

Michigan Technological University

Characterization of Unpaved Road Condition Through the Use of Remote Sensing

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Deliverable 6-B: A Demonstration Decision Support System for Managing Unpaved Roads in RoadSoft

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Purpose of this Document

This document will provide an example of how data collected from the remote sensing systems evaluated during this project can be integrated into a commercially available decision support system (DSS) software package for use by transportation infrastructure owners. This document will also act as a framework to provide guidance to the project team working on integration between the various data collection and analysis routines present in the remote sensing systems and the DSS being used for this demonstration (RoadSoft www.roadsoft.org). This document can also act as a starting point for integration of the remote sensing systems portion developed by this project with other commercially available DSS.

Motivation

One of the main goals outlined for the *Characterization of Unpaved Roads by Remote Sensing* project is to show that data collected through remote sensing can be effectively utilized in a decision support system for managing unpaved roads. Management of unpaved roads has historically been challenged by the lack of a method or system that provides decision support and allows for cost-effective data collection. Systems providing decision support or basic distress identification for unpaved roads have been developed, but data collection costs and quality have limited their effectiveness and adoption by unpaved road managers. It is the goal of this project to overcome these limitations by providing an example of how data can be collected cost effectively from remote sensing systems using a standard road assessment and inventory technique (Army Corps of Engineers Unpaved Road Condition Index system) and how this data can be integrated into a DSS. DSS make use of a variety of data, including asset inventory data, condition (distress) data, and project history data to allows users to more quickly make informed asset management decisions, and to see the impacts of these decisions on the long term health of their road network.

Distress Identification and Characterization

For the purposes of this project the Army Corps of Engineers Unsourced Road Condition Index (URCI) distress identification method has been selected for assessing the road quality. URCI distress data for unpaved roads will be collected by various remote sensing techniques during this project. The URCI method is described in *Technical Manual No. 5-626: Unsourced Road Maintenance Management* (Department of the Army, 1995). For a full listing of unpaved road distress identification methods identified by this project see *Deliverable 2-A: State of the Practice of Unpaved Road Condition Assessment* (Brooks, Colling, Kueber, Roussi, & Endsley, 2011) at <http://www.mtri.org/unpaved/>. The URCI method was selected for this project because it has a number of advantages over other assessment methods:

1. It provides a clear set of measurement criteria for each distress type utilized.
2. It is applicable to a wide variety of unpaved roads in the United States.
3. The majority of condition indicators (distresses) are amenable to data collection using remote sensing methods.
4. It has maintenance and rehabilitation decision support criteria developed in parallel with the rating method which give guidance to road managers based on conditions.
5. The method was specifically designed for use with representative samples of data as opposed to requiring a complete census of every mile of road, which increases the cost effectiveness of the method.

Characterization of Quantifiable URCI Distress Data

Distress data conforming to the URCI method includes the following distresses:

- Loss of road cross section
- Improper drainage (where possible)
- Potholes
- Ruts
- Corrugations
- Loose aggregate berms
- Dust (Department of the Army, 1995)

The only URCI distress type that was determined to be not feasible to collect with remote sensing techniques was dust. Dust was determined not to be a collectable or easy quantifiable distress using remote sensing techniques due to the need for a pilot vehicle to loft dust particles and the fact that the guidelines in the URCI method are subjective. Improper drainage was determined to be technically feasible to collect in areas where vegetation or tree cover was not excessively thick and the ground surface is visible. It was acknowledged that a clear view of the ground surface in ditch areas may not be present in many cases during the testing of the system in Michigan, but it may be more applicable in western plains states.

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The requirements for the remote sensing system provided in *Deliverable 1-A: Requirements for Remote Sensing Assessments of Unpaved Road Conditions* (Brooks, Colling, & Roussi, 2011) were derived based on being able to identify and measure distresses from the URCI method in accordance with *Technical Manual No. 5-626*, at the proper sensitivity and precision to make use of the method in a DSS. Most of the URCI distresses are discretely quantifiable. These include potholes, ruts, corrugations and loose aggregate berms. As such, it is readily apparent how the requirements relate to the measurements of distresses required for the URCI method.

Two URCI distresses – loss of road cross section and improper roadside drainage – are somewhat subjective and require definitions to map between the requirements of the physical features that the remote sensing system will collect and the distress severity levels that the DSS will receive. The following section of the report will propose criteria to quantify different distress levels for loss of road cross section and roadside drainage. The criteria used for the quantification of these distresses should be reviewed and commented upon by the Technical Work Group during the earliest possible convenience.

Characterization of Loss of Road Cross Section Distress

Figure 1 below provides an illustration of the three severity levels of the loss of road cross section distress according to the URCI method. *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* describes the criteria for assessing severity levels for the loss of road cross section distress as the following:

- “(1) At severity level L [Low Severity]
 - (a) Small amounts of ponding water or evidence of ponding water on the road surface.
 - (b) The road surface is completely flat (no cross-slope).
- (2) At severity level M [Medium Severity]
 - (a) Moderate amounts of ponding water or evidence of ponding water on the road surface.
 - (b) The road surface is bowl-shaped.
- (3) At severity level H [High Severity]
 - (a) Large amounts of ponding water or evidence of ponding water on the road surface.
 - (b) The road surface contains severe depressions”. (Department of the Army, 1995)

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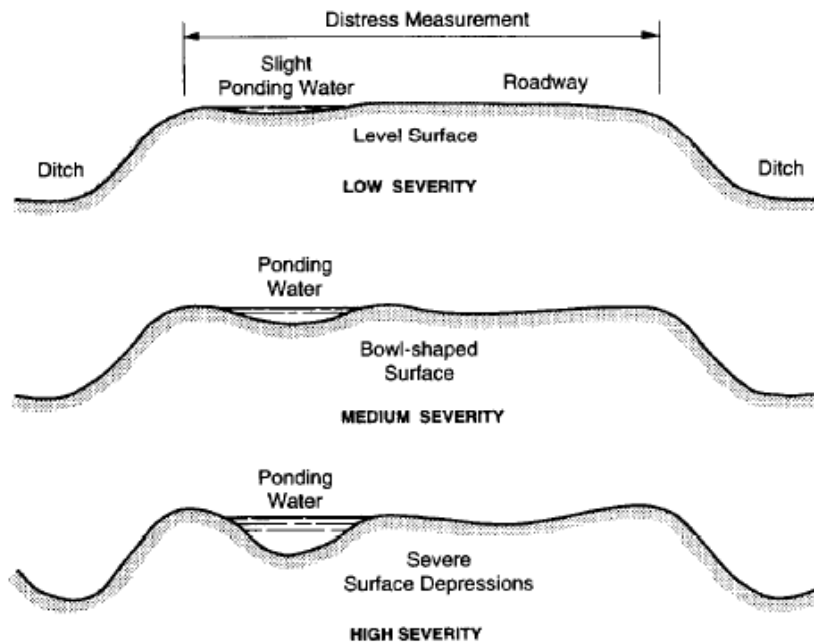


Figure 1: Illustration of URCI loss of cross section severity levels (Department of the Army, 1995)

The remote sensing system requirements outlined in *Deliverable 1-A: Requirements for Remote Sensing Assessments of Unpaved Road Conditions* for detecting a road's cross section are as follows:

The remote sensing system is required to measure the pavement cross slope between the centerline of the road to the edge of pavement where the beginning of the ditch slope start on both lanes of the pavement. The requirement is to measure the profile of the cross section of the road. For example, for a nine-foot wide lane, a 1% slope would drop approximately one inch (2.5 cm). Pavements that have negative slopes would indicate that the centerline of the pavement is lower in elevation than the edges of the pavement. Elevation points measured at the centerline of the pavement and the edge line of the pavement must be identified as such. Cross section elevation data must be recorded at intervals of at least every ten lineal feet (3.05 m) per sampling unit as measured with the direction of the road. (Brooks, Colling, & Roussi, 2011)

The remote sensing system will be capable of measuring surface grade of each lane of an unpaved road, but the criteria defined in the URCI method does not provide quantifiable levels of grade that correspond to each distress level. The following criteria will be used during the post processing of the remote sensing data to categorize each road sampling location into the four URCI severities – No Distress, Low, Medium, and High – and will be done prior to exporting the data to the DSS.

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No Distress Present

The cross section grade from the centerline of the road to the edge line of the pavement is at least 3% or more (centerline higher than edge line) for both lanes of the road.

This criterion is recommended based on guidance from the *Gravel Roads: Maintenance and Design Manual* (Scorseth & Selim, 2000) stating that ideally gravel roads should have a 4% cross slope for good drainage. The 3% minimum provides a margin of error for small local discontinuity in the cross slope grade while still providing for positive drainage.

Low Severity

The cross section grade from the centerline of the road to edge line of the pavement is less than 3% (centerline higher than edge line) but greater than 0% for at least one lane of the road.

The lower limit of this criterion is recommended based on the illustration from the *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* (Department of the Army, 1995) which indicates that at low severity the cross section would have an essentially level cross slope. While 3% to 0% cross slope is not technically “flat” it is a gradual enough cross slope to produce localized areas of ponding or drainage issues where there are localized areas of nonconformity in the grading, and both grade ranges are less than optimum.

Medium Severity

The cross section grade from the centerline of the road to edge line of the pavement is less than or equal to 0% (centerline higher than edge line) but is greater than or equal to -2% (centerline lower than edge line) for at least one lane of the road.

The lower limits of this criterion is recommended based on the illustration from the *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* (Department of the Army, 1995) which indicates that at medium severity the cross section would have an essentially “bowl shaped” cross slope, indicating a negative grade is possible (edges of the pavement higher than the centerline). A -2% grade would indicate that the edge of the pavement is approximately 2.4 inches higher than the centerline of the pavement assuming a 10-foot lane. This would provide for a significant capacity to pond water on the road surface and would require significant regarding to address.

High Severity

The cross section grade from the centerline of the road to edge line of the pavement is less than -2% (centerline lower than edge line) or more for at least one land of the road.

Differences in lane grade

In situations where the grade in one lane is worse (lower cross slope) than the other, the worst lane will drive the characterization. For example if one lane had a 4% cross slope and another had a 2% cross slope, the severity level would be “Low”.

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Characterization of Improper Drainage Distress

Figure 2 below provides an illustration of the three severity levels of improper drainage according to the URCI method. *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* describes the criteria for assessing severity levels for the improper drainage distress as the following:

- (1) At severity level L [Low Severity], small amounts of the following exist:
 - (a) Ponding water or evidence of ponding water in the ditches.
 - (b) Overgrowth or debris in the ditches.
- (2) At severity level M [Medium Severity], moderate amounts of the following exist:
 - (a) Ponding water or evidence of ponding water on the road surface.
 - (b) Overgrowth or debris in the ditches.
 - (c) Erosion of the ditches into the shoulders or roadway.
- (3) At severity level H [High Severity], large amounts of the following exist:
 - (a) Ponding water or evidence of ponding water in the ditches.
 - (b) Water running across or down the road.
 - (c) Overgrowth or debris in the ditches.
 - (d) Erosion of the ditches into the shoulders or roadway.

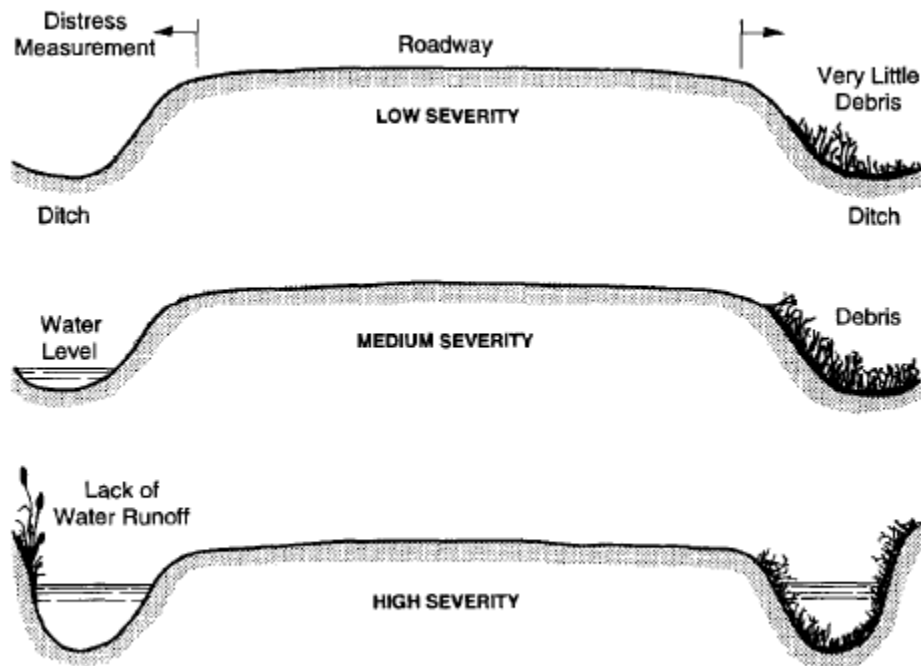


Figure 2: Illustration of URCI improper drainage severity levels (Department of the Army, 1995)

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The remote sensing system requirements outlined in *Deliverable 1-A: Requirements for Remote Sensing Assessments of Unpaved Road Conditions* (Brooks, Colling, & Roussi, 2011) for detecting improper drainage are as follows:

The remote sensing system must be able to measure the elevations of the ditch fore slope and back slope (if present) for each ditch perpendicular to the direction of the road. Ideally for a well-constructed road the ditch bottom should be 6.0 to 12.0 inches (15.2 cm to 30.5 cm) below the bottom of the pavement. The system needs to be able to measure this difference. Elevation measurements must be collected for each ditch starting at the edge of pavement to a minimum of 15.0 feet (4.57 m) either side of the pavement and must be identified as being measured on the ditch surface. Ditch elevation measurements are required to measure elevation to a precision of +/- 2.0 inches (+/- 5.1 cm). Ditch section elevation data must be recorded at intervals of at least every ten lineal feet per sampling unit as measured with the direction of the road.

The remote sensing system must be capable of sensing the presence of standing or running water in the ditch area. Water present in ditches will be noted by the section width of water surface present for each ditch and at least one elevation data point for the water surface at each ditch. Water elevation measurements are required to measure elevation to a precision of +/- 2.0 inches (+/- 5.1 cm), and width measurements are required to be measured with a precision of +/- 4.0 inches (+/- 10.2 cm). Where significant vegetation was present, this would prevent the measurement of the ditch depth and the presence of water.

The remote sensing system will be capable of measuring surface grade of each lane of an unpaved road, and comparing it to the elevation of the ditch bottom. The criteria defined in the URCI method does not provide quantifiable levels of ditch elevation or surface water extent that correspond to each distress level. Therefore, the remote sensing system will categorize road sampling locations into one of four URCI severities primarily based on ditch and water elevation with relationship to the elevation of the edge of the pavement. The URCI severity levels for improper drainage will be assessed based on the following criteria:

No Distress Present

The elevation of the ditch bottoms, including any static vegetation on both sides of the road or the elevation of any water in the ditch, is at least 2.5 feet below the edge of the top surface of the pavement as measured at the edge of the pavement.

This criterion is recommended based on general ditch design. Typically ditches are designed to provide positive drainage to the pavement structure, and at a minimum provide a drainage flow line which is below the pavement's sub grade elevation. This design guidance is summed up by the Cornell Local Roads *Roadway and Roadside Drainage* (Orr, 2003) manual which states "as a rule of thumb, the ditch should be 12 inches below the bottom of the subgrade". The 2.5 foot depth for this criterion allows for a pavement thickness of 18 inches to be adequately drained, which is typically thicker than most unpaved road aggregate layers. The 2.5 foot free ditch depth also provides a reasonable minimum depth for ditching that has associated cross culverts that are typically designed so that their crown does not extend into the pavement.

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Low Severity

The elevation of at least one ditch bottom, including any static vegetation or the elevation of any water in the ditch, is less than 2.5 feet below the edge of the top surface of the pavement but more than 1.5 feet below the edge of the top surface of the pavement as measured at the edge of the pavement. Each ditch will be evaluated as a separate measurement.

The minimum free (without water) ditch depth value for this criteria would indicate that many of the more thinly surfaced gravel pavements would be under the recommended guidance for drainage depth provided by *Roadway and Roadside Drainage* (Orr, 2003). The ditch depth provided by this criteria would indicate minimal clearance available for roadway cross culverts without protruding into the gravel layer (if any present) and having less than optimal cover.

Medium Severity

The elevation of at least one ditch bottom, including any static vegetation or the elevation of any water in the ditch, is less than 1.5 feet below the edge of the top surface of the pavement but more than 0.5 feet below the edge of the top surface of the pavement as measured at the edge of the pavement. Each ditch will be evaluated as a separate measurement.

Criteria proposed for this severity level would result in frequent saturation of any aggregate layers of the unpaved road and likely preclude the proper installation of culverts due to minimum ditch depth.

High Severity

The elevation of at least one ditch bottom, including any static vegetation or the elevation of any water in the ditch, is less than 0.5 feet below the edge of the top surface of the pavement as measured at the edge of the pavement. Each ditch will be evaluated as a separate measurement.

The criterion proposed for this severity level indicates that ditches are not functionally present or frequent saturation and ponding occurs on the driving surface.

Limitations of Collection

Heavily vegetated ditches may obscure the collection of elevation data for the improper drainage distress. Heavy grass or other vegetation that is likely to be in motion during data collection may give false ditch elevation in the case of heavier vegetation that is stationary due to the sensor perceiving the top of the vegetation as ground level.

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Demonstration of DSS Process and Functions

DSS provide an interface for storing, organizing and analyzing large quantities of data that assists users in determining a course of action. The DSS that will be utilized for this project is commercially available product called RoadSoft which uses a geographic information system (GIS) interface to spatially locate and display data related to transportation assets.

Data from two specific remote sensing and analysis processes will export data to the DSS. The eCognition process will produce the unpaved road inventory information that the DSS will use to identify the unpaved road network. The remote sensing platform system will produce road distress data and inventory features data that the DSS will use to determine asset conditions.

The eCognition process produces the unpaved road inventory information while the Remote Sensing Platform System (RSPS) produces road distress data and inventory features data. The DSS receives both data sources in addition to data collected by traditional manual processes such as ground-based inspection by a technician (see **Figure 3**). This data processing routing and the interaction of these data are outlined in the Data Transfer Format section of this document.

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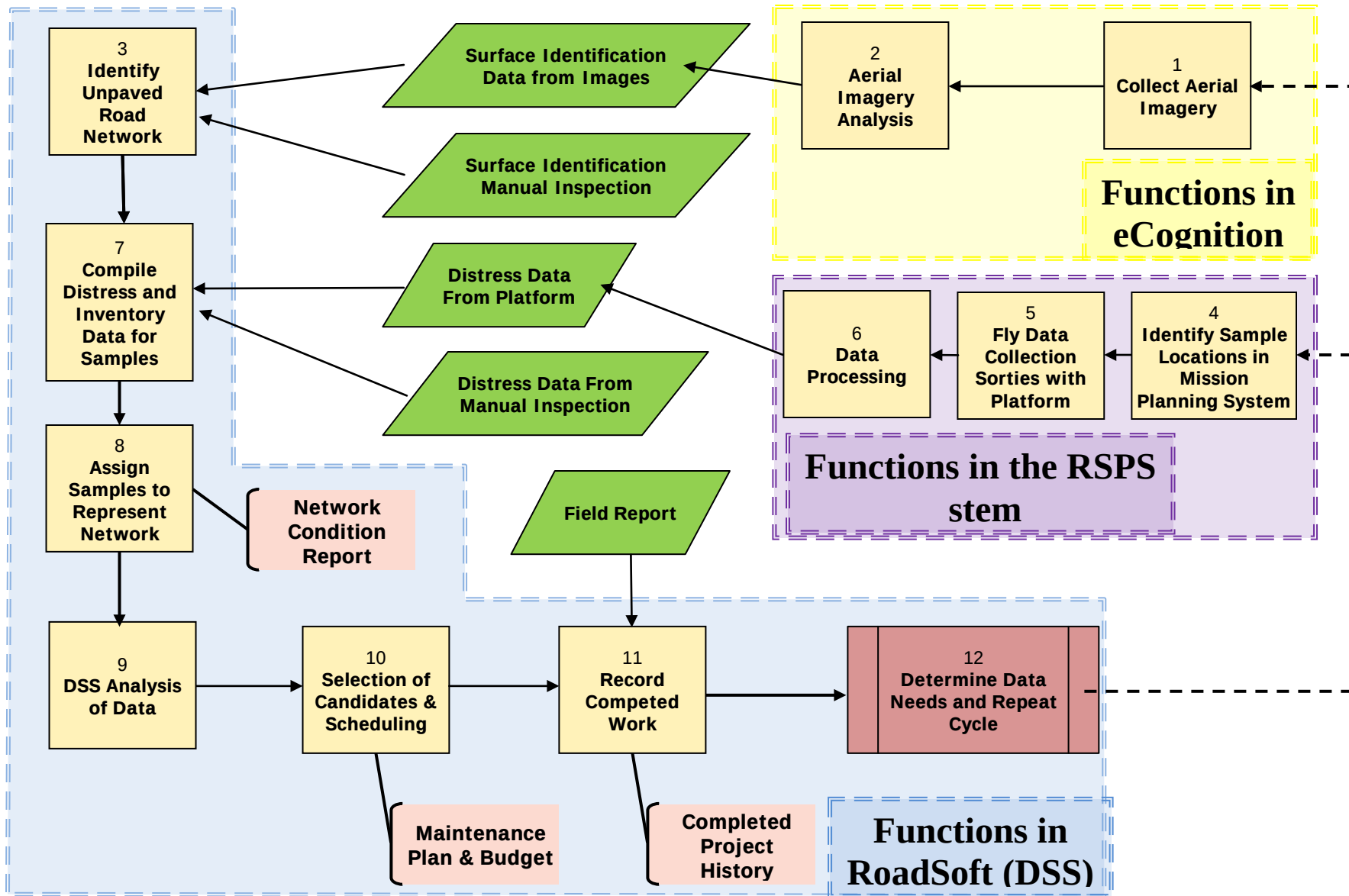


Figure 3: Road analysis process flow

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eCognition System

The unpaved road inventory information will be generated from the analysis of high resolution, 4 band aerial photos using Trimble's eCognition software. This process is defined in *Deliverable 6-A: A Demonstration Mission Planning System for use in Remote Sensing the Phenomena of Unpaved Road Conditions* (Roussi, Brooks, & Vander Woude, 2012). Identification of the unpaved parts of the road network will be completed as the first step in data collection, since it is necessary to understand the location and extent of the unpaved road network prior to collecting further data. It is anticipated that users will update unpaved road inventory data through the remote sensing system on a relatively infrequent basis (every 3 to 5 years), since once the initial inventory is complete, project data received from construction projects will serve to maintain the inventory. As a result, an updated inventory from aerial photos will only be necessary when new roads are constructed or when project records age to the point that they no longer reflect field conditions.

Remote Sensing Platform System (RSPS)

The unpaved road condition data and road width information conforming to the URCI method will be collected from flown missions by directing the remote sensing platform to representative sampling locations within the unpaved road network. Sampling locations will be pre-determined road segments that have good visibility from the air, are representative of conditions on the group of roads that the segment represent, and will be approximately 100' in length. It is anticipated that unpaved road condition data collection may be updated through successive flights as much as four to five times per year, to once every year, depending on specific user needs and budgets.

Road Analysis Process Flow

The following section of the report will give a brief overview of the interactions between the eCognition process and the DSS, as well as the RSPS and the DSS (RoadSoft). Sections numbered below are listed with respect to the unit processes in *Figure 3* above.

1) Collect Aerial Imagery

Aerial imagery data files are collected by users for a geographic area of interest where the inventory of unpaved roads has not been collected or needs to be updated. The date that the aerial image is captured will be used as the effective date associated with the unpaved road surface inventory assessment when the data is passed to the DSS.

2) Aerial Imagery Analysis

Aerial imagery is analyzed using Trimble's eCognition software. This process is defined in *Deliverable 6-A: A Demonstration Mission Planning System for use in Remote Sensing the Phenomena of Unpaved Road Conditions* (Roussi, Brooks, & Vander Woude, 2012). The aerial imagery analysis will identify the Michigan Geographic Framework (MGF) road segments that are unpaved roads. The data export from the aerial imagery analysis will include a listing of the MGF physical reference number (PRNO), beginning mile point (BMP), and ending mile point (EMP) of each unpaved road segment, and date of the aerial photo used for the assessment. Location data for unpaved roads will also include the latitude/longitude coordinates for the end points of the unpaved road segments. The format for the data export from the aerial imagery analysis (eCognition process) is more fully defined in the Data Transfer Format section of this report.

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3) Identify Unpaved Road Network

The DSS will utilize the unpaved road inventory data from the aerial imagery analysis to update its existing pavement surface inventory. Road segments in the DSS that are identified as being unpaved in the aerial imagery analysis, but that do not have a pavement type assigned in the DSS will be set as “pavement type=gravel”. Road segments in the DSS that have an existing pavement surface type will only be assigned “pavement type=gravel” if the most current surface type information in the DSS is older than the aerial image date used for the analysis. **Figure 4** provides an example of an updated road inventory in the DSS.

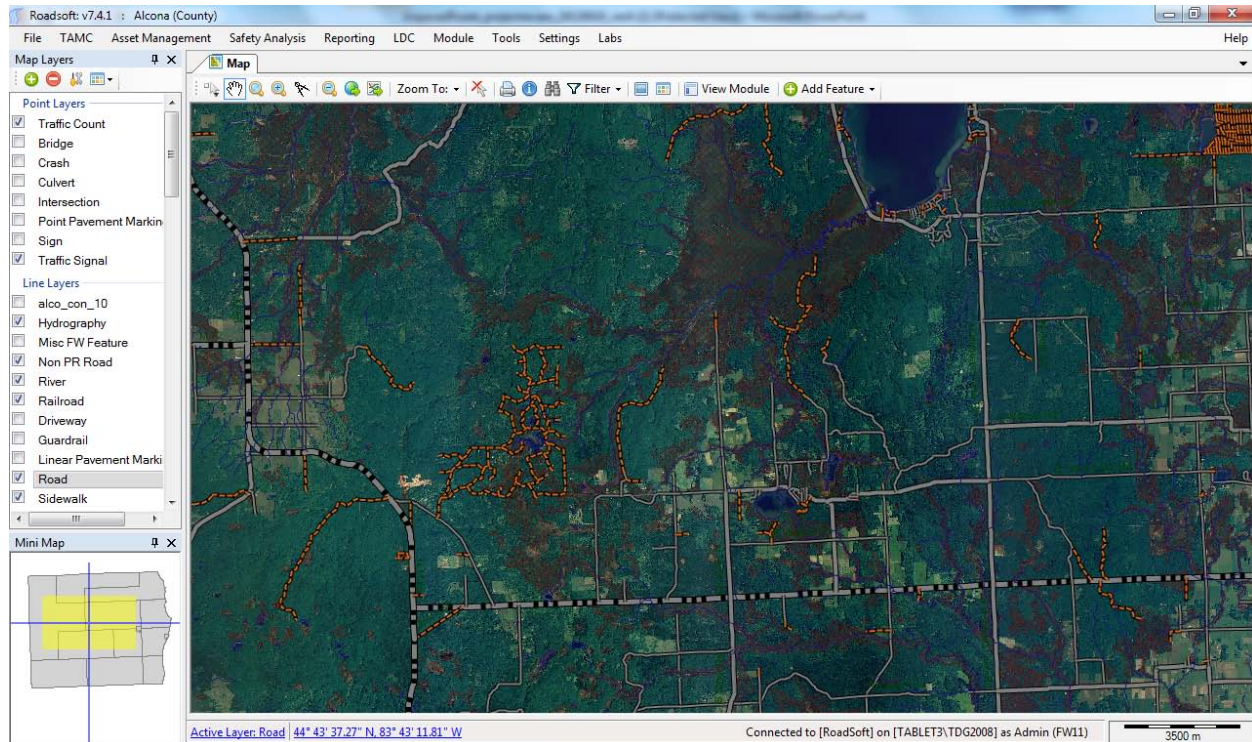


Figure 4: Example of an updated unpaved road inventory in the DSS (RoadSoft). Unpaved roads shown as brown dashes

4) Identify Sample Locations in Mission Planning System

Representative sample locations where the platform will be required to collect distress data will be user defined in the mission planning system that controls the platform. This process is defined in *Deliverable 6-A: A Demonstration Mission Planning System for use in Remote Sensing the Phenomena of Unpaved Road Conditions* (Roussi, Brooks, & Vander Woude, 2012). The selection of sampling locations will require some forethought and planning because samples will need to be representative of the larger road segments that the sample represents, as well as being visible from the air without overhead obstructions. Guidance on the selection of sample locations is described in *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* (Department of the Army, 1995).

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5) Fly Data Collection Sorties with Platform

Field collection of distress data from the platform presumably will be collected during the warm weather months when most unpaved road distress is likely to take place. Data collection events would most likely be collected in a group for a specific agency over a relatively short period of time. Data collection events could be as infrequent as annually or as frequent as monthly depending on the agency's business process and budget for data collection.

6) Data Processing

Raw data collected by the remote sensing platform during distress data sorties will likely require a degree of post processing prior to export to the DSS. At the time of publishing of this deliverable the extent of the post-processing requirements is not clear. However it will be defined in deliverable 6C – *Software and Algorithms to Support Unpaved Road Assessment*. Final processed data from the remote sensing platform will be in the form of URCI ratings for: loss of road cross section, improper drainage (where possible), potholes, ruts, corrugations and loose aggregate berms. It will also include the inventory feature of road width for each specific road sampling location. Average calculated road width will be received by the DSS at each sampling location based on intermediate measurements collected by the remote sensing platform.

7) Compile Distress and Inventory Data for Samples

Unpaved road distress and inventory (width) data from the remote sensing platform will be imported into the DSS to create an all-inclusive database of unpaved road information. Information from the remote sensing platform can be augmented with other distress or inventory data from manual field inspections as users deem necessary. An example of manual field collection of data would include dust distress measurements or estimations, since it was determined that it would be infeasible to reliably measure this distress with remote sensing to the extent necessary to make the data usable. The combined data set will provide the basis for road managers to carry out data-driven planning and asset management. **Figure 5** shows an example mockup of a data entry and evaluation screen in the DSS where URCI distress data will be visible for each sample segment.

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Unsurfaced Road Inspection

Location Information

Road Segment	Geels Rd : 0.000 - 1.224
Sample Segment	1.002 - 1.020 : 100 ft
Date	6/12/2012
Area Of Sample	1400 sq. ft.
Inspector	R. Smith
Remarks	Erosion into road; standing water in ditches in several ar...

Distress Types

81	Improper Cross Section (linear feet)
82	Inadequate Roadside Drainage (linear feet)
83	Corrugations (square feet)
84	Dust
85	Potholes (number)
86	Ruts (square feet)
87	Loose Aggregate (linear feet)

Type	81	82	83	84	85	86	87
L				☒			
M	100			☐		490	
H		200		☐		910	

Type	Density	Severity	Deduct Value
81	7.1	M	19
82	14.3	H	36
84	-	L	2
86	35.0	M	31
86	65.0	H	44

Total Deduct Value	q	URCI	Rating
132	4	25	Poor

Figure 5: Example URCI distress form for a road sample segment

When the data collection cycle is complete for the unpaved road network, there is an opportunity for users to evaluate the network-level road conditions to determine how the historical management of the asset is impacting its overall quality. The DSS will include network-level road condition reports which will allow users to graphically display the change in road condition over time. **Figure 6** below provides an example of a network condition trend graph showing a decline in the quality of pavement condition over time.

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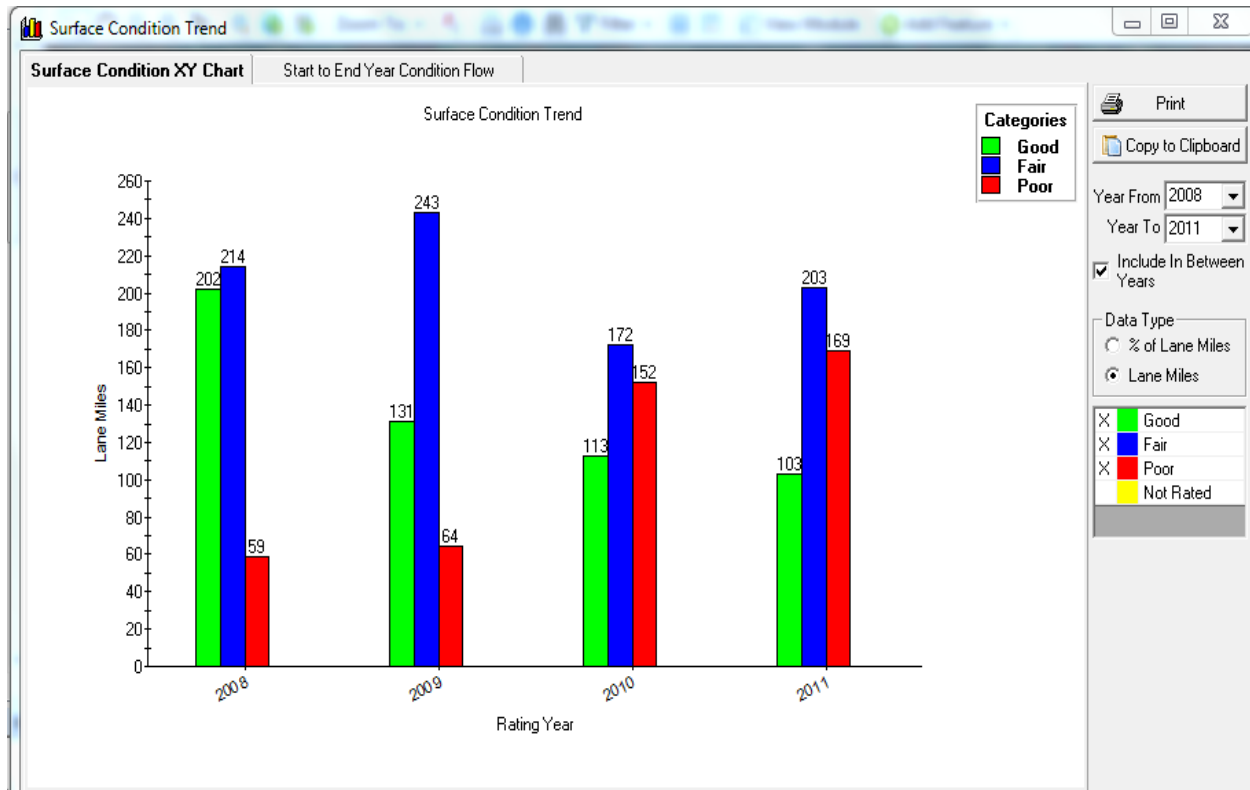


Figure 6: Network condition report

8) Assign Samples to Represent Network

The URCI method samples distress and inventory information to represent a larger network of roads. This functionality will be present in the DSS so that users can assign specific sampling locations to represent the larger road network. **Figure 7** illustrates how a sampling location (shown with the red highlighted segment) can be assigned to a larger road network (shown by the yellow highlighted road segments). *Technical Manual No. 5-626: Unsurfaced Road Maintenance Management* (Department of the Army, 1995) describes the process of dividing road networks for representation by samples.

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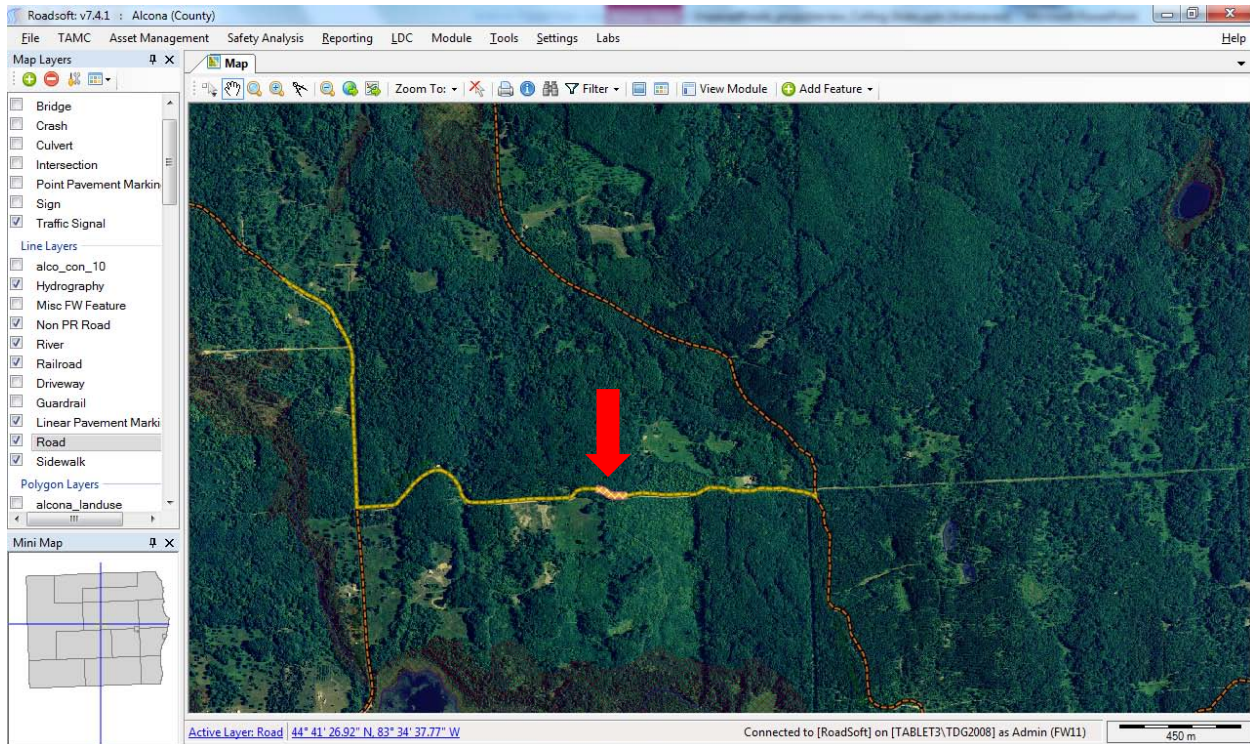


Figure 7: Assigning road sampling locations to a network of representative roads in the DSS

9) DSS Analysis of Data

The URCI method provides set of decision support criteria that guide a road manager to a specific course of action based on an observed road distress or condition. An example of decision support criteria is shown in **Figure 8**. These criteria were designed specifically for U.S. military facilities to standardize decision making given the resources and criticality of the transportation systems they were intended for. However, they may not necessarily be the best practice or provide suitable guidance for public road managers with large unpaved road systems. The DSS developed for use in this project will allow individual road agencies to customize the applicable decision-making criteria based on their individual agency goals, resources and practice.

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TM 5-626

Table 4-1. Maintenance alternatives

<i>Distress</i>	<i>Severity code</i>	<i>cost code¹</i>	<i>Description</i>
81-Improper cross section	L	B	Grade only.
	M	B/C	Grade only/grade and add material (water or aggregate or both), and compact. Bank curve. Adjust transitions.
82-Improper roadside drainage	H	C	Cut to base, add aggregate, shape, water, and compact.
	L	B	Clear ditches every 1-2 years.
	M	A	Clean out culverts.
	B	B	Reshape, construct, compact or flare out ditch.
83-Corrugations	H	C	Install underdrain, larger culvert, ditch dam, rip rap, or geotextiles.
	L	B	Grade only.
	M	B/C	Grade only/grade and add material (water or aggregate or both), and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.
84-Dust stabilization	L	C	Add water.
	M	C	Add stabilizer.
	H	C	Increase stabilizer use.
	C	C	Cut to base, add stabilizer, water, and compact. Cut to base, add aggregate and stabilizer, shape, water, and compact.
85-Potholes	L	B	Grade only.
	M	B/C	Grade only/grade and add material (water, aggregate, or 50/50 mix of calcium chloride and crushed gravel), and compact.
86-Ruts	H	C	Cut to base, add aggregate, shape, water, and compact.
	L	B	Grade only.
	M	B/C	Grade only/grade, add material, and compact.
87-Loose aggregate	H	C	Cut to base, add aggregate, shape, water, and compact.
	L	B	Grade only.
	M	B/C	Grade only/grade, add material, and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.

¹Cost code guide: A = labor, overhead; B = labor, equipment, overhead; C = labor, equipment, materials, overhead.

Figure 8: Decision support criteria based on observed distresses from TM 5-626 (Department of the Army, 1995)

The DSS functionality will be created for this project will allow road segments to be ranked as candidates for rehabilitation or maintenance treatments based on their historical distress ratings and inventory information. The ranking system will allow users to use any number of features to filter and sort candidates for ranking. For example a user would be able to filter out just unsurfaced roads of a specific functional class, in a specific region or political jurisdiction (township for example), due to funding constraints. The user could then rank potential road projects considering which road segments have the worst condition and highest traffic volume. Project ranking criteria will be available in a number of reports and tables in the DSS. The DSS will be capable of visually displaying candidate projects meeting specific criteria visually on a base map. **Figure 9** provides an example of project ranking tools.

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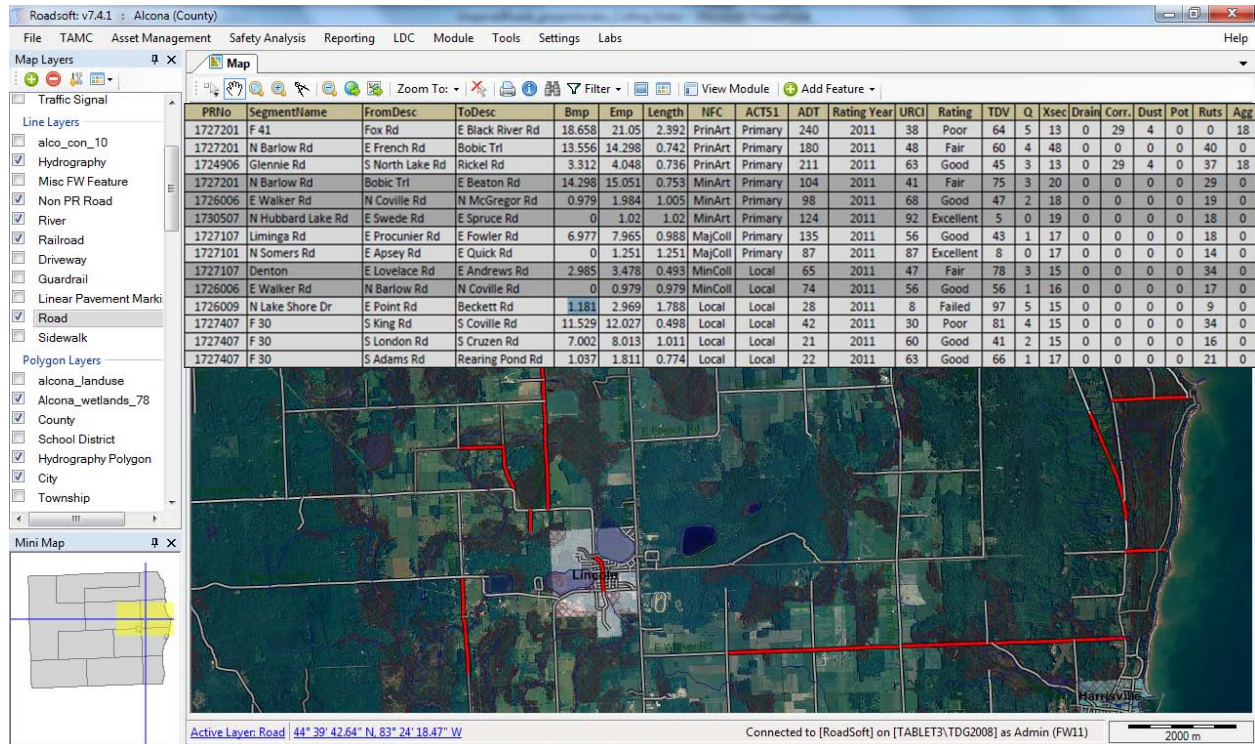


Figure 9: Example unpaved road project candidate ranking matrix based on condition and inventory

10) Selection of Candidates and Scheduling

The DSS will allow users to set up and schedule projects for all or part of a road segment or group of road segments. The scheduling tool allows users to define specific information about each planned project including project cost, project type, project location, job number and notes. Scheduled projects will be available for display in the DSS base map, as well as in a planned project report. **Figure 10** provides an example of a scheduling tool dialogue box. Planned project information can be used for construction advisories and communication with internal agency staff, and can also act as a historical record.

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Save New Project

Save

Location: (eg. Road Name - From Here to there)
 Jone Road

Project Number: 1037XP Start Date: 7/15/2012 Completion Date: 7/24/2012 Estimated Costs: 45000 Total Costs:

Surface Sub-Type: Gravel-Standard Activity/Treatment: Add 6" of Gravel Status: Scheduled

Description: Add 6 inches of 23A gravel, shape and compact Source of Funds: Local Millage and Property Assessment - 50%-50% split

Memo:

Segment Name	PR No.	P.O.B.	P.O.E.	From Description	To Description
N Somers Rd	1727101	0.000	1.070	Apsey Rd.	Quick Rd.
N Somers Rd	1727101	1.070	1.251	Apsey Rd.	Quick Rd.
N Somers Rd	1727101	1.251	1.504	Quick Rd.	Huffman Rd.
N Somers Rd	1727101	1.504	2.247	Huffman Rd.	Miller Rd.

Figure 10: Road project scheduling tool

11) Record Completed Work

As road maintenance projects are completed, field reports can be used to update the DSS database by changing the status of projects from “planned” to “completed. Completed construction and maintenance project will show up in road segment history reports along with historical rating activities. Completed projects will be will also be available in reports showing historical construction activity. **Figure 11** shows an example of a historical rating and activity screen for a specific road sampling location. **Figure 12** shows a report that summarizes historical project activity.

Inventory Segment Surface Type Segment **Rating Segment**

Save Undo Print Split

0.000 - 0.507 0.507 - 3.111

Identification

Surface Sub-Type: Gravel-Standard

From Description:

To Description:

Date	URCI	Rating	TDV	Q	Xsec	Drain	Corr.	Dust	Pot	Ruts	Agg
5/5/2012	38	Poor	64	5	13	0	29	4	14	0	18
7/20/2011	41	Fair	75	3	10	0	20	0	5	5	10
6/12/2010	63	Good	45	2	5	0	8	4	0	5	18

Date	Activity		
09/05/2011	Minor Grading		
06/14/2011	Minor Grading		
04/22/2011	Minor Grading		
06/22/2010	Add 2" & Regrade		

Add Activity

Multi-Edit

Figure 11: Road sample location form illustrating project construction history and historical rating activity

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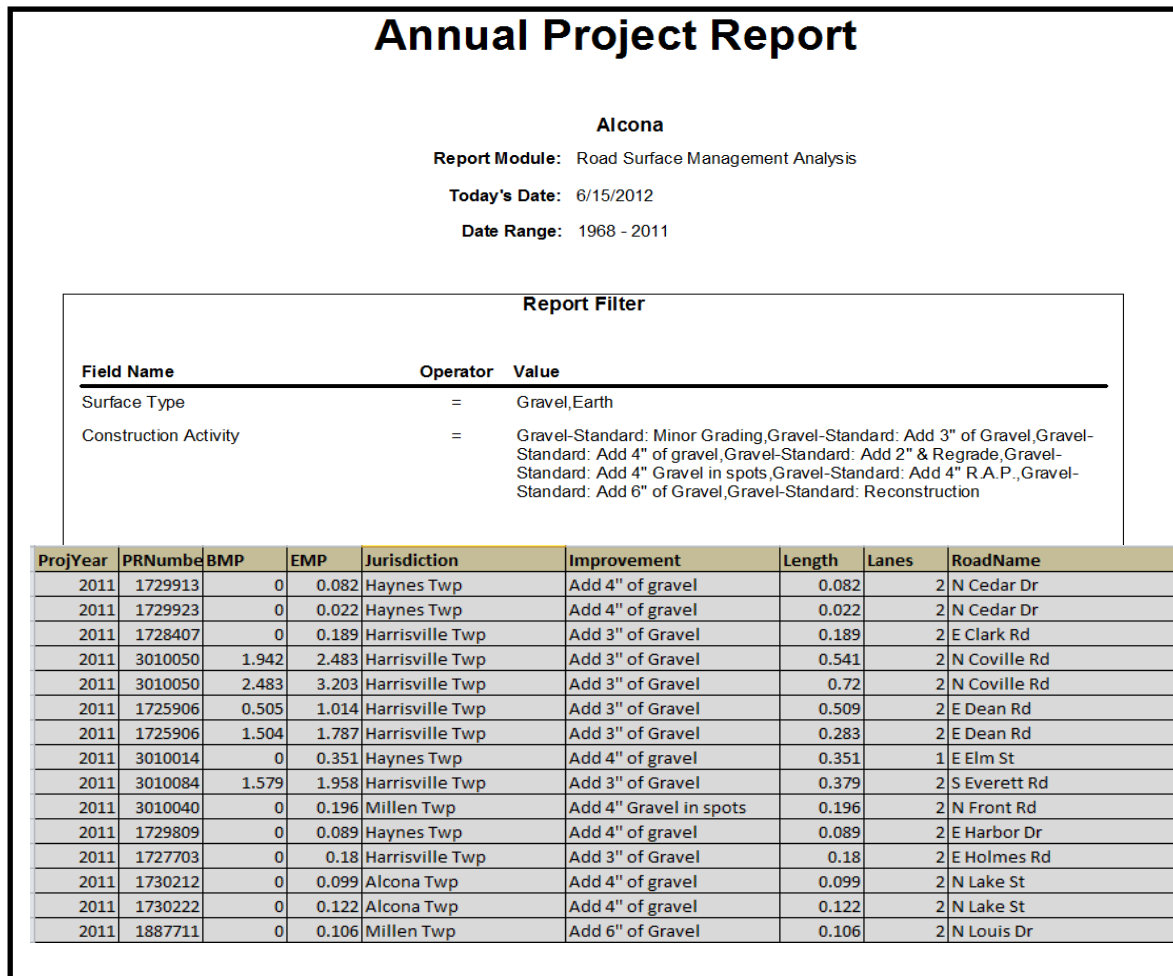


Figure 12: Annual project report illustrating historical treatment information

12) Determine Data Needs and Repeat Cycle

At the end of the unpaved road analysis user agencies will need to determine their data needs prior to restarting the data cycle. Agencies may repeat the data cycle several times per year or as little as once per year depending on how they intend to use the DSS and the level of budget that they have available for data collection activity. Less frequent data cycles will limit the type of DSS analysis that is possible with the distress and inventory information. For example, a single annual data collection event may not provide enough distress data to determine monthly schedules for routine grading, but it may provide sufficient information for determining where reconstruction or heavy rehabilitation activities need to take place, as well as provide an overall network metric for the analysis of a maintenance program on an annual basis.

Data Transfer Format

The raw data requirements that the remote sensing system must be capable of meeting are outlined in the report *Deliverable 1-A: Requirements for Remote Sensing Assessments of Unpaved Road Conditions* (Brooks, Colling, & Roussi, 2011) which can be found at <http://www.mtri.org/unpaved/> . This report defines the overall requirements for data collection; however it does not discuss the exact format and type of data that will be passed from the remote sensing systems to the DSS. This report will further define the data format that will be used to transfer data from the remote sensing systems to the DSS. It is anticipated that *Deliverable 1-A* will be a starting point to describe data transfer format. As the development of the remote sensing systems and the DSS interface progress (both of which are not scheduled for completion until several months after the date of this report), this document (Deliverable 6B) will be updated to reflect changes necessary during development.

A proposed data format is described in the appendices of this document. Appendix A provides sample XML field descriptions that could be sent to the DSS from the eCognition system, while Appendix B provides sample XML code that would accomplish this. Appendices C and D provide the same information as Appendices A and B respectively, except do so in regard to the RSPS rather than the eCognition system. Appendix E is a data comprehensive listing of all XML fields and tags used in Appendices A-D.

***Deliverable 6-B: A Demonstration Decision Support System for Managing
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References

- Brooks, C., Colling, T., & Roussi, C. (2011). *Deliverable 1-A: Requirements for Remote Sensing Assessments of Unpaved Road Conditions*.
- Brooks, C., Colling, T., Kueber, M., Roussi, C., & Endsley, A. (2011). *Deliverable 2-A: State of the Practice of Unpaved Road Condition Assessment*.
- Department of the Army. (1995). *Unsurfaced Road Maintenance Management Technical Manual No. 5-626*. Washington DC: United States Department of The Army.
- Orr, D. (2003). *Roadway and Roadside Drainage*. Ithica, NY: Cornell Local Roads Manual.
- Roussi, C., Brooks, C., & Vander Woude, A. (2012). *Deliverable 6-A: A Demonstration Mission Planning System for use in Remote Sensing the Phenomena of Unpaved Road Conditions*.
- Scorseth, K., & Selim, A. (2000). *Gravel Roads Maintenance and Design Manual*. Washington D.C.: USDOT.

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Appendix A: XML Field Descriptions in the DSS from the eCognition System

Field	Type	Size	Description	Comments
AerialDate	D	8	Aerial photo date	Date the aerial photo used was taken
Unpaved	C	3	Indicator of unpaved road	Yes indicates the road segment is unpaved
FrameworkVersion	C	3	Michigan Geographic Framework Version	Framework version used to specify the PR and mile points of the sample unit
PR	I	7	Physical Road ID Number	This value is derived from the Framework database
BMP	N	10,3	Beginning PR segment mile point of the sample unit	This value is derived from the Framework database and may not match the GIS length
EMP	N	10,3	Ending PR segment mile point of the sample unit	This value is derived from the Framework database and may not match the GIS length
BMPLat	F	8	Latitude of the BMP location	Coordinate value for latitude of BMP
BMPLong	F	8	Longitude of the MP location	Coordinate value for longitude of BMP
EMPLat	F	8	Latitude of the EMP location	Coordinate value for latitude of EMP
EMPLong	F	8	Longitude of the EMP location	Coordinate value for longitude of EMP
LRS_Link	C	23	Linear referencing segment ID	Used for summarizing the % of the road we were classifying as unpaved

Type: I – Integer D – Date (YYYYMMDD)
 C – Character B – Binary
 N – Numeric F – Floating

Appendix B: Sample Road Data Imported into the DSS from the eCognition System

```
<?xml version=1.0/>
  <AerialDate>20120612</AerialDate>
  <Unpaved>Yes </Unpaved>
  <FrameworkVersion>11a</FrameworkVersion>
  <LRSNumber>14</LRSNumber>

  <location>
    <PR>1234</PR>
    <bmp>1.000</bmp>
    <emp>2.500</emp>
    <BMPLat>38.898556</BMPLat>
    <BMPLong>-77.037852</BMPLong>

    <EMPLat>38.934562</EMPLat>
    <EMPLong>-77.136294</EMPLong>
  </location>
```

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Appendix C: XML Field Descriptions in the DSS from the RSPS

Field	Type	Size	Description	Comments
InspectionDate	D	8	Inspection Date	Date the inspection was conducted
Inspector	C	255	Inspector Name	The name of the inspector – Repeating field?
Remarks				
FrameworkVersion	C	3	Michigan Geographic Framework Version	The Framework version used to specify the PR and mile points of the sample unit
Width	I	3	Sample Width	The average width in feet of the sample unit.
Area	I	5	Sample Area	The square footage of the sample unit (length x width)
Length	I	4	Sample Length	The length in feet of the sample unit
PR	I	7	Physical Road ID Number	This value is derived from the Framework database
BMP	N	10,3	Beginning PR segment mile point of the sample unit	This value is derived from the Framework database and may not match the GIS length
EMP	N	10,3	Ending PR segment mile point of the sample unit	This value is derived from the Framework database and may not match the GIS length
BMPLat	F		Latitude of the BMP location	Coordinate value for latitude of BMP
BMPLong	F		Longitude of the BMP location	Coordinate value for longitude of BMP
EMPLat	F		Latitude of the EMP location	Coordinate value for latitude of EMP
EMPLong	F		Longitude of the EMP location	Coordinate value for longitude of EMP
Type	I	2	Indicates the type of distress present: 81 - Improper cross section 82 - Inadequate roadside drainage 83 - Corrugations 84 - Dust 85 - Potholes 86 - Ruts 87 - Loose aggregate	The distress types define the types of distresses observed on the sample unit. Type is used in conjunction with Severity and Quantity to enumerate the types of distresses present on the sample
Severity	C	1	Indicates the severity of the distress: L - Low M - Medium H - High	Severity is used in conjunction with Type and Quantity to enumerate the types of distresses present on the sample unit
Quantity	I	5	Indicates the amount of distress present	Quantity is used in conjunction with Type and Severity to enumerate the types of distresses present on the sample unit

Type: I – Integer D – Date (YYYYMMDD)
 C – Character B – Binary
 N – Numeric F – Floating

Appendix D: Sample Road Data Imported into the DSS from the RSPS

```
<?xml version="1.0"?>
<inspections>
  <inspection inspectionDate="20120612">
    <inspector>R. Smith</inspector>
    <remarks>Erosion into road</remarks>
    <FrameworkVersion>11a</ FrameworkVersion>
    <width>14</width>
    <area>1400</area>
    <length>100</length>
    <location>
      <PR> =1234</PR>
      <bmp>1.000</bmp>
      <emp>2.500</emp>
      <BMPLat>38.898556</BMPLat>
      <BMPLong>-77.037852</BMPLong>
      <EMPLat>38.934562</EMPLat>
      <EMPLong>-77.136294</EMPLong>      </location>
      <DistressTypes>
        <Type Distress="81">
          <Quantity>100</Quantity>
          <Severity>M">
        </Type>
        <Type Distress="82">
          <Quantity>200</Quantity>
          <Severity>H</Severity>
        </Type>
        <Type Distress="86">
          <Quantity>490</Quantity>
          <Severity>M</Severity>
        <Type Distress="86">
          <Quantity>910</Quantity>
          <Severity>H</Severity>
        </Type>
        <Type Distress="84"> Note this is dust, no quantity
          <Severity>L</Severity>
        </Type>
      </DistressTypes>
    </inspection> </inspections>
```

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Appendix E: Glossary of XML fields

AerialDate – Indicates the date that the aerial photo was taken.

Unpaved – Indicates that the road is an unpaved road

Inspections – Indicates that this is a collection of individual inspections (XML tag)

Inspection – Indicates the start of an inspection at a sample location (XML tag)

InspectionDate – The date of the inspection

Inspector – Names of inspectors, can be repeated as necessary?

Remarks – Notes about anything unusual about the sample unit

FrameworkVersion – Framework version of the linear referencing system used to locate the sample

Width – the width in feet of the sample unit

Area - the square footage of the sample unit (length x width)

Length- the length in feet of the sample unit

Location – Describes the location of the sample unit using PR and mile points from the Framework version specified in FrameworkVersion. This section can be repeated as necessary if the sample unit spans more than a single PR. (XML tag)

PR – Is the Physical Road ID Number for the sample unit

BMP - Beginning Mile Point is the beginning PR segment mile point of the sample unit

EMP- Ending Mile Point is the ending PR segment mile point of the sample unit

BMPLat – Describes the bmp location of the sample unit using raw GPS data

BMPLong - Describes the bmp location of the sample unit using raw GPS data

EMPLat – Describes the emp location of the sample unit using raw GPS data

EMPLong - Describes the emp location of the sample unit using raw GPS data

DistressTypes – There are seven distress types for unpaved roads. This section is used to enumerate the distress types that are present along with the quantity and severity of the distress. (XML tag)

Type – Each distress type present in the sample is specified by its Type, Quantity, and Severity level. There are seven distress types. The types are referenced by number as follows:

Type – 81 (Improper cross section)

Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit

Quantity – Linear feet per sample unit. The maximum length from all severity levels would be equal to the length of the sample unit

Type - 82 (Inadequate roadside drainage)

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Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit

Quantity – Linear feet per sample unit parallel to the centerline. The maximum length is two times the length of the sample unit (two ditches for the total length of the sample unit)

Type - 83 (Corrugations)

Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit

Quantity – Measure in square feet of surface area per sample unit parallel to the centerline. Each severity level is recorded separately. The amount cannot exceed the total area of the sample unit

Type - 84 (Dust)

Severity – L, M, or H (Low, Medium, or High). Only one severity level is selected for the sample unit

Quantity – No quantity is specified for dust. Dust is measured as low, medium, or high severity for the sample unit

Type - 85 (Potholes)

Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit

Quantity – The number of potholes of the specified severity level

Type - 86 (Ruts)

Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit and are recorded separately

Quantity – The square feet of surface area per sample unit. Each severity level is recorded separately

Type - 87 (Loose aggregate)

Severity – L, M, and H (Low, Medium, and High). Different severity levels may exist within the sample unit and are recorded separately

Quantity – Linear feet parallel to the centerline in a sample unit. Each severity level is recorded separately