Report Development

The development of this report involves three processes:

1) Data collection, auditing, and analysis
2) Engineering analysis
3) Cost analysis

Data Collection, Auditing, and Analysis

The data collection, auditing and analysis process provides data to build a comprehensive database of information relative to pavement condition, based on a systematic and defendable process for obtaining and analyzing data. Prior to 2011, the pavement condition database includes data from Visual Distress Survey (VDS) for cracking and pavement surface condition; and Road Profiler Survey (RPS) for ride and rut condition data. In 2011, the Pavement Analysis Section acquired two Data Collection Vehicles (DCV) to collect all the data types simultaneously.

In May of each year, the two DCV deploy statewide collecting continuous pavement data on approximately 22,000 lane miles of pavement. The DCV has a South Dakota type "Road Profiler" equipped with laser and accelerometer devices based on active class 1 ASTM E950 standards. At highway speeds, infrared laser sensors fire a signal to the pavement surface at 200 times per second. Combined with precision accelerometers also mounted in the front bumper, this real time measurement data is combined simultaneously with DMI (distance measuring instrument) data and GPS (global positioning system) data. The result is an accurate measurement of the longitudinal profile (ride) which is averaged and stored electronically in one-tenth mile increments for the entire 22,000 lane miles each year.

Mounted on the back of the DCV are two lasers and a 3D camera for pavement surface imaging with depth for rutting, cracking and faulting. The data collected is not affected by vehicle variation (i.e. speed, weight and suspension). Measurements are not affected by changes in temperature, pavement color or texture, sunlight, wind and speed.

The 3D Data Acquisition System leverages an incredibly fast, high-resolution 3D camera capturing both high-resolution images and transverse profiles of the road surface in real-time. The 3D camera captures a specially-designed laser line as its projected over the surface of the pavement and uses the location of this line to measure the 3D or height deviations of the pavement surface. The height deviations are used to calculate rutting on both wheel paths. The camera captures several profiles every inch at speeds up to 70 MPH.

The system provides not only rutting data, but the provided depth readings and image allow the single system to also capture cracking data from the very same profiles of

the road surface. For cracking data analysis, 528 feet sample section of each lane is the representative sample of the load and non-load associated cracking present in a one-lane mile section.

Each DCV is operated by two Pavement Analysis (PAS) employees. Two permanent driver/operators train two temporary employees at the Helena headquarters for one week prior to their data collection assignments. In addition, the Pavement Management (PvMS) Unit staff audits each van's work for accuracy throughout the data collection season.

The DCV data is reported by calculating Condition Indexes (CI), the following five CI's are reported:

1) Ride (RI)
2) Rut
3) Alligator Cracking (ACI)
4) Miscellaneous Cracking (MCI)
5) Overall Performance Index (OPI)

The Ride Index (RI) is calculated using the International Roughness Index (IRI) in inches per mile and converting it to a 0-100 scale.

The Rut Index is calculated by converting rut depth to a 0-100 scale. Rut measurements are taken approximately every foot and averaged into one-tenth mile reported depths.

The Alligator Crack Index (ACI) is calculated by combining all load associated cracking, and converting the index to a 0-100 scale.

The Miscellaneous Cracking Index (MCI) is calculated by combining all non-load associated cracking, and converting the index to a 0-100 scale.

The Overall Performance Index (OPI) is calculated by combining various, weighted amounts of the ACI, MCI, RI, and Rutting Indexes, and converting the index to a 0-100 scale. The OPI is calculated to provide one index, which describes the current "general health" of a route, or system.

All CI's are in a 0 to 100 scale, ACI, MCI and Ride have the condition levels in the following table.

Condition	Range
Good	80 – 100
Fair	60 – 79.9
Poor	0- 59.9

Condition levels for OPI

Condition	Range
Good	63 - 100
Fair	45 - 62.9
Poor	0 – 44.9

Condition levels for the Rutting Index

Condition	Range
Good	60 – 100
Fair	40 – 59.9
Poor	0 – 39.9

Once CI's are calculated for every data sample, the CI's are then averaged over management sections. The sectioning of highway systems into management sections is performed to create homogeneous sections with relevant attributes. Such as: pavement type and design, traffic, condition, sub-grade and material characteristics. Often these sections fall into the same section intervals as previous pavement projects. Homogeneous sections are created so that uniform treatments and treatment costs can be assigned in a practical manner.

For more information relating to the data collection, auditing, or analysis contact:
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Engineering Analysis

The goal of the PvMS Engineering Analysis Process is to assign the most effective treatment to each management section. Decision Trees are used to facilitate this process; each tree is composed of nodes and limbs in which decision variables and thresholds are assigned. Decision variables may include:

1) Age (years since last treatment)
2) AADT (average annual daily traffic)
3) System (functional designation)
4) Depth (thickness of all pavement & base layers)
5) Type (asphalt cement or Portland cement concrete surface layer)
6) CI (all condition indices)
7) ESAL (18 kip equivalent single axel loads)

At the end of each branch of a decision tree resides the most effective pavement treatment. PvMS pavement treatments are meant as a "general" remedy for pavement deterioration or failure based on "network" level analysis. Most treatments include several feasible pavement design alternatives, which need to be identified from further engineering "project" level data collection. Currently the PvMS categorizes its pavement treatments by pavement surface type: Asphalt Cement (AC) or Portland Cement Concrete (PCC) and include the following:

Asphalt Cement (AC) Treatments

1) Do Nothing
2) AC Crack Seal
3) AC Crack Seal & Seal & Cover
4) AC Thin Overlay
5) AC Thin Overlay_Engineered
6) AC Minor Rehabilitation
7) AC Minor Rehabilitation_Rut
8) AC Major Rehabilitation
9) AC Reconstruction

Portland Cement Concrete (PCC) Treatments

1) Do Nothing
2) PCC Crack Seal
3) PCC Minor Rehabilitation
4) PCC Major Rehabilitation
5) PCC Reconstruction

Following is a brief description of each pavement treatment:

Asphalt Cement (AC) Treatments

Do Nothing

Current pavement condition does not warrant a treatment at this time.

AC Crack Seal

The management section exhibits a variety of cracking in sufficient quantity that makes it a candidate for crack seal.

AC Crack Seal and/or Seal and Cover

The management section exhibits a variety of cracking in sufficient quantity that makes it a candidate for crack seal and the management section is old enough to be a candidate for seal and cover.

AC Thin Overlay

The management section is a candidate for a 50mm – 60mm overlay and the overall pavement structure appears to be structurally adequate.

AC Thin Overlay Engineered

On pavements that have over 300 ESAL's or that are greater than 20 years old, partial engineering is recommended to ensure that the section is truly a candidate for Pavement Preservation. Plant mix cores should be evaluated for stripping and thickness, and in some cases base course and subgrade should be evaluated. The pavement section is also evaluated using non-destructive testing deflection analysis.

AC Minor Rehabilitation/AC Minor Rehabilitation Rut

The intent of these projects is to rehabilitate the existing pavement surface through an engineered approach that considers the observed pavement distress and in-place materials. The existing width of pavement is to be maintained if it is less than or equal to the route segment width. Milling operation will be $\leq$ 60-mm w/o exposing base gravel. All slope work and other features are usually accomplished within existing right-of-way. Other surfacing improvements shall follow the Guidelines for Nomination and Development of Pavement Projects.

The objective of this treatment is to extend the life of the pavement structure by rehabilitating the wearing surface only. Other improvements such as slope flattening, guardrail and and/or other safety improvement as outlined in the

Guidelines for Nomination and Development of Pavement Projects may be included.

AC Major Rehabilitation

The intent of these projects is to rehabilitate the existing pavement structure through an engineered approach that considers the observed pavement distress, the in-place material, and roadway geometrics. Milling operations may be > 60 mm and may expose base gravel which can then be treated or modified.
New right-of-way and utility relocation may be required to improve geometrics, to flatten slopes, or enhance safety. Other surfacing improvements shall follow the Guidelines for Nomination and Development of Pavement Projects.

The focus of this treatment is to extend the life of the pavement, improve ride quality and/or enhance capacity. May include rebuilding substandard horizontal or vertical curves but the majority of the work shall be primarily on the existing alignment. Typically requires rebuilding less than 25% of the total project length. This could include base course improvement, the addition of lanes or dualization of the existing facility, and/or dig outs to remove poor or contaminated material. Other improvements such as guardrail and/or other safety improvements as outlined in the Guidelines for Nomination and Development of Pavement Projects may be included.

AC Reconstruction

Reconstruction on existing alignment of an existing route where the old pavement structure is removed and replaced, and/or where additional continuous through lanes are added through widening, dualizing or the addition of continuous collector-distributor roads that provide by design and operation for through traffic movements.

Portland Cement Concrete (PCC) Treatments

PCCP Do Nothing

Current pavement condition does not warrant a treatment at this time.

PCCP Crack Seal

The management section exhibits a variety of cracking in sufficient quantity that makes it a candidate for crack seal.

PCCP Minor Rehabilitation

PCCP Minor Rehabilitation is minor slab replacement as needed, and grinding the pavement.

PCCP Major Rehabilitation

PCCP Major Rehabilitation is slab replacement as needed, dowel, and grind, or crack and seat with an overlay.

PCCP Reconstruction

Reconstruction involves removal and/or treatment of the base and/or the sub-grade material.

MAINTENANCE TREATMENTS

The treatments that are considered preventive maintenance by the "Guidelines for Nomination and Development of Pavement Treatment Projects" are the same for maintenance and construction except for mill and rut fill. When a Minor Rehabilitation Rut is recommended for construction, a Maintenance Rut Fill is recommended for maintenance. The **differences** between the recommended construction treatments and the recommended maintenance treatments in the decision trees are summarized below.

Construction Treatment	**Maintenance Treatment**
Minor Rehabilitation Rut	Maintenance Rut Fill
Minor Rehabilitation	Reactive Maintenance
Major Rehabilitation	Reactive Maintenance
Reconstruction	Reactive Maintenance