an agency's unsealed road network's financial needs for both maintenance and rehabilitation. A method was developed to predict the cost of taking care of Johnson and Sheridan Counties' unsealed road networks *(Huntington and Ksaibati 2009b)*. The concept is very simple: Determine how much it costs per mile to take care of unsealed roads in each of four functional classes, 'resource,' 'local,' 'minor collector,' and 'major collector,' and multiply this cost by the miles in each class. Of course, the difficulty is in determining reasonable cost estimates. This procedure was carried out by T^2/LTAP staff in collaboration with county supervisors and office workers. Once these predictions were made, and the counties had actually performed work for a year, the predictions were compared to the counties' actual expenditures. As is described elsewhere in this report, particularly Appendix A: Johnson County Road Data and Dust Control Cost Savings and section 4.5.2 Maintenance and Cost Tracking: Line Items, the tasks and line items that expenses are typically assigned to do not always match up well with those that are the most logical for unsealed road management purposes. Performing this analysis involved a number of phone calls and emails trying to clarify which costs were spent on which tasks. While it was practical to perform this analysis with the data available for a research study, it would be much too labor intensive to perform such an analysis as a part of routine operations. The data were not in a convenient format, and that was a crucial lesson from this study.

2.4 United States Government Efforts

2.4.1 Forest Service Efforts

The United States Department of Agriculture's Forest Service (USFS) has a very different situation from most local governments. Their roads have two primary uses: getting logs out and recreation. Most USFS roads were originally constructed to access logging operations. The USFS must decide which roads to maintain and keep open, and which roads to abandon. As they manage their roads they are making these decisions, so condition and maintenance costs are not a major consideration. They need to know usage patterns. With these they can decide on a case-by-case basis whether or not a road should be kept open and how it should be maintained.

2.4.2 Bureau of Land Management Efforts

The United States Department of Interior's Bureau of Land Management (USBLM) generally manages their roads on a district-by-district basis, with little agency-wide management. Since much of the USBLM roads, at least those in Wyoming, are used to access oil and gas drilling operations, they, like logging roads, are used heavily for a brief period of time, then they fall into disuse and possibly abandonment.

2.4.3 Fish and Wildlife Service Efforts

The US Fish and Wildlife Service has taken active measures to manage their refuge roads, largely modeling their efforts on those of the Utah LTAP Center.

2.5 Data Collection Methods

When collecting data about the condition of unsealed roads, one is concerned with two characteristics – the road's current condition and its durability or future condition. Some characteristics – drainage, crown and gravel – are of little interest to the general public but are of great concern to the agency since they are directly related to the road's durability. Others – dust and loose aggregate – both influence the public's perception of the road's quality and reflect its durability, while the most obvious distresses – washboards, ruts and potholes – are of greatest concern to the traveling public. The first decision when establishing a data collection procedure is to decide which data to collect based on its intended use.

2.5.1 Pavement Surface Evaluation and Rating (PASER) Visual Survey Method

The Wisconsin Transportation Information Center put together a number of manuals referred to as the Pavement Surface Evaluation and Rating (PASER) manuals that describe how to perform visual 'windshield' surveys, surveys based on observations made while driving down a road or street. These include a drainage manual *(Walker 2000)*, an unimproved roads manual *(Walker 2001)*, and a gravel roads manual *(Walker 1989)*. They provide verbal descriptions illustrated with photographs that let the evaluator rate a road describing its overall quality. They also describe various distresses, as well as other factors to consider when rating a road, such as the appropriate maintenance activity for the rated road.

The 'Gravel – PASER Manual' *(Walker 1989)* uses the following distresses to arrive at a single rating on the following scale:

- 5 (10) Excellent
- 4 (8) Good
- 3 (6) Fair
- 2 (4) Poor
- 1 (2) Failed

To arrive at these, the PASER system evaluates the following distresses:

- Crown
- Drainage
- Gravel layer
- Surface Deformation
    - Washboard
    - Potholes
    - Ruts
- Surface Defects
    - Dust
    - Loose aggregate

The overall rating also considers travel speeds, transitability (open at all times or only during dry seasons) and maintenance and repair needs.

2.5.2 USACE-CRREL Unsurfaced Road Condition Index

The US Army Corps of Engineers' Cold Regions Research & Engineering Laboratory developed procedures for evaluating 'unsurfaced' roads *(Eaton and Beaucham 1992)*. By measuring the severity and extent of various distresses, deduct values are determined from graphs, and an Unsurfaced Road Condition Index (URCI) is determined. The following distresses are used to calculate the URCI:

- Cross-section
- Roadside drainage
- Corrugations
- Dust
- Potholes
- Ruts
- Loose aggregate

In addition to measuring the URCI, protocols are described for dividing a road network into discrete analytical units. The following criteria are used to divide a road network into '*sections*':

- Structural composition
    - Thickness
    - Materials
- Construction history
- Traffic

Finally, they present a one-page table that presents maintenance alternatives as a function of distress severities.

2.5.3 Canadian Automated Evaluation and Maintenance System

The Forest Engineering Research Institute of Canada (FERIC) has developed an unsealed roads routine blading maintenance scheduling program based on continuously collected data from their Opti-Grade® instrument *(Brown et al 2003)*. By mounting the instrument to a logging truck, FERIC continuously monitors road conditions. They direct maintenance motor graders to the specific parts of the road that actually need maintenance, rather than simply traveling and maintaining the entire road network. Forestry industry users of the Opti-Grade® system have reported considerable financial savings in grading costs. These savings generally derive from, for example, maintaining a road network with two instead of three motor graders since many areas that used to be bladed frequently are now bladed only occasionally since the Opti-Grade® data indicate that they are still in acceptable condition.

2.5.4 Wyoming LTAP Experiences

As part of the three-year asset management program conducted for Carbon, Johnson and Sheridan Counties during 2004 through 2006, the Wyoming LTAP Center hired and trained a number of students and retirees to perform data collection. Efforts were made to ensure that the data was collected as consistently as possible. Two-day training was performed each year both in the classroom and in the field by a staff engineer, and follow-up evaluations and retraining were performed after several weeks in the field to correct and calibrate the various road raters. Based on these experiences, a ten-scale for evaluating surface conditions and ride quality is proposed using the following scale:

1) Failed
2) Very Poor
3) Poor (closer to Very Poor)
4) Poor (closer to Fair)
5) Fair (closer to Poor)
6) Fair (closer to Good)
7) Good (closer to Fair)
8) Good (closer to Very Good)
9) Very Good
10) Excellent

When evaluating the counties' unsealed roads, the vast majority were in good, fair, or poor condition. A few lightly- or un-maintained roads are rated very poor or failed, and are kept on the network to maintain public access; an unsealed road in excellent condition is barely more than a theoretical possibility, while very good roads are uncommon and consist of roads with negligible roughness and a tightly bound surface that performs and rides like a fair to good quality sealed road. Therefore, the vast majority of roads are rated as good, fair or poor, limiting the discretion of the road raters by providing them with only three options. Raters are forced to make tough choices, particularly between good and fair, when they know they should rate it somewhere in between. By providing six choices within the ratings of good, fair and poor, the rating scale matches the experienced raters' ability to discern between different surface qualities.

2.6 Unsealed Roads Manuals

In the author's experience, four manuals stand out as providing the best guidance for those responsible for taking care of unsealed roads: They are the 'Gravel Roads Maintenance and Design Manual' by the South Dakota LTAP *(Skorseth and Selim 2000)*, the 'Low Volume Roads Engineering: Best Management Practices Field Guide' by the USDA's Forest Service *(Keller and Sherar 2003)*, Pennsylvania's 'Environmentally Sensitive Maintenance for Dirt and Gravel Roads' *(Gesford and Anderson 2006),* and the Australian ‘Unsealed Roads Manual: Guidelines to good practice’ *(Giumarra 2009)*. Simply put and in the author’s opinion, the South Dakota manual is for maintainers, the Forest Service and Pennsylvania manuals are for those responsible for design and construction, and the Australian manual is for managers. While there are other good manuals out there, these documents contain a wealth of information assembled by some of the top experts in our field. The influence of these manuals is throughout this report, particularly the American manuals. The Australian manual has verified many of the conclusions presented in this report, since it didn’t get into the author’s hands until much of this report was already written. Just to provide some scale, the South Dakota manual is about ¼” thick, the Forest Service manual is about ½” thick, the Pennsylvania manual is about 1” thick, and the Australian manual is about 3 cm thick.

2.6.1 South Dakota Manual

The SD-LTAP publication, *Gravel Roads: Maintenance and Design Manual, (Skorseth and Selim 2000)* provides guidance for those directly responsible for maintaining gravel roads. It begins with directions for maintainers, beginning with the basics of gravel roadway prism and shape. It discusses drainage considerations and the properties, procurement, handling, and placement of good surfacing gravel. It discusses stabilization and dust control. It also goes over some of the newer techniques for working gravel roads. The appendices discuss thickness design, gradation and plasticity, quantity calculations, the decision of when to pave a gravel road, and a walk-around motor grader inspection including a checklist. It is concise, well written, and well illustrated. As such, it is very accessible to those directly responsible for maintaining gravel roads.

2.6.2 Forest Service and Pennsylvania Manuals

The USDA’s Forest Service publication, *Low-Volume Roads Engineering: Best Management Practices Field Guide*, *(Keller and Sherar 2003)* and the Pennsylvanian manual *Environmentally Sensitive Maintenance for Dirt and Gravel Roads (Gesford and Anderson 2006)* both provide comprehensive and explicit guidance on the most important aspect of road construction, drainage. They also provide specific design information on virtually all aspects of low-volume unsealed road construction.

2.6.3 Australian Manual

The ARRB Group’s publication, *Unsealed Roads Manual: Guidelines to good practice (Giumarra 2009)* is perhaps the most comprehensive unsealed roads management manual available. It covers a wide variety of topics necessary to the successful management of an unsealed roads network, including maintenance, materials, design, and construction. It also covers asset management and economic evaluation, as well as environmental and safety concerns. The 21 page section on asset management concludes with a listing of key points, reproduced here:

> **”Summary of key points**
>
> - Road assets need to be managed to preserve the community’s investment in infrastructure in a way that preserves the asset in a desired condition, minimizes safety risks and takes into account the efficient use of limited resources.

- Performance management is necessary to indicate the condition of the road network at any given time and it ensures that greater value is obtained from the available maintenance resources.
- A road classification system should be established as a basis to set various intervention levels per road class.
- Performance management requires the development of an up-to-date inventory and road condition database.
- Performance measures should be selected that road users can relate to as a way of rating road conditions and performance. If you cannot measure it you cannot improve it.
- The introduction of a system of performance management should allow maintenance (routine and periodic) to be performed on a rational basis based on the level of funding and standard of maintenance for the road network.
- The database should consist of selected road sections (distances between fixed features such as intersections), inventory (traffic, physical structures, road structure and topography), and an assessment of road condition (defects, pavement life, drainage system and safety hazards).
- A pavement condition rating system is used to assess each road section in the network. This allows comparisons between individual sections in the network as well as comparisons against previously determined intervention levels.
- An asset management system should be introduced at different levels of complexity depending on local needs. Criteria determining the level adopted includes road classification, traffic type and volume, driver expectations, resources available and the need for the road section to remain open at all times.
- Intervention thresholds will depend on the category of the road section and available funding. Threshold levels will be determined using local criteria. These may be based on the number or severity of defects and/or safe speeds of travel over a road section.
- Make use of the recent unsealed road performance models to provide a better basis to predict future road network conditions.
- Asset valuations are also to be determined based on 'fair value' methods.

PERFORMANCE MANAGEMENT SYSTEMS MUST BE DESIGNED TO MEET LOCAL NEEDS AND TO ENSURE GREATER VALUE IS GAINED FROM AVAILABLE RESOURCES." *(Giumarra 2009)*

2.7 Converting Gravel Roads to Paved Roads

While there are many efforts related to low-volume roads in terms of when to convert gravel roads to paved roads, there seem to be two problems with these efforts. First, as is acknowledged in the Iowa State University/Minnesota DOT study *(Jahren et al 2005)*, consideration is not given to the cost of alignment improvements that become necessary to address the safety problems created by the higher speeds that result from paving. Second, the use of a number of intermediate surface types between conventional gravel and hot-mix asphalt pavement are becoming more prevalent. These intermediate treatments include dust suppression and soil stabilization with chemical or physical additives and the construction of surface treated roads, those roads constructed by placing a prime coat and chip seal directly on top of a gravel base. Without addressing these intermediate surface types, one has not considered all the possible options when deciding whether to upgrade a gravel road; without considering the cost of alignment improvements, one has not considered the true cost of upgrading a gravel road.

It is beyond the scope of this effort to determine when to upgrade a gravel road, though many of the procedures described in this report may provide valuable inputs to such decisions.

CHAPTER 3 METHODOLOGY

This effort pulled knowledge from many individuals and sources and assembled it into a format that will allow practitioners to benefit from the expertise of those who contributed to it.

There is no generally accepted method for unsealed road management by smaller local government agencies (LGA). By assembling experts and practitioners in the fields of both unsealed roads and roadway management, then soliciting their input on the best way or ways for small LGAs to manage their unsealed roads, this project strives to provide LGAs with guidance and methods for managing these roads. With input from a variety of experts, this effort provides both LGAs and software developers with enough guidance to institute and develop their own gravel roads management systems (GRMS).

3.1 Team of Experts

Input was solicited from a total of 83 experts, 56 of whom provided input to this project, either electronically through email, remotely through the webinar, or in person at one of the meetings. Table 4 includes the individuals who participated in this project by commenting by email or at one of the four meetings held specifically to address this topic. Others provided input through less formal venues.

Table 4 Participants in this Effort

Name	Organization	Preliminary 2009 emails	July 27, 2009; Piitsburgh, PA	October 6, 2009; Webinar	October 20, 2009; Rapid City, SD	January 12, 2010; Washington, DC	Final 2010 emails
Rodrigo Archondo-Callao	World Bank, Washington, DC	x					x
Gary Berreth	North Dakota LTAP	x	x		x		
Steve Bloser	Dirt and Gravel Roads Center at Pennsylvania State University		x				
Pete Bolander	USDA Forest Service, Portland, OR	x					
Andy Byra	FLH-Central, Lakewood, CO	x					
Gene Calvert	Collier County, FL	x					
Greg Clemmons	Washington County, OR	x		x			x
Dave Creamer	Dirt and Gravel Roads Center at Pennsylvania State University		x				
Jerry Durgin	D-Ware, Inc., Rapid City, SD			x	x		

Table 4 *(cont.)* Participants in this Effort

Name	Organization	Preliminary 2009 emails	July 27, 2009; Pittsburgh, PA	October 6, 2009; Webinar	October 20, 2009; Rapid City, SD	January 12, 2010; Washington, DC	Final 2010 emails
Max Durgin	D-Ware, Inc., Spearfish, SD			x	x		x
Bart Evans	Wyoming LTAP					x	
Stephen Ford	Mendocino County, CA					x	
Sean Furniss	US Fish and Wildlife Service	x					
Carlos Garcia	USDA Forest Service, San Dimas, CA					x	
George Giumarra	ARRB, Australia						x
Dee Hadfield	Utah LTAP		x				
Ron Hall	Colorado State University TTAP		x	x			
George Huntington	Wyoming LTAP		x	x	x	x	
Russ Huotari	Richland County, MT	x					
David James	UNLV	x		x			
David Jones	UC-Davis	x					x
Gordon Keller	USDA Forest Service, San Dimas, CA					x	x
Martin Kidner	WYDOT Planning	x		x			
John Kiefer	Michigan LTAP	x		x			
Dave Kieper	Park County, WY	x					
Renée Koller	Colorado LTAP		x				
Khaled Ksaibati	Wyoming LTAP					x	
Glen Légère	Forest Engineering Research Institute of Canada	x					
Dave Levi	North Dakota LTAP	x		x	x		
John MacGowan	North Dakota State University/UGPTI/MPC		x				x
Donaldson MacLeod	Public Works and Government Services, Canada					x	
Hesham Mahgoub	South Dakota State University					x	
Bill Masson	Fremont County, WY						x
Terry McNinch	Michigan LTAP		x				x
Scott McWilliams	Converse County, WY				x		
Steve Monlux	retired (formerly USDA Forest Service) Missoula, MT	x					x

Table 4 *(cont.)* Participants in this Effort

Name	Organization	Preliminary 2009 emails	July 27, 2009; Pittsburgh, PA	October 6, 2009; Webinar	October 20, 2009; Rapid City, SD	January 12, 2010; Washington, DC	Final 2010 emails
Dan Raterman	Missouri LTAP			x			
Jim Reiter	Converse County, WY				x		
Roger Rhowedder	McPherson County, SD				x		
Richard Rolland	Northwest TTAP		x				
Randy Sather	Converse County, WY				x		
Barry Scheetz	Dirt and Gravel Roads Center at Pennsylvania State University		x	x			
Reed Schwartzkopf	City of Jamestown, ND	x					
Jim Self	Oklahoma TTAP		x				
Ali Selim	retired (formerly South Dakota State University and LTAP)					x	
Roger Smith	Texas A&M University					x	
Ken Skorseth	South Dakota LTAP		x		x	x	
Bob Strobel	New Hampshire LTAP		x				
Roger Surdahl	FLH-Central, Lakewood, CO	x					x
Jim Sweeney	Alaska DOT					x	
Stuart Thompson	New Hampshire DOT	x		x			
Dennis Trusty	Northern Plains TTAP			x			
Lenny Urich	Edmunds County, SD				x		
Cheryl Cloud Westlund	Michigan TTAP					x	
Alex Visser	University of Pretoria, South Africa	x					
Alan Yamada	USDA Forest Service, San Dimas, CA					x	
		20	14	13	11	14	11

3.2 Draft Preparation

The Wyoming T²/LTAP Center prepared a number of drafts that both outlined progress so far and provided direction for further discussion. Copies of these drafts are available on the Wyoming T²/LTAP Center's website *(Wyoming Technology Transfer Center 2010).*

3.3 Meetings, Emails, Webinars, Personal Communications

The information gathered for this project was collected from a variety of individuals using several means including meetings, webinars, emails, and personal correspondence. Personal correspondence and emails were solicited several times, and responses were received at various times throughout the project. Meetings were either dedicated to the unsealed roads management project or the unsealed roads project was presented as part of a meeting with a broader focus. The following events were used to solicit input for this project:

- Gravel Roads Management Specific Meetings
    - July 27, 2009: Pittsburgh, PA
        - in conjunction with the NLTAPA Annual Conference
    - October 6, 2009: Webinar
    - October 20, 2009: Rapid City, SD
        - in conjunction with the Local Road Advisors Conference
    - January 12, 2010: Washington, DC
        - in conjunction with the Transportation Research Board's Annual Meeting
- General Meetings with Gravel Roads Management presented
    - September 24, 2009: Laramie, WY
        - at the Wyoming Association of County Engineers and Road Supervisors meeting
    - October 8, 2009: Rapid City, SD
        - at the D-Ware Conference
    - January 11, 2010: Washington, DC
        - at the Transportation Research Board's Low Volume Roads Committee meeting

Notes and minutes from these meetings and correspondences are available on the Wyoming T^2/LTAP Center's website *(Wyoming Technology Transfer Center 2010).*

3.4 Results

This report documents the processes undergone in this effort to develop a methodology for managing unsealed roads.

Chapter 4 Implementation presents, describes, and discusses the procedures a small agency should go through when implementing a gravel roads management system (GRMS). These recommendations will often be applicable to the implementation of any management system. It also describes procedures for planning and prioritizing maintenance tasks on unsealed roads. Chapter 5 Analytical Methods describes some of the analytical processes and outputs that should result from a GRMS. The accompanying 'Implementation Guide' presents the information in Chapters 4 and 5 in a format that is more accessible to road managers contemplating the institution of a GRMS, while the 'Programming Guide' provides information that will be needed by those contemplating writing software and managing unsealed roads data.

CHAPTER 4 IMPLEMENTATION

This chapter describes the processes that an agency should go through when implementing a gravel roads management system (GRMS). Much of the advice is not unique to unsealed roads, and should be considered for small agencies' implementation of any management system.

The first preliminary step is to assess the agency's current situation, as described below in sections 4.1 Current Information Management Practices and 4.2 Assessment of Available Resources and Assets. This process should address funding and political issues, as well as the nuts and bolts of information management and data collection. Another early decision will be how to manage the data. This decision will depend on the results of the initial assessment, as well as on the long-term goals of the management system. Section 4.3 Data Management describes some of the options and decisions that must be made when selecting a method for storing information. Once this is done, the agency should consider the three basic steps to a mature roadway management system as described below in sections 4.4 Inventory, 4.5 Historical Data and 4.6 Condition Data.

4.1 Current Information Management Practices

The first step a road manager should take when trying to improve their asset and information management processes is to assess their current strengths and weaknesses. There are many questions the road manager should ask themselves when undertaking this assessment, with some suggestions in the following paragraphs.

4.1.1 Five Core Questions about Infrastructure Management Systems

In workshop materials developed by the United States Environmental Protection Agency, 'Five Core Questions' relating to asset management are raised:

1. What is the current state of our assets?
    - What do we own?
    - Where is it?
    - What condition is it in?
    - What is its remaining useful life?
    - What is its economic value?
2. What are the required levels of service?
    - What is demanded by users and stakeholders?
    - How do actual conditions differ from those desired?
3. Which assets are critical to performance?
    - How do they deteriorate and fail?
    - What is the likelihood of failure?
    - What is the consequence of failure?

4. What are good O&M (operation and maintenance) and CIP (capital improvement plan) strategies?
    - What management options exist?
    - Which are most feasible for our agency?
    - How do they impact level of service?
5. What is a good long-term funding strategy?
    - Does it align with my agency's policy goals? *(Allbee 2007)*

These questions are applicable to infrastructure assets in general. In many cases, applying these questions to unsealed roads may lead one to the conclusion that the efforts needed are so great and the task of answering them is so daunting that unsealed road managers may feel overwhelmed and discouraged. Still, asking these questions will help identify some of the hurdles faced when managing unsealed roads. For example, when establishing the condition of unsealed roads, their rapidly changing nature may make it difficult to answer these questions; when addressing failure of an unsealed road, we first need to define 'failure,' also a difficult task. These issues and more demonstrate the need for alternate ways of thinking about unsealed roads.

4.1.2 Questions from Australia about Unsealed Roads Management

In the 'Unsealed roads manual' *(Giumarra 2009)*, five questions are posed to help practitioners arrive at a suitable GRMS:

1) How much of the road network conforms to desired standards and community expectations for each road class?
2) Is the condition of the road network improving or deteriorating over time?
3) What potential safety problems, risks and liability issues are currently present in the network?
4) Is maximum value being obtained from current resource allocations?
5) Is the current level of resource allocation able to provide sustained operations?

Given that these questions are tailored specifically to unsealed roads, they begin to hit closer to the mark for gravel roads management. Most road managers could provide subjective answers to the first two questions, though having actual data to back them up would add a lot of credibility when they try to answer them for elected officials. Questions about the value and sustainability of a road network and its management may also be answered in subjective terms, but without data to back up any such statements, they have little credibility. Safety issues on local roads often take a backseat to cost issues. Without a mechanism for identifying safety problems, solutions will not be found, so it is road managers' duty to do their best to identify and solve safety issues. The following discussions tackle these questions individually in an effort to assist gravel road managers in identifying their information management practices' most pressing needs.

4.1.2.1 Standards and Community Expectations

The goal of a GRMS should be to keep the customers happy. This may be impossible, but we should still try. In order to keep the public and their elected officials as happy as possible, we need some standards.

One quantitative approach is to minimize user costs. For unsealed roads, user costs may be put into four categories, all proportional to the number of vehicles using the road:

- Travel time
  - How long it takes to get from place to place
- Vehicle operation costs
  - Fuel
  - Filters and lubricants
  - Tires and suspension
  - Others
- Transitability
  - Access in all seasons and weather conditions
- Safety
  - Property damage
  - Injuries
  - Fatalities

In theory, one might develop mathematical ways of addressing and assessing each of these issues. However, from a practical point of view, few agencies will be able to conduct in-depth user cost studies, so they must make some sweeping generalizations about quantifiable minimum standards which the agency should provide.

The most basic decisions address 'transitability.' Can a road be traveled in all seasons and weather conditions? In all vehicles? Will snow be plowed? These questions should be answered for all the roads an agency maintains.

Next, acceptable road quality must be addressed, with travel time, safety and vehicle operating costs defining road quality, perhaps along with ride comfort, though vehicle operating costs and travel times will mirror comfort issues. For each road section, a minimum acceptable surface condition should be established; the goal should be to perform maintenance when roads reach this condition, described as the 'maintenance intervention level' which the road manager should assign to each road section. These assignments should be presented to elected officials as a way to reduce maintenance costs, with the understanding that some roads may receive less maintenance and be in worse condition than they are now, potentially leading to more complaints from those who use them. Elected officials need to understand the implications of their fiscal decisions, and assigning 'maintenance intervention levels' is a way to demonstrate the consequences of budget constrictions and a way to prioritize maintenance and rehabilitation activities.

All these issues add up to the necessity to establish 'maintenance intervention levels' for each road section. Though in an ideal world, road managers would undertake sophisticated analyses to arrive at a minimum acceptable surface condition for every road section in their network, for smaller agencies this will be cost-prohibitive. Therefore subjective 'maintenance intervention level' assignments should be made, considering the factors described above.

4.1.2.2 Changes in Network Conditions with Time

Unlike sealed roads, unsealed roads change quickly with time, traffic and weather, making it difficult to answer the question of whether the overall network condition is getting better or worse. Methods for assessing overall network condition include gravel thickness measurements and surface condition surveys, either visual or automated. Road managers should, at a minimum, ask themselves how they might evaluate the overall condition of their network, recognizing that answering this question may be difficult.

4.1.2.3 Safety, Risk and Liability

Safety issues should also be considered, though in many instances safety will compete for funds with transitability and ride quality. Road managers should use systematic approaches to identifying safety issues and should advocate their resolution in the most cost-effective ways possible, including seeking funding at the State and Federal levels. Accomplishing this will, in most cases, require the local agency to have data on the safety and liability issues on their road network. Fundamentally, the public expect roads to be safe in spite of existing conditions that make this a very difficult goal.

In spite of the relatively low traffic volumes on most unsealed roads, they may be dangerous. Instituting systematic safety and risk evaluation processes, along with the resolution of issues as they are identified and resources allow, will provide a good measure of legal protection in the event that the agency is sued over any failures to meet accepted safety standards.

4.1.2.4 Optimizing Resource Allocation

The fundamental question of whether resources are achieving maximum value is really a question of spending funds in the most cost-effective manner. This goes right to the core of asset management. It is the use of objective standards to provide the best possible service at the least cost. Fundamental questions involve materials selection, routine maintenance (blading) frequency, periodic maintenance (reshaping, regraveling and dust suppression) frequency, snow plowing policy and other decisions that impact both the cost of maintaining unsealed roads and the standards to which they are maintained. Many agencies now make these choices based on the road supervisor’s subjective judgment, with elected officials frequently making significant decisions that substantially influence and change the supervisor’s plans.

Data from a GRMS should help supervisors justify their plans. Hopefully information from a GRMS helps them persuade elected officials to make the best possible decisions for the long-term health of their unsealed roads network. Indeed, if the data are good enough and presented well enough, the case might be taken directly to the public and the media, thereby influencing elected officials by demonstrating that decisions made to balance a budget may be providing a long-term disservice to the general public, leading to the short-sighted politicians losing their next election.

4.1.2.5 Operational Sustainability

The issue of operational sustainability is related to the one of whether the overall network condition is improving or deteriorating, though it also incorporates the issues of maintenance and rehabilitation optimization. It might be demonstrated that current funding levels are adequate *if*, for example, an agency is willing to spend the additional money up front to purchase better quality gravel, or if the agency is willing to allow some very low volume roads to be maintained to a lower standard. To address these issues, one must have some way of monitoring conditions and projecting future conditions with a variety of maintenance and rehabilitation strategies. Only by collecting condition, maintenance and cost data for an extended period of time can this issue be accurately addressed.

4.1.3 Information Management Assessment Summary

When evaluating the current information management practices of a road or street agency, two primary factors, user costs and agency costs, should be kept in mind at all times. The following questions may help consolidate and clarify a road or street manager's evaluation of their unsealed roads management practices:

- How are cost data tracked, stored, analyzed, used and presented?
- How are network conditions assessed, used and presented?
- How are maintenance strategies established for each road section?
- How are maintenance and rehabilitation tasks scheduled and prioritized?
- Is information provided to the public and elected officials that lets them understand unsealed road and street management well enough to make good decisions regarding funding and other higher level management choices.
- Is the unsealed roads network managed as efficiently as practical?

Hopefully, by answering these questions, road managers will identify those areas within their own information management practices that, if improved, will yield the greatest benefit to their agency and the traveling public.

4.2 Assessment of Available Resources and Assets

Before embarking on the implementation of a GRMS, an agency should consider both its current information management status and its current resources and assets. Such resources include manpower and expertise, computer hardware and software, and information. In addition to these technical resources, financial and, perhaps more important, political resources should also be considered.

4.2.1 Support

Without the political will to carry through with implementation of a GRMS, any effort to establish such a system may be wasted. Therefore road managers need to convince their crews of the value of a management system, and if additional funding is needed, elected officials or other decision makers may also need to be convinced.

One problem many agencies will face is that it may take some time to collect data upon which good decisions can be based. Thus, there will need to be considerable effort expended before a management system shows many rewards. This reality must be understood both by those who will fund the effort and by those who will do the work. Identifying areas where benefits can be achieved quickly, such as instituting needs-based maintenance scheduling, may help get an agency through the early period when initial data is being collected. Support for an asset management program must be maintained through this early period while historical data are being accumulated.

4.2.2 Financial Resources

It is easy to agree in principle to better manage one's assets, but it is quite another thing to be willing to put forward the money needed to carry out a plan. To this end, it should be kept in mind that an agency should proceed with small steps, correcting those problems that may inhibit better management of their unsealed roads. Much of the initial assessment should be geared towards identifying those next steps that will be the most cost-effective. Implementing a GRMS does not have to be expensive, but it has to be well thought out and designed to work within an agency's financial and logistical restraints.

4.2.3 Hardware, Software and GPS

Though for most agencies, the greatest investment they will make in a GRMS will be their employees' time, there are also computer and other expenditures that may be needed. Fundamental computer equipment will be the geographic information system (GIS) software and a computer to run it, not to mention a person skilled at running the software. Global positioning system (GPS) units may also be useful. However, it is not as important to have particularly high tech computer, GIS, or GPS equipment as it is to understand how to develop an effective GRMS with the equipment already available. It is better to start out with a simple system that can be run on a spreadsheet than to get in over one's head with a complex system that is too difficult to maintain.

4.2.4 Information

An early step in developing a GRMS should be to assess what information is already available. Information may be found within the agency and it may be available elsewhere, perhaps from the State Department of Transportation.

The simplest information is a map or other location-based information. Most agencies will have an existing map of their roads. Other related information includes road lengths, distances between intersections, top widths, surface type and ownership. For additional guidance, see the list of fields in section 4.4 Inventory below.

Historical cost and maintenance data should be collected and evaluated. This information should be assessed to determine whether it is being collected so that it provides the greatest value. In many cases, data are collected in ways that are important to accountants but are of limited value to road managers. For many agencies, an early step will be to adjust and clarify how maintenance and cost data are collected. Section 4.5 Historical Data: Maintenance and Cost Tracking provides additional guidance in evaluating historical data, while section 4.5.3 Maintenance Task Definitions defines maintenance tasks that will be of interest to road managers.

The following list contains some of the types of information that might be useful when establishing a GRMS:

- Surface conditions

- Traffic counts
- Safety or crash data
- Drainage assessments
- Road section location and length
- Aerial and other photos
- Classification data, such as functional classes and maintenance intervention levels
- Maintenance and construction histories
- Costs
- Soil types

In addition, good metadata should be obtained. (Metadata is information about the data, such as how it was collected, when it was collected, what the various fields or columns represent, what units are used, and so on.) As information is collected, it should be kept in fairly standard formats whenever possible so transfer to a standard data platform can take place as different uses for the information become apparent.

4.2.5 Personnel

Having people on staff with the willingness, understanding and skills to make a management system work is critical. All the money, computers and software in the world won't be of much use if the people operating them don't understand and believe in what they are doing. The first factor is whether they understand why they are changing how they operate. They need to see the potential benefits of a management system. Many experts in the field were willing to volunteer their time to this collaborative effort. Clearly they see the potential for success in managing unsealed roads. Those responsible for maintaining and managing these roads must also understand what they are doing and why they are doing it.

In addition to understanding what they are doing, personnel will need certain skills to help with the implementation of a GRMS. Those skills fall into three classes: Computer skills, preferably with GIS, though spreadsheets will do; GPS skills; and unsealed roads skills. Of these, probably the most unique and difficult to acquire are the roads skills. Fortunately most agencies initiating a gravel roads management program already have these skills. GPS units have become relatively easy to operate, and many people currently use them for outdoor recreational pursuits. Probably the most challenging personnel issue will be finding those with the computer skills to implement a GRMS. However, a well planned management system does not need a full-time GIS expert to make it work. It *does* need at least one conscientious individual to make sure the database, even if it is only a system of index cards, is well managed and up to date.

4.3 Data Management

There are numerous ways unsealed roads data can be managed. An early decision will be whether to purchase a commercial software package, obtain a free package, or develop software internally. Each has its pros and cons.

Most data management systems can be assigned to one of these three general types:

- Manual
  - File cabinets, manila folders, and so on
- Databases or spreadsheets
  - Tables of information stored in a computer
- Geographic information system (GIS)
  - Database with a mapping function

In the most general terms, the larger the road network, the more advantageous it will be to work towards the bottom of this list. A small town with two miles of streets and thirty sections may do very well with a manual system, especially if it is already established and working well, while an agency with a thousand miles of roads and hundreds of sections may be frustrated without the mapping capacity provided by a GIS system.

In addition to the size of the network, an agency's level of available expertise, particularly computer expertise, should also play into the decision-making process when selecting the means of managing information. If an agency has an under-utilized GIS programmer available, by all means put them to work setting up a GRMS, at least in the earlier stages. It may well be worthwhile to work with a commercial software provider, particularly if an agency is preparing to institute a better system for tracking costs and maintenance tasks. Any agency contemplating instituting a GRMS should make their information management decisions based on both their needs and their resources.

4.3.1 Manual Data Management Systems

For all but the very smallest agencies, a manual system is not practical. Unless you can list from memory every sign and culvert in your jurisdiction, it is probably time to at least learn how to use a spreadsheet. If this isn't going to happen, you should pattern your filing system on those described below for spreadsheets and databases.

4.3.2 Spreadsheet and Database Management Systems

At a minimum, there should be two tables in a spreadsheet or database-type system, one with static fields, the inventory as described in sections 4.4.1 Essential Elements and 4.4.2 Other Recommended Elements, and another table with changing fields to record maintenance and performance monitoring. Realistically, once a system develops any sophistication at all, additional tables will be desirable. There should be a table with static, inventory-type data; a table to record maintenance performed and its costs; and a table to record conditions. One might also have tables recording material costs, including the costs associated with crushing and stockpiling gravel, whether by agency or contracted forces. Equipment costs might have their own table; indeed, there are entire fleet management systems available. A number of spreadsheet functions, such as filters, sorts, and lookups may be useful, not to mention macros and other code that may be used for fairly sophisticated applications, though programming time can quickly add up. There will always be a trade-off pitting ease of operation and simplicity against flexibility and sophistication.

Final decisions on what tables or sheets should be created should be made by programmers with a good understanding of both the principles and practices described in this report and with the operations and existing information management of the agency that will be using the software. The following tables are merely suggestions:

- Static Inventory
  - As described in section 4.3 Inventory
- Maintenance performed
  - Possibly derived from a Work Orders system
  - Possibly derived from Time Cards
- Performance and condition data

4.3.3 GIS – Geographic Information Systems

Most of what was said in section 4.3.2 Spreadsheet and Database Management above also applies to a GIS system. The added benefit of a GIS system is that it allows information to be displayed on a map. Given the geographic nature of road networks, this can be a tremendous advantage, both for road and street crews carrying out their daily activities and for elected officials and the public who are trying to understand what the agency is doing.

There are two main drawbacks to using a GIS system instead of a spreadsheet system. First, fewer people are familiar with GIS software than with spreadsheet software, and, second, GIS software is more complex so both programming and data analysis are more difficult. However, with that said, GIS systems have become much easier to use, and commercial packages are becoming available that utilize GIS functionality. In spite of some drawbacks, GIS should be used whenever practical, and spreadsheet or database systems should be switched over to GIS if the resources to do so are available.

4.4 Inventory

An inventory is simply a list of assets and a few of their fundamental, static attributes. Without the structure an inventory provides, other more sophisticated steps in a GRMS are not possible.

4.4.1 Essential Elements

At the very least, the following aspects of an unsealed road network should be collected and stored:

- **Unique Section Identification**
  - Each road section should be uniquely identified. Many agencies will only have road names or numbers. Some provision should be made within a database scheme to split existing roads into discrete sections should such needs arise.
- **Location**
  - This may be as simple as having references to a map or as complex as a computerized geographic information system (GIS), or it may be a verbal description stored in a file cabinet or spreadsheet.

    - The location of each section should be described, preferably with data from a global positioning system (GPS), and road networks should be divided into sections as described in 4.4.3 Dividing a Road Network into Management Sections and 5.1.1.1 Road Sections.
- **Surface Type**
    - The road's surface type should be identified and recorded. The following list contains suggested road types that may be applied to an entire unsealed road network.
        - *Earth: unformed*
            - Few or no drainage provisions
        - *Earth: formed*
            - Drainage improvements present
        - *Gravel (processed, generally crushed and screened, aggregate)*
            - Gravel only
            - Gravel with isolated dust control
            - Gravel with dust control
            - Stabilized gravel
            - Stabilized gravel with dust control
    - Each agency should determine their own surface type classes, though those above should be sufficient for most agencies.
    - This may be integrated into an overall agency road inventory that also includes sealed roads.
- **Length**
    - The section's length should be recorded as accurately as possible. This may be complicated by uncertainty as to where an agency's roads truly begin and end.

Without this very basic information, no formal road network management can take place.

4.4.2 Other Recommended Elements

In addition to the fundamental inventory elements listed above, there are a number of other desirable elements to an inventory. Some of these are straightforward and easy to obtain, others take additional monitoring effort, while still others may require varying degrees of decision-making. The following list in approximate order of importance includes other elements of a GRMS inventory that an agency should consider collecting:

- **Road Name and Number**
    - In addition to the unique road section identifier described above, the name and number of the road should also be included in the inventory. It should be noted that one road may be split into several sections, each with its own unique section ID. With road names and numbers also in the inventory, searches on information about an entire road may be made even if the road is split into several maintenance management sections.

- **Top Width**
  - Measurement of the typical usable width of the traveled way on tangents, between the hinges of the shoulder
- **Inventory Date**
  - When the inventory data were compiled or last revised
- **Inventory Data Collector**
  - Name or initials of the individual who compiled the inventory data
- **Owner**
  - The legal status of the road should be described, including whether the agency has an easement, a right-of-way, or whether the legal status is uncertain. Additionally, if a road is owned by one agency but maintained by another, this should be indicated. Each agency should compile a list of possible ownership statuses.
- **Right-of-Way or Easement Width**
- **Functional Class**
  - This assignment is made for a variety of reasons including the determination of appropriate geometry as described in the 'Green Book' *(AASHTO 2004)* and in the 'Very Low Volume Design Guide' *(AASHTO 2001)*, and for a variety of funding applications.
  - Functional Classification may be the basis for the assignment of maintenance strategies and maintenance intervention levels.
  - The following functional classifications based on the AASHTO guides are recommended, with those defined in the 'Green Book' in ***bold italics*** and those defined in the 'Very Low Volume Design Guide' in **bold**.:

    1. ***Rural major collector roads***
    2. ***Rural minor collector roads***
    3. **Rural major access roads**
    4. **Rural minor access roads**
    5. **Industrial/commercial access roads or streets**
    6. **Agricultural access roads or streets**
    7. **Recreational and scenic roads or streets**
    8. **Resource recovery roads or streets**
    9. ***Urban collector streets***
    10. **Urban major access streets**
    11. **Urban residential streets**

  - Though traffic levels are not assigned to these classifications, there should be a general correlation between traffic levels and functional classifications, with higher classifications having more traffic. Additionally, the industrial, agricultural, and resource recovery roads will usually have a substantially higher proportion of heavy vehicles.

- **Maintenance Intervention Levels**
  - Each road section should have an assigned maintenance intervention level as described in section 5.1.1.2 Maintenance Intervention Levels.
  - An agency might decide to assign all road sections within a given functional class to a particular maintenance intervention level.
- **Maintenance Strategy**
  - If a maintenance intervention level is assigned and a cyclic maintenance program is planned, then at some point the agency will need to assign a maintenance strategy to each road section, as described in section 5.1.1.4 Assign Road Sections to a Maintenance Strategy.
- **Maintenance District**
  - Typically a maintainer will be responsible for a group of road sections, their district. This identifies the district each section is in.
- **Traffic Volumes**
  - Measured
    - ADT – Average Daily Traffic
      - Cumulative traffic in vehicles per day, both directions
      - Should be corrected for season, day of the week, and time of day
    - Percent trucks >10,000 lbs
      - Any effects of intermittent operations should be accounted for
  - Estimated
    - The ADT may be estimated if actual counts are not available
    - Percent trucks may be estimated if actual counts are not available
- **Traffic Speeds**
  - Posted
  - Statutory
  - Measured
    - Mean
    - 85^{th} percentile
  - Design
- **Transitability**
  - Dry season only
  - All seasons
    - Snow plowed
    - Snow not plowed
- **Utilities**
  - Type
  - Location
  - Contact information
  - Legal agreements

- **Legal Documentation**
  - This is related to the ‘Owner’ classification above, though one might go into more detail including references to legal documents. One might reference particular documents, such as commission minutes including dates, or one might reference scanned electronic files.
- **Survey Information**
  - This may also be related to the ‘Owner’ classification above. References to any surveys performed might be useful, particularly if issues arise regarding legal status and right-of-way. Such references might include surveyor, date, and type, as well as links or references to any electronic files.
- **Subgrade Type(s)**
  - List, using AASHTO or USCS soil classification systems
- **Roadway Prism Height**
  - Below natural grade
  - At natural grade
  - Above natural grade
    - <1½’ [<0.5 m]
    - 1½’ to 3’ [0.5 – 1.0 m]
    - 3’ to 5’ [1.0 – 1.5 m]
    - >5’ [>1.5 m]
- **Road Uses: Social and Economic Benefits**
  - Residential
  - Public transit route
  - School bus route
  - Postal route
  - Emergency access
  - Industrial
  - Agricultural
  - Recreational
  - Resource recovery
    - Mining
    - Logging
    - Oil and gas drilling
    - Wind farm
  - Other uses
  - Through traffic
- **Land Use**
  - Urban
  - Rural (with residences)
  - Remote (no residences)

- **Terrain**
    - Flat
    - Rolling
    - Hilly
    - Mountainous
- **Photographs**
- **Other Roadway Features**
    - Intersections with public roads
    - Approaches
        - By type
    - Bridges
    - Box culverts
    - Large pipe culverts
    - Small pipe culverts
    - Low water crossings
    - Cattleguards
    - Railroad crossings
    - Fencing
    - Snow fences
    - Signs and delineators
    - Roadside vegetation type
    - Crash data
    - Others

Many of the features, particularly those listed in 'Other Features' above, may be monitored by other management systems.

Agencies should weigh the benefit of having each of the above pieces of information against the cost of obtaining and managing that information. When setting up a database, it may be wise to include blank fields even if it is not the intent to collect the data right away, thereby avoiding major software re-writes in the future.

4.4.3 Dividing a Road Network into Management Sections

Once an initial inventory including roads, surface types and lengths is in place, it will usually be advantageous to subdivide the roads into fairly homogeneous sections. There will always be a trade-off between the value of having very specific information and the cost of obtaining and managing that specific information. As a general recommendation, most agencies will not need to further subdivide most of their roads if they have an existing inventory, though the following discussion may shed some light on when and how further subdivisions should be made.

Currently many agencies group all costs for a particular road together. While this is a major improvement over no cost tracking, there are situations where this is less than ideal. For example, a road that originates near town may have many residences on the first few miles, with residences becoming less frequent further out. There may be a gravel pit that intermittently generates heavy traffic, or a side road that serves a subdivision. The road may travel along a ridge, and then drop down to a river bottom. The maintainer may traditionally grade the road with a break at a particular bridge or approach. These changes and more will dictate how a road is broken down into relatively homogeneous sections.

The purpose of splitting a road into maintenance management sections is to track information by sections that receive similar maintenance and improvement treatments. Other assets, such as a parking lot, might also be considered a 'section.' Section lengths could vary from as little as a few hundred yards to a dozen miles or more. The trade-off between cost and benefit should be kept in mind at all times. The more sections there are the more data that will need to be collected. However, if sections are too long, portions of a road that should be managed separately may be analyzed together, limiting the value of outputs from the management system. If with time it becomes apparent that a section is too long, it should be possible to subdivide the section.

There are a number of factors that may go into the decision of how to divide a road into appropriate sections. A fundamental consideration will be whether a section has been maintained as a single unit in the past. Often this information will be easily obtained by asking the maintainer. They will usually be the person responsible for establishing the beginning and ending points of sections within their district. The following factors should be considered when splitting a road network into sections:

- Typical surface condition
- Maintenance history
    - Typical maintenance beginning and ending points
    - Treatment beginning and ending points
- Construction history
    - Structural characteristics
    - Surfacing types
- Traffic
    - Type
    - Volume
    - Heavy vehicles, including intermittent uses
- Physical features
    - Subgrade
        - USCS or AASHTO classification systems
    - Terrain
        - River bottom/Flat
        - Rolling
        - Hilly

        - Mountainous
    - Bridges
    - Intersections
- Road use
    - Subdivisions and other residences
    - Gravel pits and other extractive and industrial activities
    - Agricultural operations
    - Recreational activities
- Land use
    - Urban
    - Rural
    - Remote

For more information on these decisions, see section 5.1.1.1 Road Sections and Chapter 2 of the USACE publication *Unsurfaced Road Maintenance Management (Eaton and Beaucham 1992).*

4.5 Historical Data: Maintenance and Cost Tracking

Without knowing where the money is going, it is nearly impossible to spend it more wisely. Without knowing what has been done to a road, it is difficult to figure out what to do to it next. Given these premises, it is critical to track the maintenance and costs associated with maintaining and improving unsealed roads.

Though each agency has its own existing information management systems, there are some basic elements that should be used to provide essential inputs to a GRMS. These are described in the following sections.

4.5.1 Data Collection Methods

Making the decision of which data to collect should begin with assessing the agency's current information management procedures. The first step in making this decision should be to evaluate where there are significant gaps in the current system. If the inventory is not complete, it needs to be brought up to date. If costs or maintenance are not being well tracked, that should be a top priority. Assuming these two elements are adequate, the next step is to decide which condition data will deliver the most 'bang for the buck.'

Before deciding to collect any additional data, an agency should ask whether the data currently being collected are being fully utilized. Are work orders and time cards being tracked so as to provide the most useful information?

Once the existing information has been assessed, the next decision should be to identify the outputs that are likely to add the most value to the agency. By identifying the outputs needed, such as those described in Chapter 5 Analytical Methods, it should become apparent what data need to be collected and how they should be collected.

4.5.1.1 Time Cards

One option for obtaining maintenance and cost information is from employees' time cards. If they simply indicate which tasks they performed and which road sections they did the work on, one would have very useful maintenance data. A drawback might be that time cards only include labor costs, but not materials, supplies, or equipment costs.

4.5.1.2 Work Orders

Another possible source of information might be work orders, particularly if an agency is planning to change or implement a work order system. Like time cards, this is a form of paperwork often being performed that might only need minor adjustments to provide more useful information about what maintenance was performed on which road sections and how much the work cost.

4.5.1.3 Field Reports

Another option might be to have crew foremen fill out forms describing the work their crews carry out; maintainers might file similar paperwork each time they maintain a road. These reports should provide a way of tracking both the maintenance tasks performed and the cost of performing these tasks, along with the road sections they were performed on.

4.5.2 Maintenance and Cost Tracking: Line Items

During the course of this project, it has become apparent that one impediment to managing unsealed (and sealed) roads is the way in which information about them is currently tracked. While many agencies track costs, they generally do so according to a system developed by accountants to track money. It is important from a management point of view to also track costs and tasks in terms of how the road itself is treated. For example, it matters to accountants whether gravel is hauled in a contractor's truck or in the agency's truck, but from a road management point of view, it doesn't matter who owns the trucks. However, it is important to the road manager to know whether the hauled gravel is used to repair a soft spot or to regravel the entire section; many systems set up by accountants do not make this distinction. Data need to be collected in a way that is useful to road supervisors and engineers as well as to accountants.

The maintenance tasks listed below are defined by NACE and are virtually identical to the five maintenance types developed during this project and described in section 4.5.3 Maintenance Task Definitions. The NACE Guide describes these tasks in considerable detail:

- Dust Control
- Stabilization
- Adding Aggregate
- Blading
- Reshaping *(NACE 1992)*

The following six proposed tasks should be scheduled as part of a GRMS:

- Dust Control

- Stabilization
- Regravel
- Reshaping
- Blading
- Drainage

Drainage should be scheduled into any regular maintenance plan, given the critical nature of timely drainage maintenance.

While the maintenance tasks may be defined and described as in the NACE Guide, sometimes only part of a section will be maintained. At some point one should consider that the section as a whole has not received the treatment. Section 4.5.3 Maintenance Task Definitions describes a method for making this distinction.

Two maintenance tasks, 'Isolated Repairs' and 'Major Work,' are very loosely defined in section 4.5.3 Maintenance Task Definitions. The distinction between these two tasks goes to the issue of whether enough work has been done to a road section to reevaluate how it is managed. If 'Major Work' has been performed, the character of the road may be significantly changed and it should be reevaluated. If only 'Isolated Repairs' have been performed, no reevaluation is necessary.

There should be a comprehensive list of maintenance and improvement tasks from which to select. There should be several activities for unsealed roads such as those listed above, several for asphalt roads, for bridges, and for other features such as culverts, signs, cattleguards, fences, and so on, as well as work in the shop and on administrative tasks. Such a list might make for a crowded piece of paper, but if electronic forms are developed, the system could be made to work much more easily.

4.5.3 Maintenance Task Definitions

Many agencies now collect cost and other data about unsealed roads (and other assets) using systems set up by accountants. When preparing to implement a maintenance and cost tracking system, serious consideration should be given to how costs and tasks will be assigned and classified. The line items to which costs are assigned should fulfill the needs of both accountants and engineers. Frequently, cost-tracking systems are established by and for accountants.

The following definitions are proposed for describing tasks performed on the surface of unsealed roads.

- **Blading** (Surface Smoothing; Dragging)
  - *Purpose*: Remove surface defects; minor crown restoration
  - *Equipment*: Motor grader, and possibly but not typically a compactor or water truck
  - *Extent*: Limited to the driving surface and shoulders, going only deep enough to remove surface defects, such as ruts, washboards, and potholes; throughout the length of the section or in extensive areas greater than 20% of the section length where surface defects are significant, ignoring those areas without significant surface defects.

- **Reshaping** (Pulling shoulders; Cleaning ditches; Blending gravel)
  - *Purpose*: Improve drainage; recover material from the foreslope or ditch; blend surface gravel; restore crown; remove surface defects; correct defects in the road's cross-section
  - *Equipment*: Motor grader, and possibly but not typically a compactor, water truck, or vegetation removal equipment
  - *Extent*: Greater than that for 'Blading;' to a depth greater than surface defects to blend the gravel, and/or the foreslope and ditch; throughout the length of the section or in extensive areas greater than 20% of the section length where such work is necessary, ignoring those areas that don't need reshaping.
- **Regravel**
  - *Purpose*: Restore structural capacity; improve quality of surfacing gravel; replace lost gravel
  - *Equipment*: Motor grader, haul trucks; typically but not always compactor, water truck
  - *Extent*: Typically the entire section length and at least 20% of the section length. Does *not* include the preparatory work of reshaping the road before placement of additional gravel; this work should be classified as 'Reshaping.' Also, it does not include dust suppression or soil stabilization.
- **Dust Control**
  - *Purpose*: Reduce emanation of fugitive dust
  - *Equipment*: Distributor, and often motor grader, haul truck, and compactor
  - *Extent*: Entire driving surface of the roadway for at least 20% of the section length. Generally applied topically.
- **Stabilization**
  - *Purpose*: Improve structural capacity; reduce routine maintenance frequency
  - *Equipment*: Motor grader, distributor, haul truck, compactor, and sometimes a reclaimer or pugmill
  - *Extent*: Entire driving surface of the roadway for at least 20% of the section length. Generally blended into the road surface with a reclaimer, pugmill, or motor grader.
- **Isolated Repairs** (Spot gravel, Patching, Soft spot repair)
  - *Purpose*: Correct isolated defects in a roadway
  - *Equipment*: Varies, but often includes motor grader, skid steer, haul truck, compactor, water truck, backhoe
  - *Extent*: All activities normally classified as 'Routine Blading,' 'Reshaping,' 'Regravel,' 'Dust Suppression,' 'Soil Stabilization' and other repairs with a total cost less than $50,000 per mile per repair event which are performed on less than 20% of the roadway.
- **Major Work** (Major Repairs, Realignment, Rehabilitation, Reconstruction)
  - *Purpose*: Correct major structural or functional flaws
  - *Equipment*: Highly variable and extensive

- *Extent*: Above and beyond that described for other activities, with surface and structural roadway repairs costing more than $50,000 per mile per event excluding work that falls into one of the other maintenance tasks, and repairs that don't fall into any other category but that take place on 20% or more of the section length.

- **Drainage**
  - *Purpose*: Restore drainage and water flow, prevent scour, erosion and piping
  - *Equipment*: Variable, but often including shovels and backhoes
  - *Extent*: Shoulders, foreslopes, ditches, backslopes, culvert ends

When establishing or changing maintenance and cost tracking systems, one should have a clear idea as to how establishing such a system will improve the agency's operations. From a gravel roads management point of view, all costs should be attributable to an individual road section and to one of the eight tasks listed above.

4.5.3.1 Maintenance Type Decision Tree

Figures 1 and 2 consist of a maintenance type decision tree, a flowchart that shows how maintenance costs should be assigned to the tasks listed above, with the exception of drainage maintenance. It is apparent from this chart that two of these tasks, 'Isolated Repairs' and 'Major Work,' are basically catch-all classifications, while the other five tasks, 'Blading,' 'Reshaping,' 'Regravel,' 'Dust Suppression,' and 'Soil Stabilization' are specifically defined maintenance tasks that would be programmed in an effective GRMS.

4.5.3.2 Section Length Cutoff for Specific Maintenance Tasks

A critical element of the above definitions and of the maintenance type decision tree is the cutoff at 20% of the section length. For the five specific maintenance tasks, they must be performed on at least 20% of the section length for the section to have received that treatment. Otherwise the work will be considered 'Isolated Repair' or 'Major Work,' depending on whether the cost of this and other work on the section is more or less than $50,000 per mile averaged over the entire section length.

For example, if a gravel patch covering 7% of a section's length is applied, representing the 'regravel' task, the section should not be considered to have been 'regraveled,' nor should the work be classified as 'regraveling.' However if 90% was regraveled and 10% was not regraveled since, for whatever reason, it had more than enough gravel already, the whole section should be considered to have been regraveled. Thus, somewhere between 7% and 90% of the section length must be a cutoff where one does or does not consider the 'regravel' treatment to have been applied. It has been suggested that 20% of the section length must receive a given treatment for the section to be considered to have received this treatment from a management point of view. This cutoff should be determined by individual agencies, with 20% being a reasonable default recommendation.

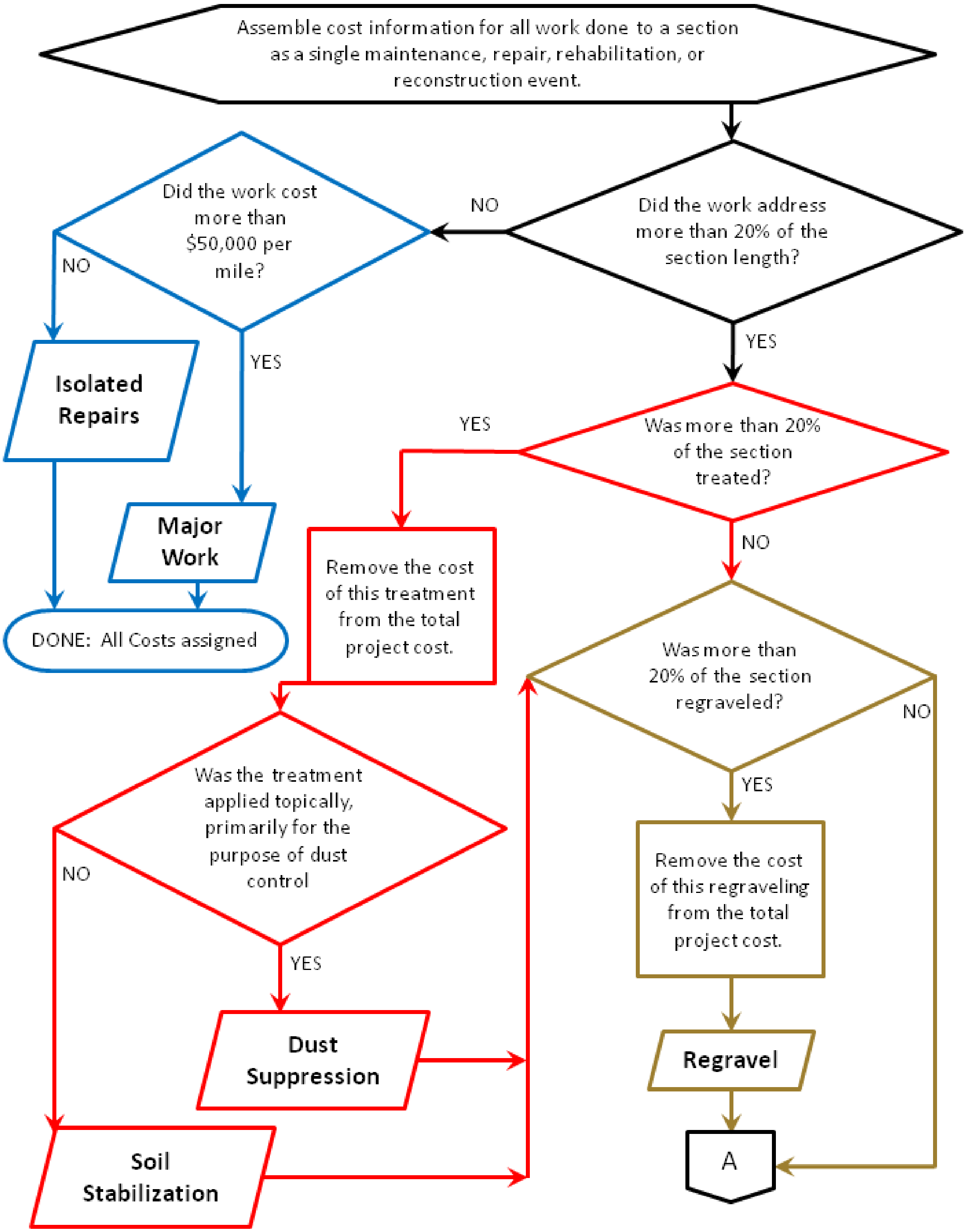

Figure 1 Maintenance cost task assignments: Part A

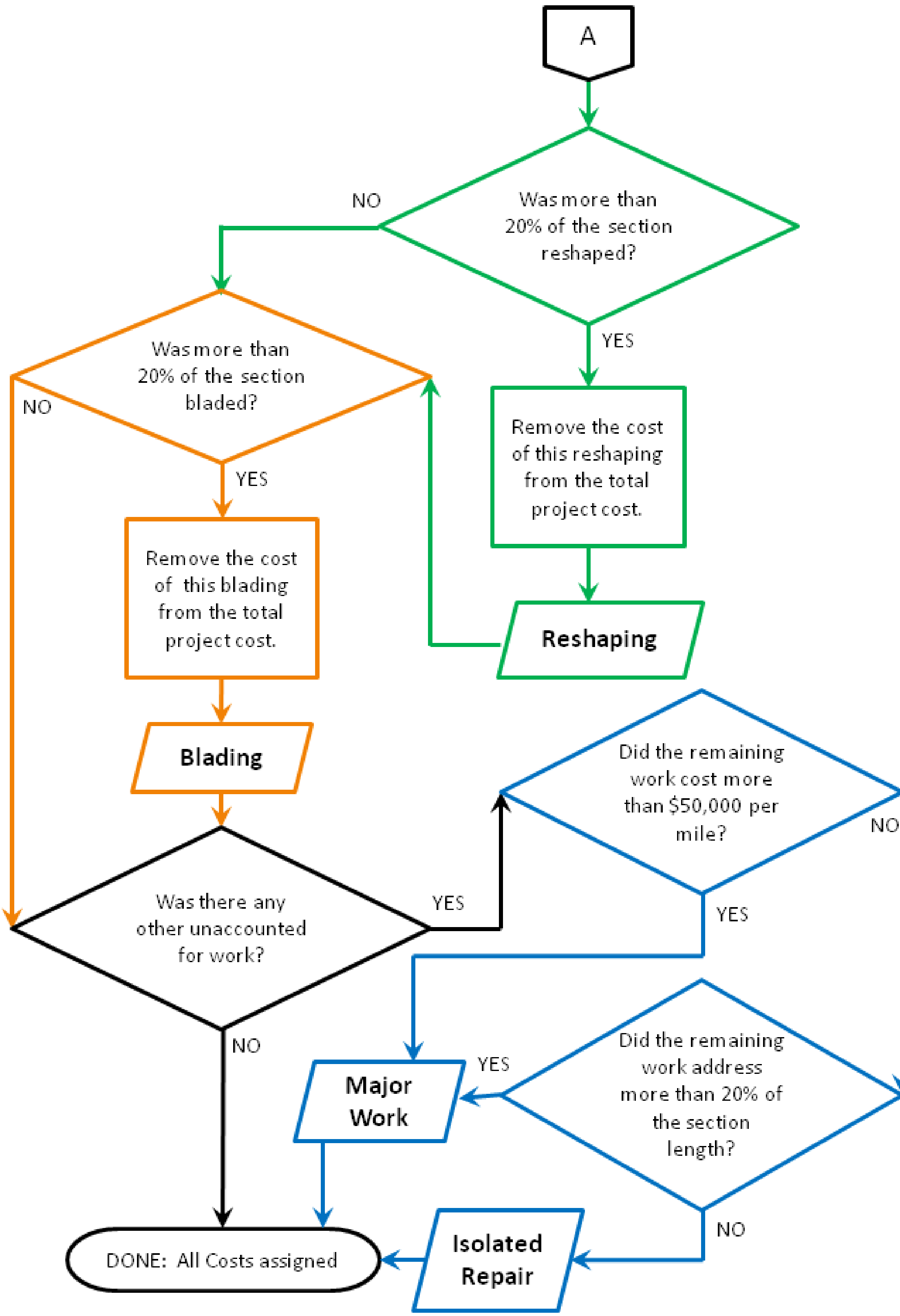

Figure 2 Maintenance cost task assignments: Part B

4.5.3.3 Cost and Section Length Cutoff for Catch-All Tasks

There will always be some work that does not fall into any of the six maintenance tasks listed above. Such work should be assigned to one of two categories, either 'Isolated Repairs' or 'Major Work.' Placing geotextile between the base and subgrade, or earthwork to improve a dangerous curve are examples of work that doesn't fall into any of the five maintenance categories. They should be classified as 'Isolated Repairs' or 'Major Work,' with the operational difference being that a road section should be re-evaluated if 'Major Work' is done, but not if 'Isolated Repairs' are done. It has been suggested that if work costs more than $50,000 per mile, or if it is performed on more than 20% of the section length, it should be considered 'Major Work;' otherwise it should be considered 'Isolated Repairs.' Like the 20% of the section length cutoff described above, this $50,000 per mile cutoff may be adjusted at the discretion of the individual agency.

The decision of how to distinguish between 'Isolated Repairs' and 'Major Work' is largely arbitrary; the reason for making this distinction is that 'Major Work' will trigger a reassessment of how a road is to be maintained, while 'Isolated Repairs' does not necessitate a change in plans. The fundamental issue is whether the work is substantial enough to warrant a reassessment of the maintenance strategy which is to be applied to the road.

It is recommended that any work beyond that which comprises any of the five specific maintenance tasks is classified as 'Major Works' *if* its average cost over the entire section length is more than $50,000 per mile or it is applied to more than 20% of the entire section length; otherwise, the work is classified as 'Isolated Repair.' The figures of $50,000 per mile and 20% of the section length are fairly arbitrary and are based upon engineering judgment, rather than on any specific or rigorous analysis.

4.5.3.4 Maintenance Task Classification: An Example

Sometimes maintenance tasks performed on an unsealed road may be subservient to other activities, but they should be classified on their own. For example, a rehabilitation project might consist of:

- Realigning a bad curve consisting of 5% of the section length,
- Pulling the shoulders and blading the ditch on 30% of the road that had significant drainage problems,
- Replacing two large culverts, and
- Regraveling the entire section with chemically stabilized gravel.

If realigning the curve cost less than $50,000 per mile averaged over the entire section length, it would be an 'Isolated Repair;' otherwise it would be 'Major Work.' The cost of shoulder and ditch work would be classified as 'Reshaping.' The culvert costs would be tracked independently of the GRMS, hopefully with a culverts or drainage management system. The cost of acquiring, hauling, and placing the gravel would be 'Regravel.' The cost of purchasing, hauling, and blending the stabilizing agent would be 'Soil Stabilization.' Though this may seem like a lot of wasted effort, it will be used to program future maintenance on the road, thereby saving substantial time and money by not over- or under-maintaining the road when a cyclic maintenance program is instituted.

4.6 Condition Data

In establishing a condition monitoring program, one should determine what the data will be used for. The two fundamental reasons for collecting surface condition data are, first, to use condition data as the trigger for scheduled maintenance, and, second, to determine the overall condition of the network including its expected performance.

Condition data may be collected visually from within the vehicle, a 'windshield' survey method; they may be collected manually by getting out of the vehicle and measuring; or they may be collected using automated devices such as roughness meters and traffic counters. Each of these has associated costs and data quality.

Section 2.5 Data Collection Methods provides further discussion on possible means of collecting condition data. The two basic elements of condition data, current performance and durability, should be kept in mind. Current performance is determined primarily by the extent and severity of potholes, washboards and ruts and secondarily by dust and loose aggregate (safety concerns also factor into current performance though they should generally be addressed separately). Durability or future performance is predicted primarily by crown, drainage, and gravel thickness and secondarily by dust and loose aggregate which reflect gravel loss. Other factors, particularly climate, subgrade and maintenance practices including snow plowing, also affect the durability of unsealed roads.

Once an inventory is established and a road network's history is being recorded, the next step in gravel roads management is monitoring sections' condition. By evaluating road surface conditions in a systematic way, maintenance and repair schedules can be generated. Such schedules will lead to a wide variety of outputs, including triggered maintenance programs and assessments of how an unsealed road network's overall condition is changing with time. However, there is a trade-off. It takes time and money to collect and manage data. In addition there are several logistical problems with monitoring the surface condition of unsealed roads:

- Rapid Deterioration
  - Unsealed road surfaces deteriorate much more quickly than sealed roads, even under the best of circumstances. The fact that they do so means a road that is in very good shape today may look quite different next week, making condition data suspect at best and irrelevant at worst.
- Weather and Precipitation
  - Unsealed roads are highly susceptible to weather changes, particularly precipitation and snowmelt. No matter how good the road's crown and drainage, some moisture remains on or in the road, softening it and making it more prone to ruts and potholes.
- Maintenance
  - Unsealed roads are maintained much more frequently than sealed roads. In order to collect meaningful condition data, one must coordinate condition data with maintenance data.

- Vehicle Path
    - When driving down an unsealed road, most drivers will try to miss potholes, washboards and ruts. One can often greatly increase travel speeds by dodging most of the road's distresses. This consideration makes even automated monitoring of unsealed road conditions suspect.

In spite of these problems, it may be possible to obtain meaningful condition data. The rapid deterioration and maintenance issues may be addressed by considering the time since the most recent maintenance when assessing condition data. Recording the moisture condition of the road along with condition data may provide some insights into the true typical condition of the road. Having a single driver operate an automated test vehicle may reduce the impacts of different drivers taking different paths down an unsealed road. These issues need to be considered before undertaking an unsealed roads condition monitoring effort.

4.6.1 Condition Monitoring Methods

There are several methods for evaluating the quality of an unsealed road's surface as perceived both by the traveling public and by those who work on those roads. Simply put, the public is concerned with conditions now, while agency employees are concerned with the maintenance the roads will need and how current conditions predict future conditions.

There are several options when contemplating monitoring surface conditions of an unsealed roads network, each with its own strengths and weaknesses. Most agencies will decide upon one or more of the following data collection techniques, depending on the purposes to which the data will be applied.

- Visual surveys from within a vehicle
    - Surface and ride-related conditions
    - Crown and super-elevation
    - Foreslopes and shoulders
    - Ditches and culverts
    - Safety and Clear Zones
    - Supplement with digital photographs
- Manual measurement of distress severities and extents
    - Sampling road sections and performing measurements to determine a condition index
- Automated condition surveys
    - Use of a vehicle that routinely travels a road network to automatically collect roughness data
- Gravel thickness measurement
    - Excavation
    - Ground penetrating radar (GPR)
- Reasonable travel speeds
    - Limited by surface roughness
    - Limited by alignment

- Limited by sight distance

For any of these methods, the data collector should be trained. This is essential to gathering consistent data. Overall instructions to data collectors need to be explicit. Should the data collector record the current condition of the road or the typical condition? Ideally, for long-term network level uses and for regraveling or dust suppression issues, the typical condition should be recorded. If adjusting routine maintenance schedules is the objective, current conditions may be the most important. In all cases, the training and methods of data collection should be appropriate for the data's application.

The following discussions attempt to describe the pros and cons of several approaches to unsealed road condition data collection.

4.6.1.1 Subjective Visual Survey

The simplest method of evaluating a road's surface is to drive it and subjectively rate it as described in section 2.5 Data Collection Methods. The PASER system *(Walker 1989)* is a good example of this approach. Training is critical to maintaining consistency using a subjective visual survey. Additionally, one should tailor training and evaluation standards to the purposes for which they are to be used, keeping in mind that a visual survey may try to merely evaluate current ride conditions, or it may provide an overall condition rating that both assesses current conditions and predicts future conditions.

Using a subjective rating of the road surface condition based on a system, such as the PASER method, has both advantages and disadvantages. The main advantage is that it is quick and inexpensive to perform. The main up-front expense is training, a critical step to getting some consistency from evaluator to evaluator. This leads into the main disadvantage; it is difficult to get consistent ratings, not just from evaluator to evaluator, but even a single individual may have some drift in their standards, depending on such uncontrollable variables such as how much sleep they got last night (more sleep, better condition ratings) and whether they had time for a third cup of coffee (more coffee, worse condition ratings). It is difficult to rate roads the same way from day to day. However, with that said, it is also surprising how consistently well trained evaluators will rate a road. In spite of these problems, a simple subjective rating of a road's surface condition, particularly when the evaluator is focusing on current conditions alone, can provide good, repeatable results at a very low cost. This is particularly true if evaluators receive both classroom and field training in rating unsealed road surface conditions.

When using such a system, one should adopt a ten-scale, with the following verbal descriptions of the surface condition:

1. Failed
2. Very Poor
3. Poor (closer to Very Poor)
4. Poor (closer to Fair)
5. Fair (closer to Poor)
6. Fair (closer to Good)
7. Good (closer to Fair)
8. Good (closer to Very Good)
9. Very Good
10. Excellent

The PASER ratings only evaluate on a five-scale (Excellent, Good, Fair, Poor, Failed), but when using a five scale, one is often torn between Fair and Good or between Poor and Fair. Further justification for using a ten-point rating scale is provided in section 2.5.4 Wyoming LTAP Experiences.

4.6.1.2 Unsurfaced Road Condition Index

The USACE has developed a method of deriving an unsurfaced road condition index (URCI) using severity and extent measurements to determine deduct values, resulting in an URCI between 0 and 100 *(Eaton and Beaucham 1992*) as described in section 2.5.2 USACE-CRREL Unsurfaced Road Condition Index. This method is too time-consuming to be used on road networks on the order of hundreds of miles, though it may have some value as a check of other data collection methods or as part of a sampling condition assessment procedure.

Manual measurement of distress severities and extents are fairly reproducible, though, like with visual surveys, there is also a considerable degree of subjectivity and judgment when employing a method such as the one proposed by the USACE-CRREL. Unlike visual surveys, these distress measurement methods take considerable time to carry out, so they may not be practical for agencies that maintain large networks with very few employees.

4.6.1.3 Automated Data Collection

At least two automated roughness measurement devices for unsealed roads are available and in use by a number of jurisdictions around the globe. They have been used effectively to adjust maintenance schedules when used continuously. One is described in section 2.5.3 Canadian Automated Evaluation and Maintenance System and by *(Brown et al 2003)*; the other is used in Australia *(Giumarra 2009).* As global positioning system (GPS) and other related systems become more sophisticated, automated data collection is becoming more viable, perhaps even for small, local agencies. For such a system to be most cost effective, continuous data collection systems should be mounted on a vehicle that will be traversing the road network whether or not it is collecting data. While a dedicated data collection event could be carried out with an automated system, the problems of a rapidly changing surface may reduce the usefulness of data collected only occasionally with an automated roughness measurement system. One advantage they have is that they can be used to continuously monitor road conditions on a vehicle that routinely travels the roads being evaluated and managed. Thus the additional cost involves only the equipment, download, and analysis costs since the monitoring vehicle will be traveling the monitored roads regardless of whether or not it carries the roughness measurement equipment.

Automated data collection methods have considerable promise. On county road networks, they would probably need to be mounted on vehicles that routinely drive the county roads, such as parcel or mail delivery vehicles, propane delivery trucks, or electric meter readers' vehicles. These vehicle types all serve residences. Other vehicles, such as fuel trucks, might be used to monitor remote industrial roads, such as those serving oil and gas drilling operations.

4.6.1.4 Gravel Thickness

Though the traveling public doesn't care how thick the gravel is, for agency employees it is a critical indicator of both time until the next regraveling and the road's future performance. In an ideal world, an agency would always know not only the thickness of the gravel but also its current gradation and plasticity index. Though all this information will never be available, we may be able to occasionally assess the gravel thickness of some unsealed roads.

Measuring the gravel thickness on unsealed roads is usually determined with a skid steer and auger such as a fencing crew might use, though other methods of digging may also be used. A hole is punched 3 or 4 inches into the road and the operator looks inside to see how thick the surfacing gravel is. Often, one may simply enter 'thicker than 4 inches' and consider that to be enough information. Unfortunately, any road will have some variety in its lift thicknesses, and this is probably more pronounced on unsealed roads. Therefore, thicknesses should be checked in several places within a road section. This information provides a method to estimate the remaining life of an unsealed road surface, with 'remaining life' defined as the time until the most expensive unsealed roads maintenance procedure, regraveling, needs to be performed.

Measuring gravel thicknesses by excavating the road's surface is fairly labor-intensive. For a given road section, several holes should be dug to get a representative value for the gravel thickness. It takes a trained eye to discern lifts in unsealed roads since the lift lines are generally not as distinct as they are for other pavement types. Given the labor-intensive nature of collecting thickness data, an agency should use some discretion when deciding where to collect this data. The highest volume roads, those that receive periodic regraveling the most often, should be the top priority for this measurement, while those with very low volume may only rarely need to be measured.

Alternatively, thickness data may be collected using ground penetrating radar (GPR), though this technology may not yet be ready for production-scale applications.

The purpose of collecting these data is likely to be two-fold. First, regraveling can be programmed based on existing thickness, rather than on the time since the road was regraveled or on visual observations, and, second, this information can be used to generate a 'remaining service life' (RSL) for each road and for the network as a whole.

4.6.2 Condition Data Collectors

There are several options when it comes to deciding who will collect unsealed roads data, and agencies may choose to collect data in several ways. Operators, supervisors, and other regular agency employees may evaluate roads, either during the course of their other activities or as a separate task. Dedicated data collectors may be hired to evaluate roads. Recent agency retirees are obvious people to hire since they have a good knowledge of the road network and of unsealed roads in general.

Automated data collection may be performed as described in section 4.6.1.3 Automated Data Collection.

Condition data, particularly the ride-related distresses of potholes, ruts, and washboards, can be rated by anyone with experience driving unsealed roads and sufficient diligence to provide consistent data.

Other data, such as drainage and safety ratings, should be collected by skilled individuals. These elements of a road are not necessarily obvious to the general public.

Thickness data should be collected by individuals who have either a GPR or the equipment at their disposal to quickly dig holes in the road to estimate gravel thickness, a skid steer with an auger or other suitable equipment. They must also have sufficient experience with unsealed roads to discern lift lines from a core hole or the ability to discern lift thicknesses from the output from a GPR.

The least expensive data will be those which are collected as a part of someone's usual routine. A maintainer might take an extra minute and evaluate the surface conditions of the road section he is about to maintain.

Intermediate in cost will be the data collected by agency employees, generally during slow periods. They are already hired and on the payroll, so keeping them productive during slow times by sending them out to perform visual surveys may save money in the long run by allowing the supervisor to make better resource allocation decisions when things get busy.

The most expensive data will be those which are collected by people hired or equipment purchased specifically for data collection. This data will also be the most consistent since there will be fewer individuals collecting the data and, since they are dedicated data collectors, they should be well trained and focused on the task of gathering information.

4.6.2.1 Operator-Collected Condition Data

Having operators collect condition data has one primary advantage – they are already out there, so the cost of data collection is very low, both in terms of time and money. No specialized equipment is needed so initial costs are limited to training. Data may be collected at the time of routine maintenance. Operators may also collect data during the performance of their other duties as they traverse the agency's unsealed roads. Of course, this type of data collection is subject to the disadvantages described earlier in section 4.6 Condition Data, particularly the weather, path, and maintenance concerns. If data are collected as part of routine blading, they will be collected at roughly the time when the road is assumed to be in its minimum allowable condition, particularly if a cyclic maintenance schedule is implemented, as described in section 5.1.2.4 Optional Surface Condition Evaluation. This is the condition we are most concerned with when programming maintenance, so, in some ways, this is the ideal time to perform data collection, another advantage of this data collection method.

4.6.2.2 Dedicated Data Collector Inputs

Hiring or assigning dedicated road evaluators has one main advantage: The data will be collected by a few evaluators, so they will be more consistent. The obvious disadvantage is that by dedicating someone to just collecting data, the cost of the data will be substantially higher, though by using knowledgeable part-time employees, such as recent retirees from the agency's road or street crew, costs may be kept within reason.

Using dedicated data collectors raises issues with the timing of data collection, though there may be solutions to these problems, as well. If retirees wanting to supplement their retirement checks are hired, they may be flexible as to when they work. If considerable time has passed since an agency's roads have been maintained, they may be as near as they ever get to being in 'typical' condition. This might be a good time for dedicated road evaluators to spend a week or two rating the agency's roads, particularly the higher volume roads where accurate condition data are most important.

If costs can be kept within reason and evaluations can be timed so that they provide reasonably valuable information, hiring or assigning dedicated data collectors may be a viable alternative. Data collection would probably be performed either with a visual survey method or with an automated roughness measurement device.

4.6.2.3 Supervisor or Other Agency Personnel Data Collectors

Data collected by agency personnel other than those who collect the data as an aside to their usual activities, as described above in section 4.6.2.1 Operator-Collected Condition Data, will have similar issues to those described in section 4.6.2.2 Dedicated Data Collector Inputs. However, having people already on staff will save the cost of hiring additional personnel, though it may detract from some of their other work.

4.6.3 Timing of Condition Data Collection

Timing condition data collection is a particularly vexing issue, since surface conditions may change so often and so quickly.

If a system-wide data collection effort is to be undertaken, it should be done at a time when most roads are in a relatively static condition. This might take place in late fall when the last rain has already fallen but before the roads' surfaces are covered with snow and ice. At least in semi-arid climates, routine maintenance is often put off until there is sufficient moisture naturally present in the road surface. This moisture often causes a substantial increase in surface distresses, particularly ruts and potholes. In cold regions, roads change little during the coldest months when the road is frozen. If there is little enough snow on the roads, they may be rated during this time as well, since it may represent the 'typical' road condition fairly well. In any case, from a network-wide point of view, most of the roads should have been maintained neither too recently nor too long ago – they should be in 'typical' condition.

The other type of data collection will be ongoing data collection – that which takes place largely as a part of an agency's other activities. Generally, the timing of this data collection will be driven by the availability of labor. Still, some consideration should be given to recent precipitation and maintenance activities. Generally, we should try to rate roads when they have neither been maintained nor rained on too recently so their current ride is typical of that throughout much of the year.

An exception to this generalization occurs if data are used to determine when to perform routine maintenance. For this purpose, we want to know the current condition, particularly the quality of the riding surface, so we should simply rate the current conditions. This type of data will most likely be collected automatically, since one generally can't collect data fast enough to establish routine maintenance schedules with a non-automated system.

An option to consider would be to have a prioritized list of roads to be evaluated. Roads with higher volumes and functional classes would receive the highest priority, as would those that have gone the longest since they were last evaluated.

4.7 Safety Evaluation

Safety assessment should be undertaken on a regular schedule, probably every few years or so. Since much of the safety focus in this project relates to making the roadway prism geometry as safe as possible, and since this is established mainly during reshaping, it makes sense to schedule safety inspections just before reshaping is performed. A road section safety summary could be presented to maintainers so they might correct as many safety defects as possible during the reshaping operation.

In addition to the proactive, routine inspections described above, safety inspections could also be reactive if a particular location has a crash history that indicates it should be examined in more detail. Such inspections should assess both the cause of any crashes and any factors that may impact the severity of future crashes.

The safety component of this effort should compliment other safety efforts, such as those based on crash data, road safety assessments, and other formalized safety improvement procedures. Other safety issues on unsealed roads, such as signing and delineation, should be addressed, but they are outside the scope of this project. This safety effort is tailored to roads with too little traffic for crash data to be statistically useful and it should address safety issues that can be improved at low cost during maintenance activities, such as minor geometric improvements made while pulling shoulders and reshaping ditches.

These evaluations should be performed by dedicated data collectors. The information collected using this method should be used by maintainers and supervisors to evaluate where additional safety efforts might be applied to improve the overall safety of the unsealed road network. It might also be used to modify some maintainers' practices so they leave a road safer after maintenance, particularly when reshaping the roadway prism.

Safety issues on unsealed roads include the need for maintainers to understand the safety implications of their operations, both the immediate threats posed by their presence during maintenance and the long-term effects of how they leave the roadway, particularly shoulder steepness, edge drop-offs, clear zone width, objects and overturning hazards within the clear zone, and proper crowns and superelevations.

Several features that might be rated and suggested rating formats might include the following:

- Foreslopes: Overturning Potential
    - Severity
        - Steeper than 3:1
        - 3:1 to 4:1
        - 4:1 to 5:1
        - Flatter than 5:1
    - Extent
        - >50%
        - 20% - 50%
        - 5% - 20%
        - 2% - 5%
        - <2%
        - None
- Isolated Overturning Hazards within the Clear Zone
    - Severity
        - High, Medium, Low
    - Extent
        - >10 per mile
        - 5 to 10 per mile
        - 2 to 5 per mile
        - <2 per mile
        - None
- Immovable Objects within the Clear Zone
    - Severity
        - High, Medium, Low
    - Extent
        - >10 per mile
        - 5 to 10 per mile
        - 2 to 5 per mile
        - <2 per mile
        - None
- Clear Zone Width
    - Width
        - <2'
        - 2' to 5'
        - 5' to 8'
        - 8' to 12'
        - 12' to 16'
        - >16'
    - Extent
        - >50%
        - 20% - 50%

        - 5% - 20%
        - 2% - 5%
        - <2%
        - None

The following potential problems do not lend themselves to easy rating as do the situations above, so they should be noted and described:

- Geometric Issues
    - Horizontal curves
    - Vertical curves
    - Blind driveways/approaches
    - Limited sight distance intersections
    - Inconsistent design: surprise curves, dips, and so on
    - Superelevations and crowns
- Surface Issues
    - Potholes and ruts
    - Corrugations/washboards
    - Slippery when wet
    - Loose material
    - Dust
- Other Issues
    - Edge drop-off
    - Bridge approaches
    - Soft shoulders
    - Signage and delineation
    - Vegetation
    - Animals

Before collecting safety data, an agency should have a commitment not only to identifying safety problems but also to correcting problems as they become aware of them. To this end, it would be wise for agencies to focus on identifying issues that they have the resources to improve, rather than simply identifying all safety problems. For this reason, with the *'Geometric Issues'* and *'Other Issues'* above, the evaluator is only instructed to describe the issue. Such descriptions might be used for a preliminary evaluation of areas for improvement as funding becomes available. The other four areas rated, *'Vehicle Overturning Hazards: Steep Shoulders and Foreslopes,' 'Isolated Overturning Hazards within the Clear Zone,' 'Immovable Objects within the Clear Zone,'* and *'Clear Zone Widths'* may be rectified by altering maintenance practices or by other minor, low cost actions. Since these last four areas are potentially very extensive, they are also subject to quantitative analysis, so it is worthwhile to enter quantitative values into a database.

An alternate approach might be to evaluate some of these eleven safety problems identified in the Australian manual *(Giumarra 2009)*. These are:

- "poor road surface conditions (loose surface materials, slippery surface when wet, dust emissions)
- poor geometric standards (tight curves, restricted sight distance, poor signage and delineation, poor vertical and horizontal coordination, roadside hazards) – multiple hazards often coexist
- inconsistencies in the road driving conditions that can suddenly surprise an unsuspecting driver (e.g. sudden dip or an isolated sharp curve on an almost straight road)
- low traffic volumes which can encourage higher travel speeds
- traffic composition which may include a high proportion of heavy vehicles
- driver behaviour (excessive speed, lower levels of restraint use, failing to keep left)
- collisions with native animals
- driver impairment (alcohol, fatigue)
- driver inexperience
- low levels of enforcement
- longer emergency services response times due to rural and remote location of crashes" *(Giumarra 2009)*

The first three of these might easily be evaluated while performing a 'windshield' safety survey, using an extent and severity approach such as the ones outlined above or with a description of problems.

4.8 Drainage Evaluation

As for safety above, drainage inspections should take place just before reshaping since drainage problems may be corrected during this procedure. Drainage inspection should also take place after an exceptional runoff event, both because it is easier to see how drainage performs during or just after these events and because these events may reveal problems that either weren't apparent or didn't exist before the flooding event.

Drainage should be rated to identify sections with significant problems, particularly those related to maintenance, and to provide insights as to why a given road may be performing poorly. It should assist maintainers with identifying areas where better or additional maintenance is needed.

Culverts should be evaluated for factors that can only be mitigated by replacement or other major work, such as proper placement, flow, erosion prevention, and scour resistance, but these evaluations are not unique to unsealed roads and should be addressed by a culvert management system. This effort only addresses those culvert drainage issues that can be corrected by routine maintenance practices.

Bridges should also be managed, though their management is beyond the scope of this study.

The following drainage features should be rated for severity and extent. Suggested extents for all these are: >50%; 20% - 50%; 5% - 20%; 2% - 5%; <2%; and None.

- Surface Drainage: Crown
  - *Very Good*: 4% to 5% cross slope, well-defined 'rooftop' shape; very good superelevations
  - *Good*: 3% to 6% cross slope; good 'rooftop' shape, minor flattening at the centerline; good superelevations
  - *Fair*: 1½% to 3% or >6% cross slope; generally has reasonable crown shape with limited flat spots at the centerline; minor superelevation deficiencies
  - *Poor*: 0% to 1½% cross slope; significant and extensive areas with deficient crown and flattening at the center; significant superelevation problems
  - *Very Poor*: 0% to inverted cross slope; generally lacks crown; poor or no superelevations
  - *Failed*: inverted cross slope; primary drainage is within the traveled way
- Surface Drainage: Shoulders
  - *Good*: Shoulders adequately and consistently carry water to the foreslope without obstruction
  - *Fair*: Occasional diversion of water away from the ditches by high shoulders, leading to limited erosion
  - *Poor*: Significant channeling of water above the ditches due to high shoulders, leading to extensive erosion
  - *Very Poor*: Extensive channeling of water in secondary ditches caused by high shoulders, leading to extensive and dangerous erosion
- Subsurface Drainage: Ditches
  - *Very Good*: No or negligible ponding or obstructions within ditches; depth of ditches at least 3' below the edge of the shoulder
  - *Good*: Only minor obstructions and ponding less than 6" deep within ditches; depth of ditches and any standing water at least 2' below the edge of the shoulder
  - *Fair*: Some ponding less than 1' deep within ditches; depth of ditch and any standing water at least 1' below the edge of the shoulder
  - *Poor*: Extensive ponding or blockages within the ditches; intermittent areas without ditching and extensive areas with ditches less than 1' deep
  - *Very Poor*: Water frequently standing by much of the roadway; ditches often not present or very shallow
  - *Failed*: Ditches generally not present; water is channeled onto the road surface
- Subsurface Drainage: Culverts
  - *Very Good*: Culvert ends clean and resistant to scour; barrel has less than 10% of its depth blocked
  - *Good*: Culvert ends in adequate condition with only minor susceptibility to scouring; only minor barrel blockage for less than 25% of the culvert's depth

- *Fair*: Some damage to culvert ends; significant scour potential; significant barrel blockage up to 50% of the culvert's depth
- *Poor*: Significant damage to culvert ends; significant risk of scour and piping; barrel blocked up to two-thirds of the culvert's depth
- *Very Poor*: Culvert's capacity a small fraction of its original capacity due to blockage or damage; high risk of scour
- *Failed*: No flow through culvert

Due to the relatively time consuming nature of collecting these data, they are designed to be collected on dedicated data collection efforts, rather than as part of routine activities. For ratings performed during routine activities, a simple evaluation of the overall drainage might be used, such as the one described in the drainage manual developed in Wisconsin *(Walker 2000).*

4.9 Implementation Summary

This chapter describes the process of implementing a gravel roads management system (GRMS). It begins by describing the assessment process when an agency evaluates its current situation and the tools and resources at its disposal to improve the situation. To a large degree, this process is an evaluation of the agency's current information management practices. Next, various data management options are described and discussed. Agencies are encouraged to adopt some sort of computer-based system for tracking information. The benefits of a geographic information system (GIS) are also discussed. Next, the critical step of developing a good inventory of the road network is described, providing details as to which pieces of information about various road sections within the agency's network are most critical. The process of dividing the network into maintenance management sections is described. Issues related to how maintenance and cost data are collected and classified are addressed next. The common problem of line items being established for accounting, not engineering or management, purposes are discussed and solutions are presented. A list of eight unsealed road maintenance tasks is presented. The collection of performance and condition data is described, with particular emphasis on solving the issues that make collecting surface condition data particularly challenging on unsealed roads. Finally, procedures for assessing safety and drainage issues are described. This section guides agencies from where their information practices are now to a situation where they gain considerably more value from their information collection, management and analysis efforts.

CHAPTER 5 ANALYTICAL METHODS

5.1 Cyclic Maintenance Scheduling

Once an agency has an inventory of their unsealed roads, including some sort of prioritization using techniques involving functional classes, minimum acceptable conditions, maintenance intervention levels, maintenance strategies, or other means, they may begin to develop prioritized lists of roads to receive maintenance ranging from routine blading to stabilization and regraveling. Figure 3 illustrates how such a system might work, including initial inputs, the routine maintenance cycle, and a condition-based feedback option.

5.1.1 Inputs

At the top of the flowchart in Figure 3 are two fundamental inputs, dividing the network into road sections and developing maintenance strategies, which are combined when a maintenance strategy is assigned to each road section.

5.1.1.1 Road Sections

An initial inventory is the starting point for a gravel roads management system (GRMS). Once an inventory is established, the road network should be broken down into maintenance management sections.

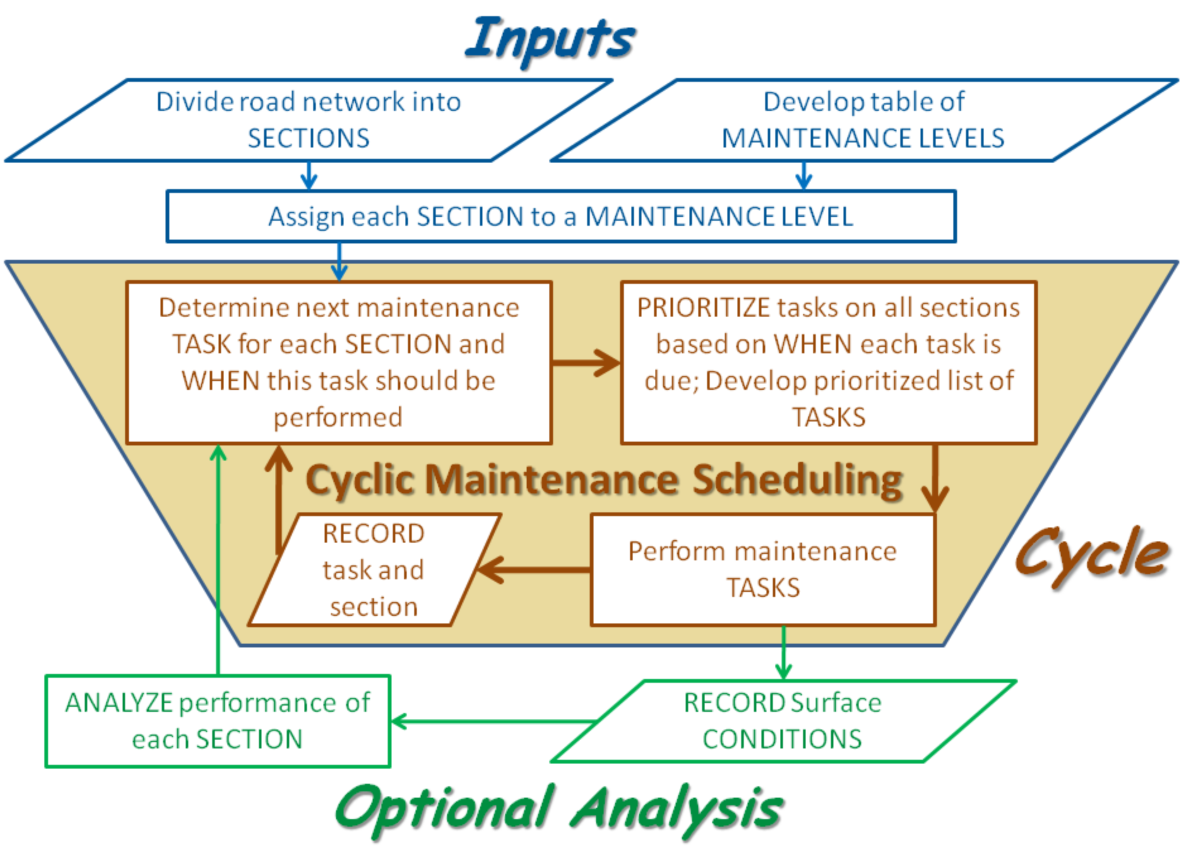

Figure 3 Cyclic maintenance scheduling

Often county road data are collected and organized by road name or number. In many cases, it will not be worth the additional effort to further subdivide a road network into smaller maintenance sections, particularly early in the implementation process. Breaking a road network into smaller sections provides better information, but it also means more time and effort must go into collecting the data. The process of splitting a road network into sections should seek a balance between the value of the information and the cost of obtaining and managing the data. For further discussion of the division of a road network into sections, the reader is referred to section 4.4.3 Dividing a Road Network into Management Sections and to Chapter 2 of the USACE publication *Unsurfaced Road Maintenance Management (Eaton and Beaucham 1992)*.

5.1.1.2 Maintenance Intervention Levels

Once the network is divided into sections, the agency must determine the minimum acceptable surface condition for each section and assign this condition as the 'maintenance intervention level.' A number of considerations should go into the decision of how to assign maintenance intervention levels, including the following:

- Traffic Volume
- Functional Class
- Road Usage
- User Costs
- Political Considerations

Considering these factors, a maintenance intervention level should be assigned to each section on a ten-scale from 1-Failed to 10-Excellent.

Section 2.2.1.2 Optimal Maintenance Levels in Latin America of this report provides some guidance on how to establish minimum surface conditions based on traffic levels. User cost analyses as described in section 7.3 Selection of Maintenance Intervention Levels could also provide some guidance in this assignment.

5.1.1.3 Maintenance Strategies

Each agency should describe and document the standard maintenance strategies they currently use, along with any other maintenance strategies they would like to program into their GRMS. This could be based on historical maintenance data or simply on the knowledge of agency road and bridge personnel. The goal of this assignment is to keep each road section in at least its maintenance intervention level as described in the preceding section. The following maintenance patterns are suggested options:

- ***N****: No maintenance*
    - Some earth roads may never be maintained. They will generally be jeep or 4WD trails traversable only during the dry season.
- ***D****: Drainage maintenance*

  - Some earth roads will only receive occasional drainage maintenance. They will generally be open seasonally and be inaccessible to many passenger cars.
- ***BD**: Routine blading and drainage maintenance*
  - Some very low volume earth roads will receive only routine blading and simple drainage maintenance, such as clearing culvert ends.
- ***BDS**: Routine blading, drainage maintenance, reshaping*
  - A few low volume earth roads may never receive additional gravel, particularly if they are placed on high quality subgrade, but they will need occasional blading and reshaping along with drainage maintenance.
- ***BDSG**: Routine blading, drainage maintenance, reshaping, regraveling*
  - This will be the typical, basic maintenance applied to many gravel roads.
- ***BDSGI**: Routine blading, drainage maintenance, reshaping, regraveling, isolated dust suppression*
  - This will be the typical, basic maintenance applied to some gravel roads with the addition of dust suppression in localized areas where dust is an environmental concern.
- ***BDSGU**: Routine blading, drainage maintenance, reshaping, regraveling, dust suppression over the entire section*
  - This will be the typical, basic maintenance applied to some gravel roads with the addition of dust suppression over the entire section.
- ***BDSGT**: Routine blading, drainage maintenance, reshaping, regraveling with stabilization*
  - This will be the typical, basic maintenance applied to a few gravel roads with the addition of a soil stabilizer.
- ***BDSGTU**: Routine blading, drainage maintenance, reshaping, regraveling with soil stabilization, dust suppression*
  - This will be the typical, basic maintenance applied to a few gravel roads with the addition of a soil stabilizer when the section is regraveled and periodic dust suppression.

Agencies should select their own list of possible maintenance strategies.

Figures 4 and 5 graphically represent two of the nine maintenance strategies in Table 5, with the lines pointing down indicating the cost of maintenance tasks performed. Note that some tasks are also included in higher level tasks; for example, in Figure 4 'Drainage' is not performed at years 0, 8 or 16 since 'Drainage' is assumed to be included in 'Reshaping.' Table 6 shows the secondary tasks assumed to be included in each primary task.

Though the timelines shown in Figures 4 and 5 are labeled from 0 to 20 years, their time frames could be extended or compressed, depending on characteristics of each road section, such as material quality, subgrade, and traffic.

Table 5 Sample Maintenance Strategies and Frequencies

Strategy	Example Frequencies, Events per Year: Drainage Maintenance	Routine Blading	Reshaping	Regravel	Isolated Dust Suppression	Section Dust Suppressoin	Soil Satbailization	Maintenance Interevention Level
N	0	0	0	0	0	0	0	1 - Failed
D	0.1	0	0	0	0	0	0	2 - Very Poor
BD	0.1	0.1	0	0	0	0	0	3 - Poor
BDS	0.2	0.4	0.05	0	0	0	0	4 - Poor
BDSG	0.267	2	0.133	0.067	0	0	0	5 - Fair
BDSGI	0.267	2	0.133	0.067	0.5	0	0	5 - Fair
BDSGU	0.2	1	0.1	0.05	0	0.5	0	6 - Fair
BDSGT	0.2	0.6	0.1	0.1	0	0	0.1	7 - Good
BDSGTU	0.2	0.6	0.1	0.1	0	0.4	0.1	7 - Good

TABLE 6 Tasks Included with Each Primary Task

Primary Task	Included Tasks: Drainage	Blading	Reshaping	Regravel	Isolated Dust Supression	Section Dust Supression	Soil Stabilization
Drainage	**X**	--	--	--	--	--	--
Blading	--	**X**	--	--	--	--	--
Reshaping	X	X	**X**	--	--	--	--
Regravel	--	X	--	**X**	--	--	--
Isolated Dust Suppression	--	--	--	--	**X**	--	--
Section Dust Suppression	--	X	--	--	X	**X**	--
Soil Stabilization	--	X	--	--	X	X	**X**

5.1.1.4 Assign Road Sections to a Maintenance Strategy

The goal of a maintenance strategy assignment should be to maintain the section in at least the maintenance intervention level which is economically appropriate for the traffic it receives, as described in section 5.1.1.2 Maintenance Intervention Levels. For each section, the agency should make their best estimate of which maintenance strategy should be assigned to each road section. Usually, this will closely approximate the maintenance the section typically receives. Based on estimates of factors that affect the maintenance frequency necessary to provide this service level, the frequency at which various elements of the maintenance pattern are to be performed should be assigned to each road section. Table 5 shows example maintenance frequency assignments based on functional classes and maintenance intervention levels. These frequency assignments should be based on agency personnel's best estimates of the maintenance frequencies needed to keep the road in at least the minimum acceptable surface condition, defined as the maintenance intervention level. It would be easy to have a standard frequency for strategy BDSG – blading, drainage, reshaping and regraveling – with the entire schedule expanded for roads expected to perform better and compressed for those expected to perform worse.

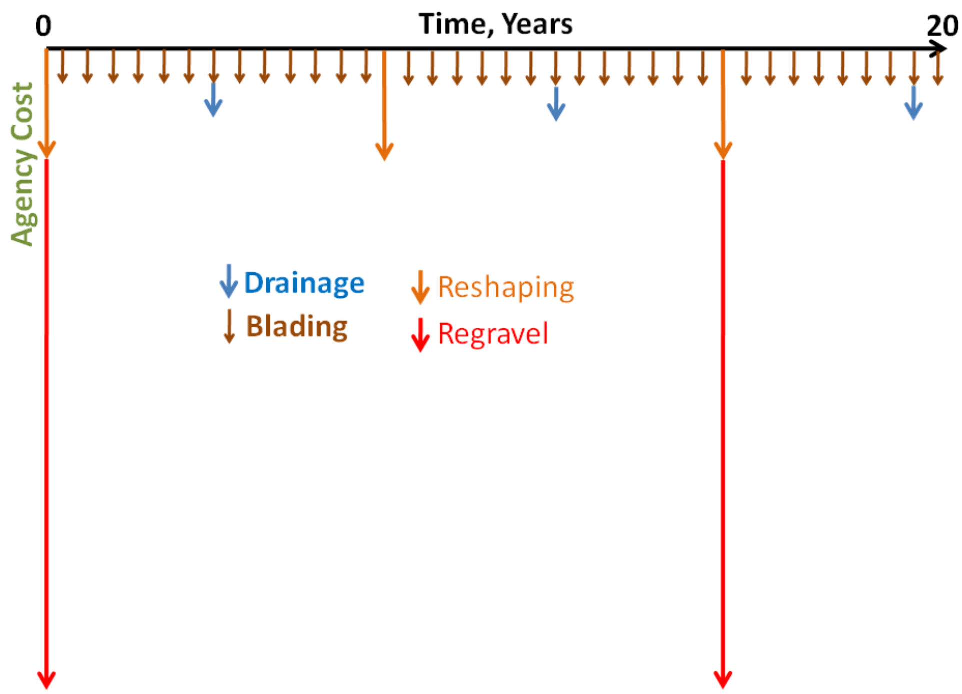

Figure 4 Strategy *DBSG*: Drainage, Blading, Reshaping and Regravel

Making these maintenance frequency assignments for each unsealed road section completes the input portion of the cyclic maintenance scheduling process. These are examples only, and maintenance frequencies should be influenced by a variety of factors, particularly traffic volumes.

5.1.1.5 Cycle Initialization Points

The final input needed to enter the cyclic maintenance process addresses when within its assigned maintenance schedule each road section is currently, that is: At what point on the timeline such as those in Figures 4 and 5 should each section start the maintenance cycle? Maintenance records should be used to establish this, with the time of the last blading, reshaping, regraveling, and dust suppression being the main entries.

5.1.2 Maintenance Cycle

The central maintenance cycle shown in the middle of Figure 3 should be used to direct maintenance tasks for both individual maintainers performing blading and reshaping and for the agency as a whole for drainage, regraveling, dust suppression and soil stabilization.

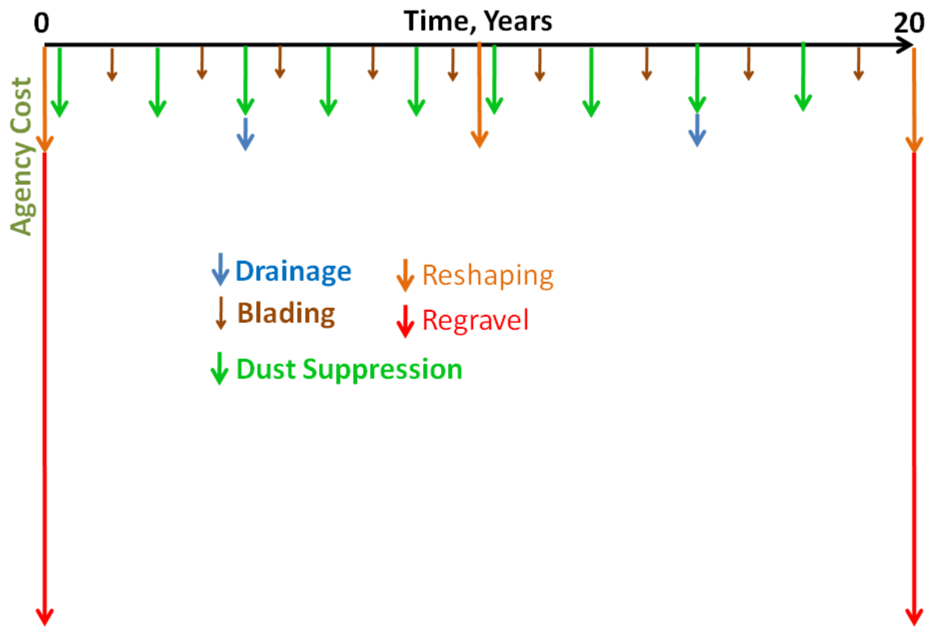

Figure 5 Strategy *DBSGU:* Drainage, Blading, Reshaping, Regravel and Section Dust Suppression

5.1.2.1 Prioritize Next Maintenance Tasks

The first step in developing a prioritized list of maintenance tasks is to determine what the next maintenance tasks are for every section and when they are due, as shown in the upper two rectangles in the 'Cycle' trapezoid in Figure 3. To do this, one needs to know when each task was last performed and the scheduled time between tasks.

For example, Table 7 shows the calculations that might be performed for a road receiving strategy DBSG – drainage, blading, reshaping and regravel – as shown in Figure 4. The current time in this example is 2011.0, January 2011. The 'time of last performance' indicates when each of the four programmed tasks was last performed; the 'scheduled time between task performances' comes from the selected maintenance strategy. The 'time since last performance' is the current time minus the 'time of last performance.' Dividing the 'time since last performance' by the 'scheduled time between task performances' yields a percentage, the 'current percent of scheduled time.' In this example, 'reshaping' at 123% of the scheduled time is due to be performed. However, if no maintenance is performed on this section until 2011.7, August 2011, the numbers will change, as demonstrated in Table 8. Now, blading at 180% of the 'scheduled time' is the highest priority task, followed by reshaping at 133%.

Ideally, the road would now be reshaped which would also include blading, though this section might only receive blading now if other sections have tasks at more than 133% of their scheduled time, moving them higher on the prioritization list.

This process would be repeated for every section within the network, an impossibly laborious task if done by hand, but an easy procedure with a properly programmed computer. It would yield a list for maintainers, perhaps after a rain or whenever it was determined that blading or reshaping are to be performed, which would show the roads most in need of blading and reshaping. The maintainer would then combine this information with his or her knowledge of the district's geography to plan a route that gets to the top priority roads as quickly as possible. It would also generate a prioritized list for supervisors indicating which roads need drainage maintenance, regraveling, stabilization and dust suppression. The maintenance crews could then be guided by this needs-based list, rather than simply responding to complaints or following a set cycle.

Table 7 Example Strategy DBSG at Time 2011.0

Task	Time of Last Performance, Year	Time Since Last Performance, years	Scheduled Time Between Task Perfromance, years	Current Percent of Scheduled Time
Drainage	2004.8	6.2	7.0	89%
Blading	2010.8	0.2	0.5	40%
Reshaping	**2002.4**	**8.6**	**7.0**	**123%**
Regravel	2002.4	8.6	14.0	61%

Table 8 Example Strategy DBSG at Time 2011.7

Task	Time of Last Performance, Year	Time Since Last Performance, years	Scheduled Time Between Task Perfromance, years	Current Percent of Scheduled Time
Drainage	2004.8	6.9	7.0	99%
Blading	**2010.8**	**0.9**	**0.5**	**180%**
Reshaping	2002.4	9.3	7.0	133%
Regravel	2002.4	9.3	14.0	66%

5.1.2.2 Perform Maintenance Tasks

Once the maintainers and supervisors have their prioritized lists in hand, they will maintain the roads.

The system as proposed does not directly provide a sequence for the maintainers since going right down the list might cause the maintainer to spend too much time moving the motor grader from section to section. Maybe someday someone with considerable expertise in fleet management and GIS programming will combine this method with geographic information to come up with a route for each maintainer such as the system developed in South Africa and referred to in section 2.2.2.1 Routine Maintenance Schedules. Recent developments in GIS software may make such applications easier. Until then, it is envisioned that the maintainer will use the prioritized list to adjust his or her schedule, with the final geographic planning being performed by the maintainer, perhaps in consultation with the supervisor.

5.1.2.3 Record Maintenance Tasks

As maintenance is performed, the work performed on each section will be recorded and this information will be stored in a database. This could be done with time cards, work orders, or some other type of field reports.

This new information is used to generate new priority lists, and the cycle continues. An option might be to generate work orders for the high priority tasks identified by the cyclic maintenance schedule generated as described in section 5.1.2.1 Prioritize Next Maintenance Tasks above. On such a work order, the maintainer might indicate the time spent performing the task and the equipment used, including both actual work time and the time it takes to get to the job site each day.

A GRMS should be able to identify the cost of maintenance with and without travel times and haul costs included. For presenting an overall picture of the cost to maintain a road or network, travel times and haul costs must be considered. However, when comparing the performance of similar roads, one will want to look at the costs of maintaining the roads using average rather than actual travel times and haul costs.

5.1.3 Optional Surface Condition Evaluation

The frequencies at which maintenance is performed may be adjusted based on the maintainers' evaluations as they work on the road. As shown in Figure 3, there is an optional approach in which the maintainer records the surface conditions when blading is performed, perhaps based on observations made while setting up traffic control signs. Such evaluations would be subjective ratings, perhaps based on the PASER system, though it seems advantageous to rate the surface conditions on a ten-scale, such as the one described in section 4.6.1.1 Subjective Visual Survey.

Since each section should have a targeted minimum surface condition rating based on the type and volume of traffic it receives, the targeted minimums can be compared to the observed surface conditions when maintenance is performed. A road that consistently is in better condition than its desired minimum could have its time between maintenance activities extended, while one generally in worse than the desired minimum condition could have its time between maintenance activities shortened. This approach provides a very simple means of lowering maintenance costs and keeping all roads in adequate condition with very minimal field data collection.

5.2 Triggered Maintenance Scheduling

Two methods of triggered maintenance scheduling, the use of current condition data to program maintenance have been discussed, though other methods might also be possible. One is the use of a continuous monitoring device to program routine blading, such as the method described in section 2.5.3 Canadian Automated Evaluation and Maintenance System, while the other is the use of gravel thickness data to program regraveling. The Canadian system is documented elsewhere *(Brown et al 2003)*, while the use of gravel thickness as a maintenance trigger is not known to be well documented.

The principles of any triggered maintenance program are simple. Minimum performance thresholds are established. When conditions fall below the threshold, maintenance is performed. It is unclear which proactive maintenance practices analogous to crack and chip sealing of asphalt pavements are most beneficial and when they should be applied. When proactive approaches are used, systems could be developed to program, for example, regraveling whenever surfacing gravel thickness drops below two inches or adding soil stabilizer on roads with over 200 vehicles per day. The future of triggered maintenance programs is not well defined, though as more sophisticated and inexpensive data collection, particularly automated systems, become more prevalent, triggered maintenance may become more commonplace.

5.3 Network Level Outputs

There are likely to be two types of outputs from a GRMS. One will be the routine outputs, derived by simply clicking a button, and programmed in a static manner. The other will be flexible outputs generated to answer specific questions and performed by individuals with considerable familiarity with the software who are able to perform queries and other data manipulations to come up with desired outputs. The following discussions describe some of the outputs that might be derived from software used to operate a GRMS.

Another way of splitting outputs into two types would be, first, those that are useful for external communication with elected officials and the public. Justifying expenditures and practices is a necessary part of managing a road network, and an effective GRMS will be useful in fulfilling this function. Second, information can be generated that lets the agency provide better service at a lower cost by using more cost-effective practices and by making better decisions.

5.3.1 Network Level Condition Monitoring

A primary objective of a road management system is to provide an overall assessment of the network's condition and performance. Such assessments and other agency-wide information are referred to as 'network-level' management. One of the most basic pieces of information that will be of interest to elected officials and the general public is whether the overall condition of the network is improving, staying the same, or getting worse. With sealed roads, there are numeric ways of quantifying average network condition, using instruments that measure IRI (international roughness index). While there are similar instruments available for unsealed roads, there are systematic problems, mainly the weather and maintenance practices, that may easily cause substantial network-wide systematic bias in condition data collected during a single data collection event.

Estimates based on maintenance frequency as it is modified with conditions observed at the time of maintenance combined with gravel thickness and gravel loss rates will allow an agency to predict the RSL of the network as a whole. Though such methods are not thoroughly developed here, there are some basic principles that should govern the development of algorithms that could assess the RSL of a network.

5.3.2 Remaining Service Life (RSL) and Gravel Thickness

A good assessment of an unsealed road network's long-term condition and remaining service life (RSL) is gravel thickness. For a sealed road, the situation is much simpler. Surface conditions change slowly and in a predictable manner, so they may be used to generate RSL predictions. While, in an ideal world, frequent condition monitoring might yield overall condition assessments for unsealed roads, until very inexpensive means of collecting and processing a lot of real-time data become available, a proxy, such as gravel thickness, is needed to assess an unsealed road network's current typical condition.

It should be kept in mind that using an RSL approach for unsealed roads is different than it is for sealed roads. A properly maintained unsealed road, it may be argued, has an infinite service life. The term RSL should be used to indicate how far ahead an agency is in terms of the average time until regraveling is needed next. A decreasing average surfacing gravel thickness means a shorter time until the roads need more gravel, and it provides an indication that the network as a whole is falling behind. If an agency used thickness measurements to estimate the RSL of its higher volume unsealed roads, cyclic maintenance assumptions could be made for the lower volume roads, allowing an agency to arrive at reasonable values for the network-wide RSL without having to measure the thickness of every section. A final step when using thickness as a proxy for RSL would be assuming a rate of gravel loss, probably based on traffic and, if the information is available, on gravel properties such as the percent passing a #200 (75 µm) sieve, the plasticity index, and the presence of a soil stabilizer or dust suppressant. Probably the best assessment of how much service life is left in a unsealed road network is to measure gravel thicknesses.

Using the cyclic maintenance procedure described in section 5.1 Cyclic Maintenance Scheduling, one can easily derive the time until the next regraveling is scheduled. As time passes and more data are collected, this estimate will become better and better if some of the feedback and modification mechanisms described in section 5.1.2.4 Optional Surface Condition Evaluation are employed. This information could be used as the basis for remaining service life estimates. If thickness data are available, they could be used to calibrate estimates of the remaining service life of roads, particularly for the higher volume roads that need the majority of the gravel replacement. Perhaps combining the time until the next scheduled regraveling with thickness data could generate a more refined RSL, possibly one that could be derived without too much time spent measuring actual thicknesses.

5.3.3 Financial Tables

Financial tables should describe where the money is being spent. Three fundamental variables will be:

- Maintenance and Rehabilitation Tasks
- Road and Road Section
- Time Frame

Hopefully, the costs could be determined, for example, for 'blading' and 'regraveling' for all roads of a given type over a ten year period. Other costs would probably also be included, such as sign, culvert, bridge and asphalt road costs. Such tables could provide a good overall picture of where and how an agency is spending its money.

What these tables will *not* tell you is whether these expenditures are yielding good results. Indeed, this is the crux of the 'accountants problem' described in section 4.5.2 Maintenance and Cost Tracking: Line Items. We want to know not only what we are spending our money on, but also if we are spending it effectively, something financial tables won't tell us.

5.3.4 Road Maintenance History: Tables

A simple output that could be generated for any given road or road section would be its maintenance and rehabilitation history, hopefully including costs. This would have several functions. If questions come up, either from elected officials or the public, as to what work has been performed on a given road section recently, this question could be answered easily. Plans for a given road will usually be predicated on what work has been done to it in the past. Such a function could provide this information quickly and easily. Finally, different road sections, particularly those fulfilling similar functions could be compared using metrics such as tons of gravel applied per square yard per year. This might be useful, for example, to assess the performance of gravel from different sources under similar circumstances.

To generate these histories, a network inventory would be needed and maintenance histories would have to be available. To be useful, the maintenance history would have to be coded to identify maintenance tasks that are of interest, such as blading, dust suppression, and regraveling.

5.3.5 Road Work Maps and Tables

If a GIS based system is used, maps could be generated showing where a given type of work has been performed over a set period of time. If maps are not possible, tables could list where different maintenance tasks have been performed over a given time. For example, one might want to show where dust suppressants have been applied during the past two years. A map might be generated to display this, perhaps to justify applying dust suppressants to some roads but not to others. Roads bladed within the past month might also be mapped or listed. There could be a wide variety of applications for such maps and tables, both as a tool for communicating with the public and elected officials and for internal decision-making.

To generate this information as maps, maintenance histories and a simple inventory must be available within a GIS.

A related set of maps or tables would show how much money per mile is being spent throughout a road network. This might be used to answer questions about relative expenditures on roads.

Yet another related map or table might show how many tons of gravel per mile-year have been applied to each road section throughout the network. Though of little value to the general public, this would be very useful to agency personnel, particularly if they could relate this information to different gravel sources or maintenance practices, such as dust suppression or soil stabilization.

5.3.6 Condition Maps and Tables

If condition data are collected, an agency might be able to generate maps of the current and past surface conditions. Of course, for such maps to be meaningful, data would have to be collected in such a way that it accurately reflects the true 'typical' surface conditions. This issue is discussed more thoroughly in section 4.6 Condition Data.

5.3.7 Condition Projection Maps and Tables

As more data are accumulated and unsealed roads modeling becomes more sophisticated, it may become possible to project the future condition of an unsealed road network given various funding scenarios. Unfortunately the tools to make such predictions are not yet available, but this situation may change soon, making realistic predictions possible, particularly if a number of agencies collect unsealed roads data in useful ways as described throughout this report.

5.4 Analytical Methods Summary

This chapter describes areas of analytical outputs from a gravel roads management system (GRMS). Two project level outputs address how maintenance of unsealed roads are scheduled, cyclic maintenance which uses general properties of the road to develop a prioritized list of maintenance activities that should be performed, and triggered maintenance which uses current roadway conditions to program maintenance activities. There is also a description of various network-level outputs that may be used by both elected officials and roadway managers to assist them in making good decisions as to how the unsealed road network is funded and managed.

The process of implementing cyclic maintenance scheduling has several stages, each of which is described in detail. First, the fundamental inputs needed to make this process work are described. Appropriate inputs include the division of the road network into maintenance management sections, the assignment of minimum acceptable conditions or maintenance intervention levels to these sections, and the assignment of an appropriate maintenance strategy to each section. Next, the cyclic process is described where the timing of maintenance practices is programmed and maintenance tasks are performed. Finally, the process of adjusting the maintenance schedules based on sections' conditions as observed when maintenance is performed are described. This process allows those roads that need more frequent maintenance to receive the extra attention they need, while maintaining roads that remain in better shape less frequently, thereby performing maintenance more effectively.

Triggered maintenance is described in general terms, with the objective of outlining some of the ways in which current data may be used to program periodic and routine maintenance more efficiently. The use of automated surface condition data collection instruments is discussed, as is the use of gravel thickness data to program maintenance tasks. Though these methods are not yet widely practiced, their potential for improving maintenance efficiency on unsealed road networks is described.

Network level outputs are described, with various examples provided. This chapter describes some of the options available so agencies may decide which are most important to them. Different outputs that may be of use to elected officials and to roadway managers are provided. Depending on the type of GRMS in place, various options, such as those involving mapping and condition reports, may or may not be possible. The level and type of reports that may be generated depend on the availability of current and historical data and on the availability of models to project future needs and conditions. Selecting the outputs most useful to their agency will provide roadway managers with insights as to which data are worth their while to collect.

CHAPTER 6 SUMMARY AND CONCLUSIONS

This report addresses the need for a gravel roads management methodology suitable for counties of the rural western and central United States. By meeting and communicating with numerous experts in the fields of unsealed roads and roadway management, the Wyoming T^2/LTAP Center has prepared a set of recommendations and procedures for both roads managers and software developers implementing a gravel roads management system (GRMS).

In addition to this, the body of the report, there are two other guides, an Implementation Guide and a Programming Guide that provide specific instructions for implementing a GRMS.

Previous efforts to manage unsealed roads are briefly described, including some of the World Bank's economic analyses, South African maintenance programming efforts, Canadian routine maintenance programmed with a continuous condition monitoring device, the Wyoming T^2/LTAP Centers' previous unsealed roads management work, and unsealed roads management efforts by several US government agencies.

Several data collection procedures are described, including visual 'windshield' surveys and automated condition monitoring. Different approaches, both in terms of personnel and timing, are discussed. Several gravel roads manuals are briefly described, as is the decision of when to pave a gravel road.

6.1 Methodology

This effort assembles information and opinions from a variety of experts and generates a recommended methodology based on their opinions. By hosting face-to-face meetings, a webinar, and soliciting input by telephone and email correspondence, a gravel roads management methodology has been developed, and procedures for implementing a GRMS are described.

6.2 Implementation

The process of implementing a GRMS is described, beginning with an assessment of an agency's current situation. Factors that should be examined in this initial assessment include:

- Support
- Financial Resources
- Hardware, Software, and GPS
- Information
- Personnel

It is the objective of an initial assessment to identify the next logical step in improving how an agency manages its unsealed roads.

Data management options are described next, with a primary focus on spreadsheet and database systems and on geographic information systems (GIS).

The first step in managing a road network, establishing an inventory, is described next, listing the basic properties of an unsealed road that should be collected. The process of splitting a road network up into maintenance management sections is also described.

Options for collecting historical data, particularly maintenance and cost data are described, including the issue of getting away from line items geared towards accounting systems and moving towards systems that track items of interest to engineers and road managers. To this end, eight maintenance tasks are defined and described (see section 6.4 Conclusions below).

Specific instructions are presented that allow for work performed on unsealed roads to be assigned to these various tasks.

Procedures for collecting condition data are presented. Four basic difficulties with collecting unsealed roads condition data are identified as:

- Rapid Deterioration
- Weather and Precipitation
- Maintenance
- Vehicle Path

These problems are described and means for overcoming them are discussed. Methods of collecting data are described; personnel options are discussed; and the timing of collecting unsealed roads condition data is discussed.

6.3 Analytical Methods

A number of ways of analyzing and using data from a GRMS are described in considerable detail, including:

- Cyclic Maintenance Scheduling
- Triggered Maintenance Scheduling
- Network Level Outputs
- Safety Assessment
- Drainage Assessment

6.3.1 Cyclic Maintenance Scheduling

A process where a maintenance strategy is assigned to each road section is described (see Figure 3, page 67). By tracking each section's maintenance history and having a maintenance plan for it, prioritized maintenance lists can be generated. By assigning a 'maintenance intervention level' to each section, evaluations performed during routine maintenance can be used to customize the prioritized maintenance lists in an effort to come up with a more cost-effective way of managing unsealed roads.

6.3.2 Network Level Outputs

Several suggestions are made for network level outputs that may be both used to communicate with the public and elected officials and to help agency personnel manage their unsealed roads network more efficiently. These include:

- Condition monitoring
- Remaining service life (RSL) and gravel thickness
- Financial Tables
- Road maintenance history tables
- Road work maps and tables
- Condition maps and tables
- Condition projection maps and tables

6.4 Conclusions

Several basic conclusions and specific recommendations were drawn from this effort:

- ➢ Simplicity is critical to making a gravel roads management system (GRMS) work for small agencies. They have very limited resources. This fact, combined with the reality that it doesn't make economic sense to spend a whole lot of time or money managing very low volume roads, dictate that any GRMS must not consume a lot of resources while still producing useful results both for elected officials and for road managers.
- ➢ Functional classes should follow those described in the two AASHTO publications, the 'Green Book' *(AASHTO 2004)* and the 'Very Low Volume Roads Design Guide' *(AASHTO 2001)*.
- ➢ Maintenance activities should be assigned and tracked using these eight tasks:
  - Blading
  - Reshaping
  - Regravel
  - Dust Control
  - Stabilization
  - Isolated Repairs
  - Major Work
  - Drainage
- ➢ A transition to these tasks is needed since, historically, many unsealed road networks' costs have been tracked using line items and procedures useful to accountants, but of lesser value to roadway managers.
- ➢ Cyclic maintenance procedures can be implemented with relatively little effort.
- ➢ Automated data collection systems, such as the one used by FERIC in Canada *(Brown et al 2003)*, show considerable promise as this type of technology develops.
- ➢ Visual 'windshield' survey methods are currently the most easily adapted to small agencies' operations.

CHAPTER 7 RECOMMENDATIONS

The authors recommend that a pilot scale implementation of the procedures described in this report be undertaken as described below. There should be several basic elements to such a project. The list below provides a brief overview, while the numbered list in section 7.1 Details of a Proposed Pilot Project provides a more detailed outline:

- Assess the agency's **cost tracking system** and adjust it so that the **line items** needed to manage an unsealed roads network are in place and used. This will begin the process of collecting data in a way that is more useful to road managers.
- Verify that the unsealed road network **inventory** is adequate, both in terms of its content and its storage media, and upgrade it if it is not. Divide the network into maintenance management sections.
- Implement a **cyclic maintenance schedule**.
    - Evaluate and monitor the success of the cyclic maintenance scheduling.

The goal of this gravel roads management methodology development is to enable local agencies, such as Wyoming's counties, to implement and maintain a gravel roads management system (GRMS). Similarly, there should be two goals of a pilot project using the recommendations in this report. First, it should test the recommendations in this project and determine where changes should be made. Second, it should provide the pilot agencies with both data and a GRMS that will be used for the foreseeable future.

Conventional research and development projects begin at the bench scale with laboratory experiments providing preliminary information, followed by the pilot scale where a smaller version of the final product is prepared and evaluated. Lessons learned during the pilot stage are applied and the project goes to the production stage. This project's collaboration of experts was analogous to the bench scale. Though every effort has been made to come up with a final product that is immediately applicable, some refinements to the methods presented in this report and its accompanying guides will inevitably be needed. The need for such adjustments will only be exposed as the recommendations in this paper are applied. Therefore, a pilot scale project is needed.

The change from the accounting-based line items now in common use to the engineering-based line items suggested in this report can and should happen as soon as possible. Indeed, it seems likely that a significant part of the reason that gravel roads management has not advanced much in recent years, at least in America's rural west, is that maintenance and cost data are being collected in such a way that they are of limited value to roadway managers.

7.1 Details of a Proposed Pilot Project

The following outline describes the process of implementing the recommendations of this project on a pilot scale:

1. Determine which county road and bridge departments are good candidates for the pilot project.
    a. Establish whether they are willing and able to make the necessary changes in how they track their maintenance costs.
    b. Establish whether they have one or more maintainers willing to participate in the cyclic maintenance scheduling aspect of the project.
2. Modify cost tracking line items as recommended in section 4.5.3 Maintenance Task Definitions.
    a. Work in conjunction with accounting personnel to devise a system that will work for both accounting and engineering purposes and with any existing cost tracking software.
    b. It may be advantageous to perform similar changes for asphalt roads, bridges, culverts, signs, and so on.
3. Modify the inventory as described in section 4.4 Inventory so it will work well for gravel roads management.
    a. Divide the network into maintenance management sections as described in sections 4.4.3 Dividing a Road Network into Management Sections and 5.1.1.1 Road Sections.
    b. Collect as much of the information described in section 4.4 Inventory as practical.
    c. Assign maintenance intervention levels as described in section 5.1.1.2 Maintenance Intervention Levels.
        i. Consider various factors including connectivity, school bus routes, road use, traffic volume, traffic type, and user costs.
4. Convert as much of the existing maintenance, rehabilitation and cost data to the new inventory and line items as possible.
5. Develop a means for entering future cost and maintenance data into the new line item and inventory database structure.
    a. Options include existing software, work orders, time cards, and other field work reports.
6. Develop standard maintenance strategies such as those in section 5.1.1.3 Maintenance Strategies.
7. Assign a maintenance strategy to each maintenance management section as described in section 5.1.1.4 Assign Road Sections to a Maintenance Strategy.
    a. Assign a standard maintenance strategy to each maintenance management section.
    b. Apply a timing adjustment factor based on the road section's durability.
    c. Determine where in the maintenance cycle each section is currently.
8. Write software code to generate cyclic maintenance schedules.
9. Begin a cyclic maintenance program.
    a. Generate a prioritized blading and reshaping list for each maintainer.
        i. Perform maintenance as directed by the list and adjusted by the maintainer.
        ii. Evaluate surface conditions at the time of maintenance.
    b. Generate a prioritized drainage, regraveling, dust control and stabilization list for the county.
        i. Perform maintenance as directed by the list and adjusted by the supervisor.
10. Adjust the timing of the cyclic maintenance schedule for blading based on the relationship of the surface conditions observed during routine blading to the maintenance intervention levels.

11. Develop prioritized surface condition and gravel thickness evaluation schedules.
12. Begin condition and gravel evaluations based on prioritized lists.
    a. Visual condition survey
    b. Gravel thickness measurements
    c. Gravel gradation and plasticity properties
13. Adjust the timing of cyclic maintenance schedules based on evaluation results.
14. Prepare interim reports
    a. On the status of the pilot project.
    b. On the status of the counties' unsealed roads.
15. Evaluate and Monitor the Cyclic Maintenance Process.
    a. Interview county personnel.
    b. Evaluate complaint and request frequencies.
    c. Assess changes in maintenance costs.
    d. Estimate user costs.
16. Prepare and present final report.

Following through on these steps will provide those maintenance districts and counties that participate in the pilot program with a management system that is designed to make maintenance operations more efficient. It will also begin the process of collecting historical data that may be used to introduce further efficiencies as better information about the performance of the counties' unsealed roads is collected. Finally, it will demonstrate the effectiveness of the methods proposed in this study and expose those areas that need further refinement.

7.2 Selection of Candidate Counties for a Pilot Project

Several counties should be solicited to participate in this project. The first step will be to assess their current situation. Some counties may feel that the methods proposed here will not work for them, particularly the changes to the cost tracking systems. The implementation of different line items to monitor the maintenance tasks performed on each road should take place for all the county's unsealed roads maintenance tasks. This will take some consultation with accountants and others who currently rely on the existing system. Before a county is selected to participate in the pilot program, it should be established that they are willing and able to make the needed changes in how they track maintenance costs.

Another critical factor will be the county's commitment to undertaking a new way of tracking their costs for an extended period. Changing the way costs are tracked requires a change in how the county road and bridge department does business, and there needs to be a willingness to change, both in the office and in the field. The three proposed elements of the pilot project are; first, changing the cost tracking method to one that is more tailored to making engineering decisions; second, performing routine blading on a computer-generated schedule while briefly rating surface conditions; and, third, measuring gravel thicknesses. The development of analytical software and data entry forms could be done by non-county personnel, as could the generation of prioritized maintenance lists and other reports, but changes in cost tracking and maintenance scheduling must be done by the counties.

The first commitment that will be needed from candidate counties will be their willingness to come up with a system of assigning costs that enables them to be tracked by maintenance task and road management section. This will take discussing the current system with those who now rely on it and finding a way of tracking costs that both works for them and works to satisfy the road management functions described in this report.

The next commitment will be to upgrade the inventory. Most counties already have some form of inventory. The main change will be the division of roads into maintenance management sections. This should be done in consultation with the supervisor and with each maintainer for their own district.

Implementation of a cyclic maintenance schedule needs to happen, though it would not need to happen throughout the county. Some maintainers could participate while others could opt out. Several actions will have to be taken by the counties, some by the supervisor, some by the maintainer and supervisor, and some by the maintainer, as described below:

- Supervisor
    - Assist with implementing a system to track maintenance activities.
    - Develop maintenance strategies.
    - Assign crews to perform maintenance tasks as recommended by the cyclic maintenance schedule.
        - Drainage maintenance
        - Regravel
        - Dust suppression
        - Stabilization
- Supervisor and Maintainer
    - Divide the maintainers' districts into maintenance management sections.
    - Assign a strategy to each section and determine the timing of the tasks included in the selected maintenance strategy.
- Maintainer
    - Perform maintenance tasks in rough accordance with the prioritized lists.
        - Blading
        - Reshaping
    - Rate the surface condition at the time the maintenance is performed.
    - Record the extent of the maintenance and the time spent performing it.

Before committing to participate in a pilot project, supervisors and maintainers should understand the various tasks they are committing to, particularly those listed above.

The only one that is likely to take cooperation from other individuals within the county is the modification of the system used to track maintenance tasks and costs. It would be adjusted by those such as accountants who currently use the existing cost tracking system, the road and bridge supervisor, and those leading the pilot project. The other tasks will be performed either by the maintainers and supervisors on their own or in conjunction with those leading the pilot project. Though simple to state, this problem may be more difficult than it first appears since it may require some modification of and cooperation with existing information management systems. The ability to make these modifications may be the most critical aspect when selecting agencies to implement this pilot project.

7.3 Selection of Maintenance Intervention Levels

Agencies should have minimum standards to which they will let roads fall. Once a road falls below this level, the agency should intervene by performing maintenance or repairs. The worst surface condition an agency allows an individual road to fall to should be based on both economic and human considerations. For virtually any road, or indeed almost any facility, the more that is spent on it, the lower will be the costs to those using it. Agencies should try to establish the condition at which they will intervene by performing maintenance. The appropriate minimum condition level for intervention on a given road section should consider both agency and user costs.

Assessing user costs may not always be simple, particularly when one considers the value of keeping a road open at all times even if it serves only a few residences. The cost of road closure may be very low unless there is a need for fire trucks or an ambulance to get through, but in these instances, the value of a single one mile trip may be hundreds of thousands or even millions of dollars. There is also a considerable financial impact to keeping open, for example, roads used to haul crops, cattle, or logs, or roads needed to maintain oil wells or windmill farms. Given that many unsealed roads provide the only access to large areas, determining the true cost of keeping them maintained to various standards is not always an easy task. However, several primary factors should be considered when establishing user costs, including:

- ✓ Travel time
    - Value of vehicle and operator's time
    - Economic impacts
        - Delayed delivery of crops or other products
        - Delayed or deferred maintenance, for example on wind turbines or wells
        - Fire truck delays
    - Human impacts
        - Trip to the hospital
        - Ambulance delays
        - School bus travel times
        - Social isolation
- ✓ Vehicle costs
    - Maintenance and repair costs
        - Tires
        - Filters
        - Lubricants
        - Suspension
    - Depreciation
    - Fuel

As the only route to many areas, unsealed roads have economic and social impacts different from those on sealed arterials and collectors. These impacts make maintenance, particularly drainage maintenance, critical, since catastrophic failure of culverts and bridges or other washouts may sever often vital travel routes, particularly in times of emergency. Calculating the value of preventing such failures is difficult but it should not be ignored.

Costs to the agency are more straightforward. Routine blading, pulling shoulders, regraveling and drainage maintenance, not to mention costs associated with bridges and culverts, should all be considered along with user costs when deciding how good a condition to keep any individual unsealed road in, and therefore how much money to invest in their improvement, repair and maintenance.

CHAPTER 8 REFERENCES AND OTHER RESOURCES

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APPENDIX A: Johnson County Road Data and Dust Control Cost Savings

During the pilot asset management program which the Wyoming T^2/LTAP Center conducted for and with Johnson County, it became apparent that the county needed a better way to monitor their expenses, so the County purchased and implemented a commercial cost tracking software package.

The tasks used to track the County's costs do not match up with the seven tasks originally identified in this project (Major Work, Regravel, Dust Suppression, Soil Stabilization, Spot Graveling, Reshaping, and Blading). Twenty tasks were identified as being relevant to surface maintenance of unsealed roads. (Travel time was not included due to restrictions on the time available to perform this analysis.) Costs assigned to these twenty tasks were assigned to one of six tasks as defined in this project. (Soil stabilization was not differentiated from dust suppression by the county, so both these uses of chemical and physical treatments are classed as dust suppression.) Table A.1 shows the tasks as defined by Johnson County and which one of the six tasks defined in this project to which they were typically assigned. In some cases, it was apparent that the costs should be assigned to a different task upon closer examination of charges, based upon the activities undertaken. One major source of error in this assignment process is the question of how to allocate the haul gravel costs. These costs should go to either Major Work, Regravel, or Spot Graveling, and in many cases there is no way to tell which they should be assigned to. There are many other instances where costs are improperly assigned, such as Spot Graveling costs being assigned to Regravel, or Regravel costs assigned to Major Work, since there is no good way to discriminate between these tasks.

Table A.1 County Tasks as Typically Assigned to Management Tasks

Johnson County Task	Gravel Roads Management Task
Haul Gravel Contractor	Major Work
Contract Engineering	Major Work
Major Construction	Major Work
Contracted Water Truck	Major Work
Flagging	Major Work
Dust Suppression	Dust Suppression
Dust Control - Prepare Surface	Dust Suppression
Dust Control - Prewater	Dust Suppression
Dust Control - Apply Magnesium Chloride	Dust Suppression
Dust Control - Apply Calcium Chloride	Dust Suppression
Dust Control - other unspecified tasks	Dust Suppression
Loading Trucks	Regravel
Prepare Surface for Graveling	Regravel
Haul Gravel	Regravel
Lay Gravel	Regravel
Water	Regravel
Blade Patching Gravel	Spot Graveling
Routine (pothole) patching gravel	Spot Graveling
Pulling Shoulders/Ditchwork	Reshaping
Roads - Blade gravel	Blading

In spite of the inaccuracies in how costs are assigned to each of the management tasks, Table A.2 provides some very rough assessments of the average annual system-wide costs of performing each of the six tasks identified in the gravel management system. Johnson County knows that their dust suppression costs about $5,000 per mile, and their regraveling costs about $45,000 per mile. When viewing Table A.2, one should consider that a significant part of the Major Work might better be assigned to Regravel. As much as anything, the exercise of attempting to assign Johnson County's costs to the gravel management tasks illustrates that cost data need to be collected with the goal of managing unsealed roads and planning maintenance strategies. When unsealed roads managers elect to track costs with a computer, they should consider how these tracked costs might be used to develop gravel roads management strategies. The lesson learned from both this exercise and discussions regarding the South Dakota Department of Legislative Audit procedures is that unsealed roads experts, not accountants, need to be selecting the tasks to which road and bridge departments charge their time, equipment, supplies, and materials.

Table A.2: Approximate Unsealed Roads Maintenance Costs per Mile-Year

	Cost/Mile-Year ***(Weighted Average by Length)***							
	Major & Contracted	**Dust**	**Regravel**	**Patching**	**Blading**	**Shoulders & Ditches**	**TOTAL**	**Non-Major SUB TOTAL**
Resource	$190	$0	$132	$0	$51	$0	$374	$183
Local	$433	$192	$431	$8	$260	$163	$1,488	$1,055
Minor Collector	$2,287	$882	$663	$9	$487	$128	$4,457	$2,169
Major Collector	$5,155	$2,906	$2,126	$17	$892	$252	$11,349	$6,193
SYSTEM	$1,570	$722	$639	$8	$402	$129	$3,470	$1,900

Dust control use has increased substantially on Johnson County's roads over the past several years. Table A.3 shows their expenditures on dust control by year from July 1, 2005 through September 30, 2009. Based on their 456 miles of unsealed roads, this translates to a system-wide average of $10/mile in 2006 and $1,756/mile in 2009. Table A.4 shows the number of roads that received dust treatment by year. Both these tables demonstrate that Johnson County has instituted a significant dust control program over the past five years.

Table A.3 Johnson County Dust Control Costs by Year

Year (and Quarter where entire year's data was not available)	**Total County Expenditures**	**Cost per System-Mile**
2005 Q3 & Q4	$4,189	$9
2006	$4,406	$10
2007	$77,607	$170
2008	$726,657	$1,594
2009 Q1, Q2, & Q3	$800,607	$1,756

Table A.4 Number of Roads Receiving Dust Control in Johnson County by Year

	2005	**2006**	**2007**	**2008**	**2009**
No Dust Control	45	44	41	34	33
Minor Dust Control <$500/mile	7	8	8	3	4
Intermittent Dust Control $500 - $2500/mile	0	0	2	7	5
Project Dust Control >$2500/mile	0	0	1	8	10

An obvious question is: Does this dust control program save the county money? One would expect four primary benefits from the dust control program: Improved performance; lowered routine maintenance costs; less frequent regraveling due to reduced gravel loss; and, of course, dust reduction. Improved performance and dust reduction cannot be evaluated since the county does not collect condition or dust data, and the county hasn't had their dust control program in place long enough to assess whether regraveling costs are reduced. However, one can assess whether some of the lower cost, routine maintenance costs have been reduced, either by dust control or by other substantial improvements to various roads.

The county-wide costs of four routine tasks are shown in Table A.5. The two patching tasks are ignored in future analyses since their costs are insignificant. However, blading and pulling shoulders incur significant costs, so reducing their costs would also be significant. Since these two tasks' total cost over four years is less than the dust control budget for 2008 & 2009, one could not justify dust control with this cost reduction alone, but if the anticipated reduction in regraveling costs takes place, it, combined with expected improvements in performance, might justify the additional cost of dust suppression. Over $2,500 per mile was spent on one road in 2007, eight roads in 2008, and ten in 2009. The roads receiving dust treatment in 2009 haven't been down long enough for reliable analyses to be performed, but the other nine roads' costs have been analyzed.

Table A.5 Cumulative County-Wide Costs of Routine Maintenance

Maintenance Task	4¼ Year Cost
Blade patching gravel	$2,189
Routine (pothole) patching gravel	$13,680
Roads - Blade Gravel	$779,954
Pulling shoulders/ditchwork	$262,485

Table A.6 shows the eight roads receiving extensive dust control, along with the amount per mile spent on dust control, blading, pulling shoulders and ditch work, and other work including major rehabilitation. It should be noted that many of these roads, particularly Dead Horse, Upper Powder River, and Schoonover, serve oil and gas field drilling traffic, so they are subject to dramatic variations in traffic, particularly heavy truck traffic, so one should not infer too much from the actual cost savings. To accurately assess any cost savings realized from dust control on these roads, one would need traffic and heavy vehicle counts. This example is not included to evaluate the effectiveness of dust control measures, but to demonstrate how data collected as part of an asset management system might be used.

Table A.6 Johnson County Dust Control and Routine Maintenance Costs per Mile by Road and Year

Road	Cost Type	2005 Q3 & Q4	2006	2007	2008	2009 Q1, Q2, & Q3	TOTALS
Dead Horse	Other	$0	$1,218	$26,590	$343	$350	$28,501
	Dust Control	$18	$33	$4,593	$5,990	$5,120	$15,756
	Blading	$949	$2,605	$1,966	$307	$142	$5,970
	Pull Shoulders	$38	$58	$559	$0	$0	$655
	TOTAL	$1,005	$3,914	$33,708	$6,641	$5,613	$50,881
Lower Piney	Other	$0	$137	$83	$15,296	$194	$15,710
	Dust Control	$0	$0	$0	$4,272	$5,306	$9,578
	Blading	$198	$594	$767	$461	$198	$2,218
	Pull Shoulders	$0	$0	$0	$1,784	$0	$1,784
	TOTAL	$198	$732	$850	$21,813	$5,698	$29,291
TTT	Other	$337	$3,013	$20,424	$264	$428	$24,465
	Dust Control	$29	$0	$28	$8,699	$9,128	$17,883
	Blading	$678	$1,266	$992	$482	$395	$3,812
	Pull Shoulders	$0	$1,140	$272	$0	$0	$1,412
	TOTAL	$1,043	$5,419	$21,715	$9,445	$9,951	$47,572
Tipperary	Other	$217	$1,938	$13,137	$170	$275	$15,736
	Dust Control	$19	$0	$18	$5,595	$5,871	$11,503
	Blading	$436	$814	$638	$310	$254	$2,452
	Pull Shoulders	$0	$733	$175	$0	$0	$908
	TOTAL	$671	$3,485	$13,967	$6,075	$6,400	$30,598
Streeter	Other	$1,806	$9,292	$175	$35	$87	$11,394
	Dust Control	$114	$30	$19	$4,965	$5,153	$10,281
	Blading	$1,386	$564	$455	$0	$0	$2,405
	Pull Shoulders	$146	$84	$23	$0	$68	$320
	TOTAL	$3,451	$9,969	$673	$5,000	$5,307	$24,400
Thompson Creek	Other	$94	$29	$6,633	$620	$386	$7,761
	Dust Control	$33	$0	$0	$4,503	$5,172	$9,709
	Blading	$289	$406	$198	$37	$0	$929
	Pull Shoulders	$0	$38	$0	$0	$119	$157
	TOTAL	$416	$473	$6,830	$5,160	$5,677	$18,556
Upper Powder River	Other	$491	$35,164	$7,959	$5,733	$590	$49,937
	Dust Control	$47	$13	$59	$4,595	$5,827	$10,542
	Blading	$731	$958	$923	$152	$172	$2,936
	Pull Shoulders	$0	$54	$120	$202	$136	$512
	TOTAL	$1,270	$36,189	$9,061	$10,682	$6,725	$63,927
Schoonover	Other	$1,497	$494	$28,950	$457	$162	$31,560
	Dust Control	$13	$0	$1,622	$4,882	$4,976	$11,494
	Blading	$1,213	$1,030	$861	$14	$127	$3,245
	Pull Shoulders	$41	$575	$560	$0	$0	$1,176
	TOTAL	$2,764	$2,099	$31,994	$5,353	$5,266	$47,475

APPENDIX B: NACE Survey Results

Survey Respondents

At the National Association of County Engineers' Spring Conference held in Fort Worth, Texas in April 2010, a summary of this project was presented and a survey was distributed to the attendees. A total of eighteen surveys were completed by county representatives, and one was completed by a representative of the United States' federal government. A copy of the survey is provided at the end of this appendix (Figure B.9). The results summarized below are for those eighteen counties that completed the survey. Figure B.1 shows the responses by state while Figure B.2 shows the populations reported by the responding counties.

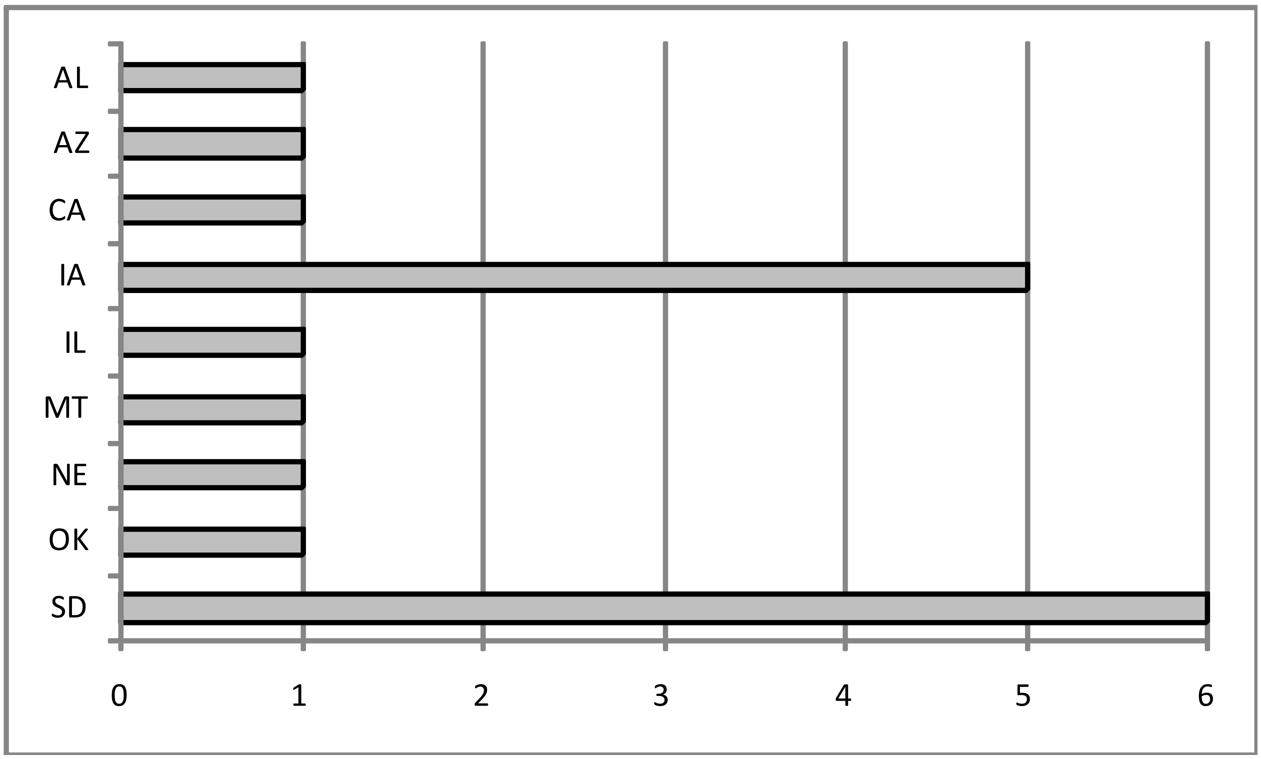

Figure B.1 NACE Survey responses by State.

Figures B.1 and B.2 show that the responses are dominated by two States, Iowa and South Dakota, and that there is a good distribution in the populations of the responding counties.

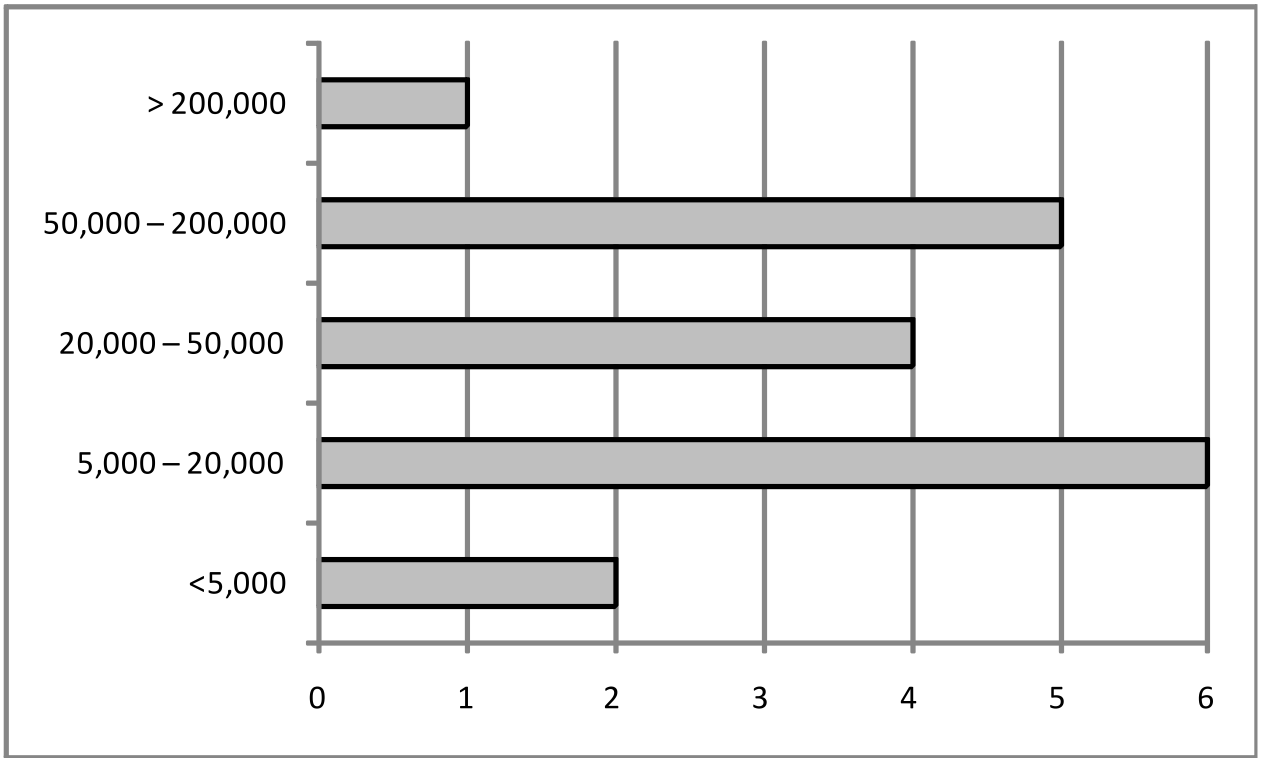

Figure B.2 Populations of responding counties

Survey Questions and Results

The following questions were asked, with check boxes provided for each of the listed responses. The respondents were asked to check as many of the boxes as were appropriate.

Who evaluates the condition of your dirt and gravel roads?

100% of the county respondents indicated that conditions are evaluated by *'Supervisor or Foremen,'* while 6% indicated that *'Trained agency staff'* also evaluate road conditions. The federal respondent indicated that their roads are evaluated by *'Trained agency staff.'*

No respondents checked any of these options:

- *No one*
- *Untrained agency staff*
- *Staff hired specifically to collect data*
- *Outside entity*
- *Other*

When do you evaluate the condition of your dirt and gravel roads?

The federal respondent and 78% of the county respondents indicated that they collect condition data *'When time allows.'* The other 22% of the county respondents collect condition data *'On a set schedule.'*

No respondents checked any of these options:

- *Never*
- *When staff is on site already*
- *Other*

How do you evaluate the condition of your dirt and gravel roads?

22% of the county respondents and the federal respondent indicated that they only use *'Informal visual evaluation.'* 61% of the county respondents indicated that they only use '*Visual windshield condition surveys;'* 11% use *'Visual windshield condition surveys'* and *'Surface distress and extent measurement'* and 6% use *'Visual windshield condition surveys,' 'Informal visual evaluation'* and *'Gravel thickness.'*

No respondents checked any of these boxes:

- *No evaluation*
- *Automated data collection*
- *Other*

How do you store dirt and gravel roads condition data?

56% of the county respondents and the federal respondent indicated that they store data only *'In your head;'* 30% of these used *'Informal visual evaluation,'* while the other 70% used *'Visual windshield condition surveys.'* 28% of the county respondents store data *'Manually, with a paper system.'* The other 17% use spreadsheets, and 6% also use a GIS system.

No respondents checked any of these boxes:

- *With commercial software*
- *In a database*
- *Other*

How do you schedule routine surface blading?

The federal respondent indicated that they perform routine maintenance at the maintainer's discretion. The county responses are indicated in Figure B.3.

How do you schedule regraveling?

The federal respondent indicated that they perform regraveling when it is scheduled. The county responses are indicated in Figure B.4.

How do you assess the effectiveness of dust control and stabilization practices?

61% of the county respondents indicated that they do not use dust suppressants or soil stabilizers. The responses of the other 39% are shown in Figure B.5. The federal respondent indicated that they observe dust to assess the effectiveness of their practices.

What dirt and gravel roads reports do you generate?

The federal respondent indicated that they only generate *'Maintenance performed'* reports. The responses of the county respondents are shown in Figure B.6.

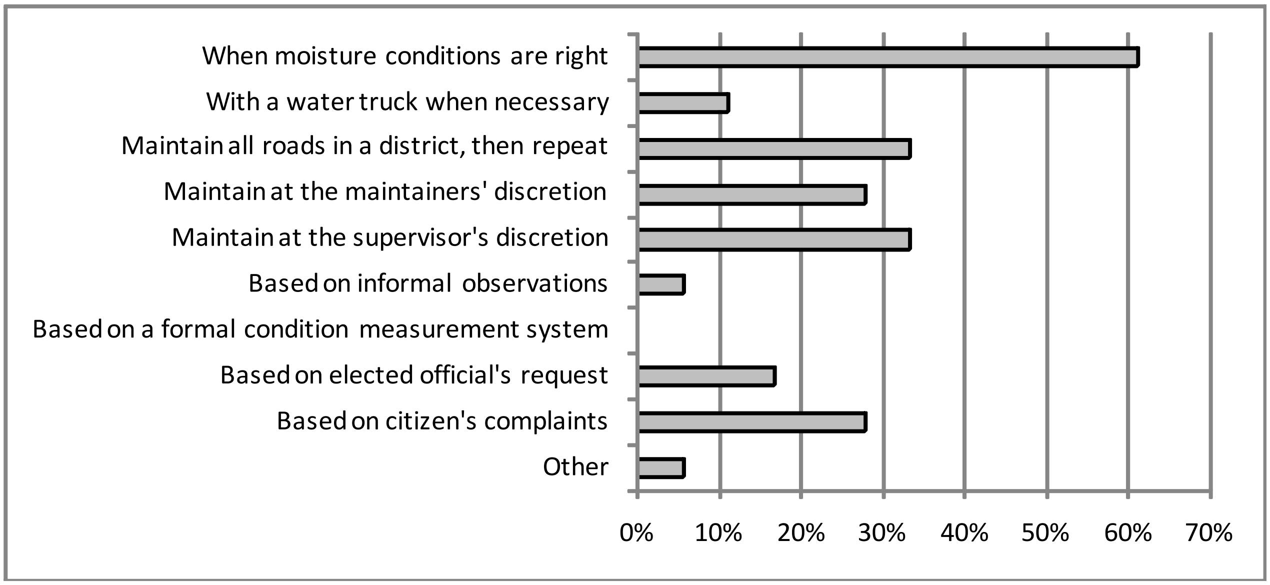

Figure B.3 County responses to 'How do you schedule routine surface blading?'

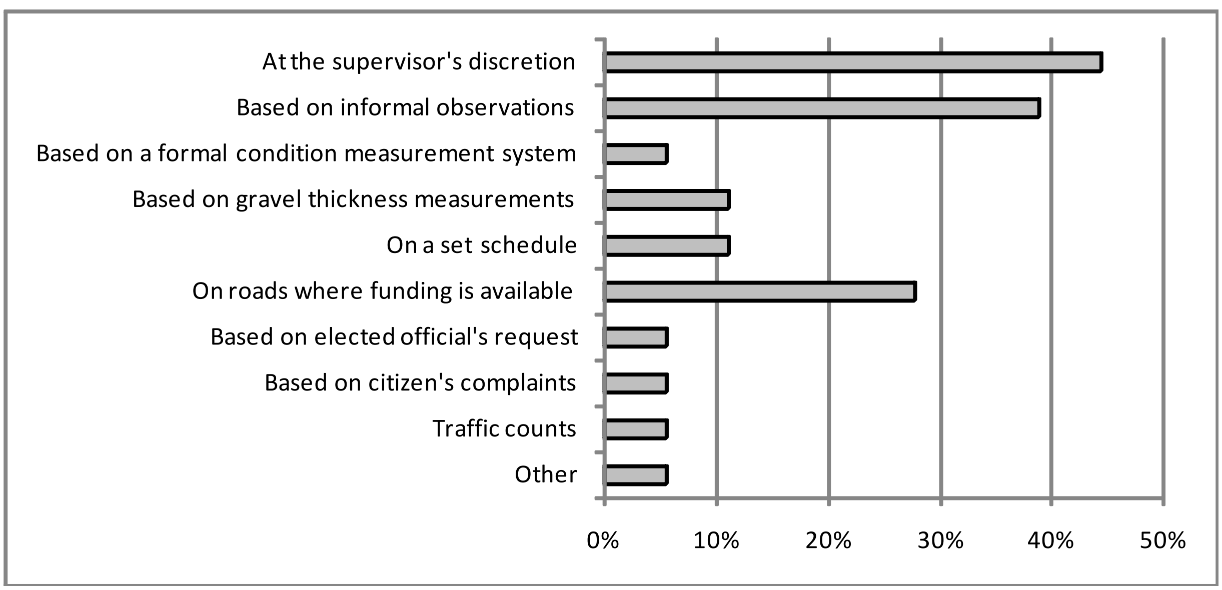

Figure B.4 County responses to '*How do you schedule regraveling?*'

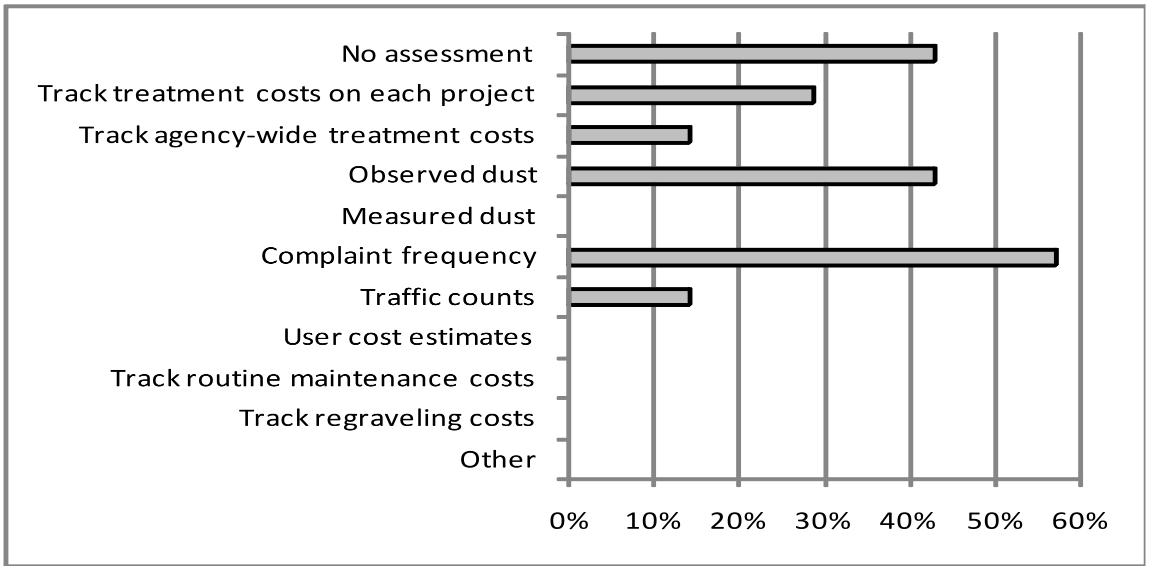

Figure B.5 Responses of counties that indicated they use dust suppressants and/or soil stabilizers to '*How do you assess the effectiveness of dust control and soil stabilization practices?*'

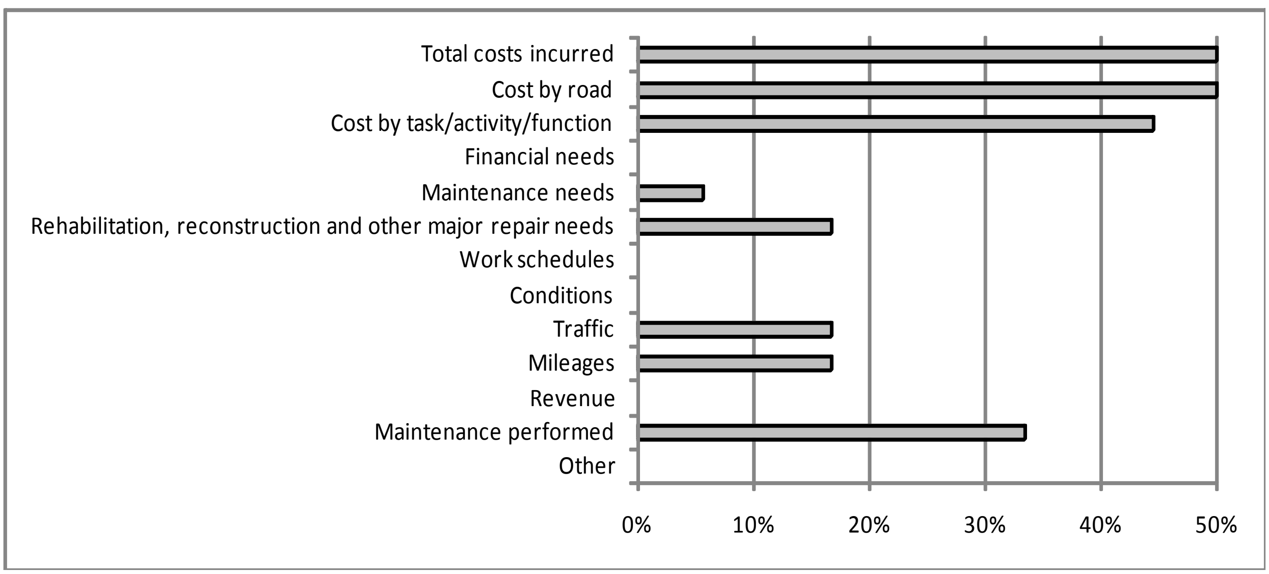

Figure B.6 County responses to '*What dirt and gravel roads reports do you generate?*'

What assistance in the management of your dirt and gravel roads would be particularly useful to you?

The federal respondent indicated that *'System assessment,' 'Automated data collection'* and *'Data analysis'* would be most useful to them. The county responses are shown in Figure B.7.

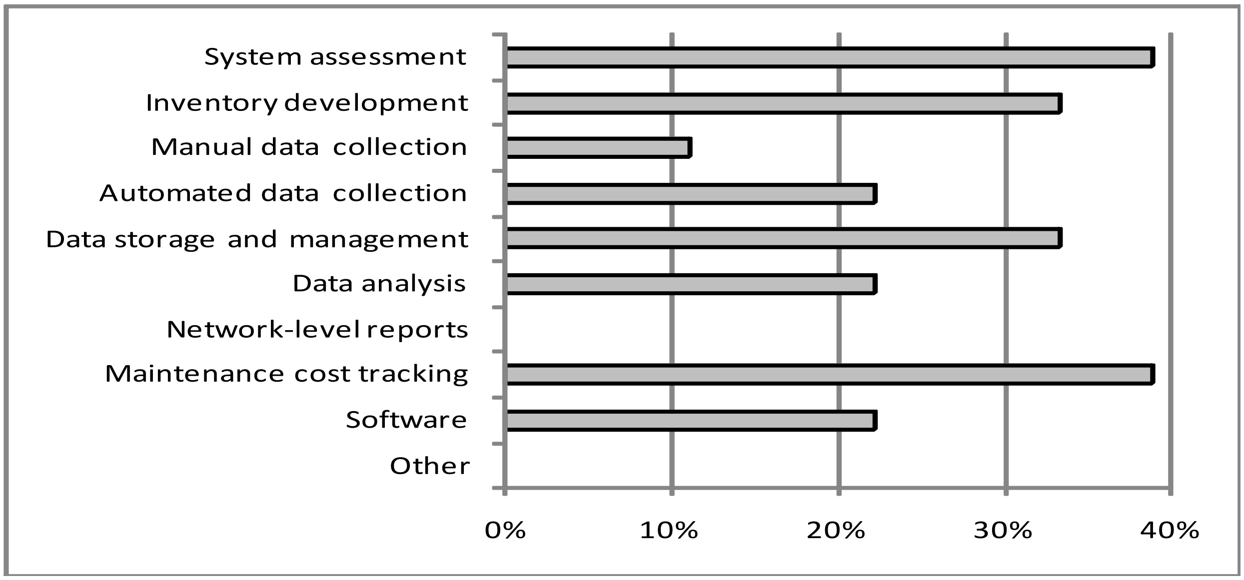

Figure B.7 County responses to *'What assistance in the management of your dirt and gravel roads would be particularly useful to you?'*

What dirt and gravel road reports are or would be particularly useful to you?

The federal respondent indicated that *'Conditions'* and *'Maintenance needs'* would be most useful to them. The county responses are shown in Figure B.8.

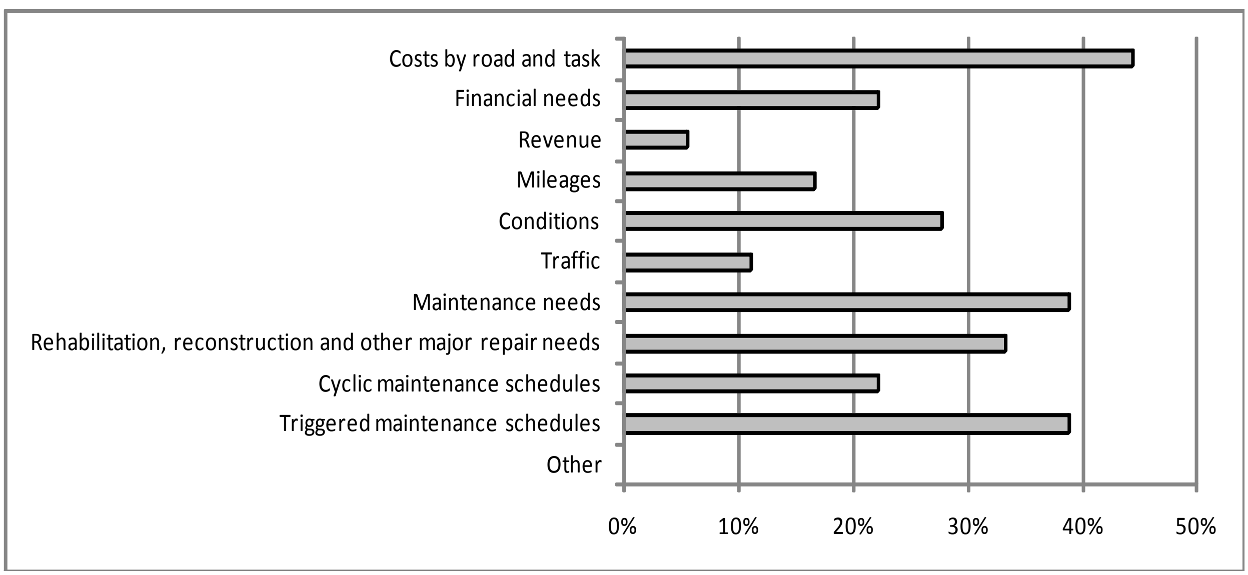

Figure B.8 County responses to *'What dirt and gravel road reports are or would be particularly useful to you?'*

Survey Summary

This survey verifies earlier, less formal assessments that indicate that gravel roads management is in its infancy. Based on a sample size of one, the federal government is in a similar situation. The following observations reinforce this point:

- 61% of the county respondents indicated that evaluation of their county's dirt and gravel roads' condition is performed by supervisors and foremen when time allows using a visual rating system and that their results are stored only in their heads.
- 78% of the county respondents do not store dirt and gravel road condition data in a computer.
- 33% of the county respondents perform routine surface blading on all roads in a district, and then repeat.
- 83% of the county respondents use neither a formal condition measurement system nor gravel thicknesses to schedule regraveling.
- 0% of the county respondents track routine maintenance or regraveling costs to evaluate the effectiveness of their dust control and soil stabilization efforts.
- 83% of the county respondents indicated that they do not generate reports of either maintenance needs or of major repair needs.

These points make it clear that there is considerable room for improvement in how unsealed roads are managed.

When asked questions directly pertaining to their current gravel roads management needs, the assistance most respondents identified is tied between 'system assessment' and 'maintenance cost tracking,' with 'inventory development' and 'data storage and management' following close behind. This indicates that the county respondents generally understand that they have problems with their GRMS, and it appears that they have a good understanding of where improvements would be most useful.

The situation is not hopeless. One county stood out, the only one using a geographic information system (GIS) to store their dirt and gravel roads condition data. They collect condition data on a set schedule with both visual surveys and distress extent and severity measurements. They use traffic counts, informal observations, and gravel thicknesses to develop a 2-year maintenance program that includes regraveling schedules, though routine surface blading is performed based on informal observations. They track the cost of dust control and soil stabilization, though they don't evaluate any reductions in routine maintenance or regraveling costs. In spite of their use of some relatively advanced practices, this county identified inventory development, manual data collection, data storage and management, data analysis, and maintenance cost tracking as areas where assistance would be particularly useful to them. One might argue that the fact that they view some of these elementary aspects of a GRMS as areas where they could use assistance demonstrates clearly that better development of GRMSs is needed. If even a progressive county still struggles with tracking maintenance costs, there is certainly significant room for improvement.

Figure B.9 Gravel roads management survey for NACE

Gravel Roads Management Survey for NACE

Describe your current dirt and gravel road management practices and needs by checking all appropriate boxes and with verbal descriptions:

Who evaluates the condition of your dirt and gravel roads?

☐ No one ☐ Supervisor or Foremen ☐ Trained agency staff ☐ Untrained agency staff

☐ Staff hired specifically to collect data ☐ Outside entity ☐ Other

When do you evaluate the condition of your dirt and gravel roads?

☐ Never ☐ When staff is on site already ☐ When time allows ☐ On a set schedule ☐ Other

How do you evaluate the condition of your dirt and gravel roads?

☐ No evaluation ☐ Informal visual evaluation ☐ Visual 'windshield' condition surveys

☐ Surface distress and extent measurement ☐ Gravel thickness ☐ Automated data collection ☐Other

How do you store dirt and gravel roads condition data?

☐ In your head ☐ Manually, with a paper system ☐ In a computer ☐ With commercial software

☐ In a spreadsheet (such as Excel) ☐ In a database ☐ In a GIS system ☐ Other

How do you schedule routine surface blading?

☐ When moisture conditions are right ☐ With a water truck when necessary

☐ Maintain all roads in a district, then repeat ☐ Maintain at the maintainers' discretion

☐ Maintain at the supervisor's discretion ☐ Based on informal observations

☐ Based on a formal condition measurement system ☐ Based on elected official's request

☐ Based on citizen's complaints ☐ Other

How do you schedule regraveling?

☐ At the supervisor's discretion ☐ Based on informal observations

☐ Based on a formal condition measurement system ☐ Based on gravel thickness measurements

☐ On a set schedule ☐ On roads where funding is available ☐ Based on elected official's request

☐ Based on citizen's complaints ☐ Traffic counts ☐ Other

How do you assess the effectiveness of dust control and soil stabilization practices?

☐ Don't use dust suppressants or soil stabilizers ☐ No assessment ☐ Track treatment costs on each project

☐ Track agency-wide treatment costs ☐ Observed dust ☐ Measured dust

☐ Complaint frequency ☐ Traffic counts ☐ User cost estimates

☐ Track routine maintenance costs ☐ Track regraveling costs ☐ Other

What dirt and gravel roads reports do you generate?

☐ Total costs incurred ☐ Cost by road ☐ Cost by task/activity/function ☐ Financial needs

☐ Maintenance needs ☐ Rehabilitation, reconstruction and other major repair needs ☐ Work schedules

☐ Conditions ☐Traffic ☐ Mileages ☐ Revenue ☐ Maintenance performed ☐ Other

What assistance in the management of your dirt and gravel roads would be particularly useful to you?

☐ System assessment ☐ Inventory development ☐ Manual data collection

☐ Automated data collection ☐ Data storage and management ☐ Data analysis

☐ Network-level reports ☐ Maintenance cost tracking ☐ Software ☐ Other

What dirt and gravel road reports are or would be particularly useful to you?

☐ Costs by road and task ☐ Financial needs ☐ Revenue ☐ Mileages ☐ Conditions

☐Traffic ☐ Maintenance needs ☐ Rehabilitation, reconstruction and other major repair needs

☐ Cyclic maintenance schedules ☐ Triggered maintenance schedules ☐ Other

Please describe your agency:

Population (check one):

☐ > 200,000 ☐ 50,000 – 200,000 ☐ 20,000 – 50,000 ☐ 5,000 – 20,000 ☐ <5,000

Agency Type (check one):

☐ County/Parish ☐ City ☐ Town/Village ☐ Township ☐ MPO ☐ Federal

☐ State ☐ Private ☐ Other (and describe) ____

Estimate your centerline miles for each category:

	Urban/Suburban /Subdivision	Rural (serving residences)	Remote (not serving residences)	Total Miles
Dirt/Earth				
Gravel				
Treated Gravel				
Sealed/Oiled				
Paved				

Additional Comments:

Please enter your name and contact information which will only be used to ask you more about your dirt and gravel roads management practices; your name and contact information (other than State) will not be shared.

Name: ____ Title: ______________________________

Agency: ____

City: ____ State: ______

Email: ____ Phone: __________________________