Pavement Management Systems - PMS

Value for money
PMS Objectives

Optimal Pavement Management based on socio-economic considerations
BENEFITS OF PMS

• A base to show the needs of funds now and in the future as well as the consequences of lack in funds

• Allocation of funds based on facts

• Use of funds to get the best result possible and be able to show it

• Feed-back of pavement performance

• An uniform and objective picture of pavement condition
Planning pavement maintenance and rehabilitation activities

A tool for the pavement engineer to decide

- WHERE
- WHEN
- HOW

an action will be done
Asset Management System

Pavement Management Systems is a component in Asset Management Systems
Old poor road
Sweden

Poor road stops the school bus
Russia

Federal highway in Russia
Russia
England

"Repaired" pothole
Poor roads

USA

Cameroon

India
Good roads

Morocco

Congo

Mali

Tanzania
Good roads

Canada

Chile

USA

Serbia
Good roads

New Zealand

Spain

Sweden
A pavements life cycle
Roads for the users
Pavements for the road users

- Comfort
- Road Safety
- Noise
- Internal
- External
- Particles
- PM10
- PM2.5
- Emission
- CO2
- Fuel
- Tire
- Rep-air
- Vehicle operating costs
- Travel time
- Access
- Vehicle operating costs
- Access
A pavements life cycle
Pavement Life Cycle Cost
Optimizing

Cost per year

Time

Total cost

Minimum cost

Road user cost

Road administrator cost
Pavement Management Systems is multidisciplinary

**Technomy**

- Highway engineering
- Geotechnical engineering
- Structural engineering
- Mechanical engineering
- Business economics
- Socio economics
- IT
- Logistics
- Measurements
- etc
PMS - Overview

PMS Components

- Road condition
  - Longitudinal unevenness
  - Transversal unevenness
  - Budget needs

- Road Inventory
- Pavement information
- Database
- Evaluation models
- Condition monitoring
  - Change in roughness 1989 - 2000
  - Percentage IRI > 5mm/m
  - 89 90 91 92 93 94 95 96 97 98 99 00
- Project identification
- Follow-up contracts
Network level - Overview

GOVERNMENT

REGION 1

REGION 2

REGION 3

REGION XX

ROAD ADMINISTRATION

REHABILITATION MAINTENANCE
Network to project level

Network - identification of projects

ROAD ADMINISTRATION

PROJECT 1

PROJECT 2

PROJECT 3

PROJECT NN

PRIORITY 1

PRIORITY 2

PRIORITY 3
PMS - Project Level

Detailed analysis of individual projects
Network level

Network to project

Project level
PMS - Overview

Road condition
- Longitudinal unevenness
- Transversal unevenness
- Budget needs

PMS Components

Road Inventory

Pavement information

Database

Evaluation models

Change in roughness 1989 - 2000
Percentage IRI > 5mm/m
- 1989: 11%
- 1990: 12%
- 1991: 12%
- 1992: 13%
- 1993: 13%
- 1994: 14%
- 1995: 14%
- 1996: 14%
- 1997: 89%
- 1998: 90%
- 1999: 90%
- 2000: 90%

Year

Percentage of network
- < 2000 AADT
- > 2000 AADT

Condition monitoring

Project identification

Follow-up contracts
Need of information

Models to explain performance

- Fast and automated methods
- Fast and automated methods?
- Visual inspections
- Slow, traffic disturbing measurements
Visual inspection

Severity and extension of different damages are registered
Unevenness – Roughness - Smoothness
Local unevenness or bumps
Rut depth

Wear of studded tires

Plastic deformation

Structural deformation
Poor surface drainage
Macrotexture
Cracking
Cracks
Frost dependent cracks
Edge cracking
Poor drainage

Water plants in the ditches

Stagnant water in the ditches

Eroded soil is filling the ditches
Pot hole
Bleeding asphalt
Ravelling

Surface dressing where stones get loose
Patching and local repair
PMS - Overview

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Change in roughness 1989 - 2000
Percentage IRI > 5mm/m

89 90 91 92 93 94 95 96 97 98 99 00
Year

Percentage of network

< 2000 AADT
> 2000 AADT

Evaluation models

Budget needs

PMS Components

Road condition
Automated measurements
Measurement quality

**Repeatability**
Measure again and get the same results.

**Validity**
Measure what is intended to measure
Visual inspection by using images

Inspection of damages

Measurement in stereo images
Automated measurements
Condition data

- Rut depth (1987)
- Unevenness IRI (1987)
- Cross fall, curvature, hilliness (1991)
- Cross profile
- Texture (2005)
- Edge deformation (2002)
- Longitudinal profile
- Cracks (not yet)
- Pictures
Measured road lane length
Computer

Laser height sensors

Accelometer

Inertial reference

Speed/distance
Profile measurements

Height sensora (laser)

Accelerometers

Inklinometer
Principle - Height Measurement

64 kHz and 90 km/h gives a measurement every 0.39 mm
Laser height sensors

Accelometer

Computer

Inertial reference

Speed/distance

Laser height sensors
IRI – International Roughness Index

IRI = 0.784

IRI_{20} = NaN

© Peter Andrén
- Measurement of three longitudinal profiles
- Development of full-car model
- Interpretation of vibration (ISO2631 and EU directive 2002/44/EG)
Types of evenness

- Microtexture
- Macrotexture
- Megatexture
- Evenness

Wavelength

0.5 mm  5 mm  50 mm  0.5 m  5 m  50 m
Macrotextur-Mean Profile Depth

Beräkning av makrotextur från profil

\[ MPD = \frac{\text{Peak}_1 + \text{Peak}_2}{2} - \text{average} \]

ETD = 0.2 + 0.8 MPD

100 mm
Modern profilometers can give a detailed 3D map of the road surface
Modern laser scanning equipment can give a 3D image of the road and surroundings.
Collection of images

- Collection of high resolution images in traffic speed
- Processing at the office
### Stereo images

#### Metadata

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![Stereo Images](image.jpg)
360-pictures
Visual inspection by using images

Inspection of damages
Measurement in stereo images
Laser scanning
Falling Weight Deflectometer - FWD

50 kN

90 cm
45 cm
20 cm

D0  D20  D45  D90

Bearing Capacity
Ground Penetrating Radar (GPR)

- Measuring thicknesses of pavement layers.
- Different antennas for different depth
PMS - Overview

PMS Components

Road condition
- Longitudinal unevenness
- Transversal unevenness
- Budget needs

Evaluation models

Road Inventory

Pavement information

Database

Condition monitoring

Project identification

Follow-up contracts

Change in roughness 1989 - 2000
Percentage IRI > 5mm/m

Year

Percentage of network

< 2000 AADT  > 2000 AADT
Road condition

Longitudinal unevenness

Transversal unevenness

Coordinates x, y, z

Road Inventory

Pavement information

Node

Link
Traffic numbers are collected in the "Traffic Measurement System"

- Number of vehicles
- Number of axles
- Vehicle type

Based on traffic measurements, Equivalent Standard Axle Loads is calculated.
Example of output from the maintenance treatment database
The maintenance treatment database covers a long period.
Expected durability

![Expected durability chart]

- **Trafik**
  - 0-249
  - 250 - 499
  - 500 - 999
  - 1000 - 1999
  - 2000 - 3999
  - 4000 - 7999
  - 8000 - 11999
  - >12000

- **Livslängd (år)**
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
PMS - Overview

Road Inventory

Database

Pavement information

Evaluation models

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Follow-up contracts

Road condition

Longitudinal unevenness

Transversal unevenness

Budget needs

PMS Components
Planning pavement maintenance and rehabilitation activities

A tool for the pavement engineer to decide

- WHERE
- WHEN
- HOW

an action will be done
Who are the users?

Primary users
Performs analysis and produce outputs from the system (measurements, data storage, analysis, further development)
Skilled engineers

Secondary users
Uses the results of the system
Managers
PMS is a Decision Support System
Benefits

Systems

Evaluation

Data collection and storage

Users

Road Data Bank

Data collection and storage
PMS - Overview

PMS Components

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- Longitudinal unevenness
- Transversal unevenness

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Evaluation models

Road Inventory

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Change in roughness 1989 - 2000
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Year

Percentage of network

< 2000 AADT
> 2000 AADT

81
Output example from the New Swedish PMS
Output example from the New Swedish PMS
Output example from the New Swedish PMS
Output index
Output index
Road Surface Condition
Dalarnas län, Väg: 60.00
Sträcka: 0 - 5000, Körfält: 10, Riktning: Framåt, Sida för vägdata: 1

Vägbredd(m) | 7.0 | 8.0 | 11.7
Trafik(ÅDT) | 3190 | 6090 | 5780
Tung traf(ÅDT) | 550 | 530
Bel.lager 1 | 0Y1B1681 | 35ABS1198 | 32HABS1293
Bel.lager 2 | 16MABT1280 | 0ABT1698 | 1) 0MABT1292
Bel.lager 3 | 24MABT1275 | 32HABT1287 | 2) 3) 28HABT1286

Spårdjup (mm) | 0 | 5 | 10 | 15 | 20

Ojämnhet IRI(mm/m) | 0 | 1 | 2 | 3 | 4 | 5 | 6

Best1
Example PMS planning module – Road graph
Change in condition

\[ y = 0.0741x + 1.5298 \]

\[ R^2 = 0.8817 \]

- 610 vehicles/day
- 90 trucks/day
- 3055 m
- 7.0 m
- 90 km/h
The decrease is larger than 9 mm = heavy action.

11 mm

5

New overlay

Not reported fictive action

AADT 5590
Measured rut depth | Predicted rut depth

AC

Stone mastic asphalt

New overlays

Stone mastic asphalt

AADT 22490

# Maintenance standard IRI

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<th>Skyltad hastighet (km/h)</th>
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<td>4000-8000</td>
<td>2,4</td>
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<td>2,4</td>
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<td>Skyltad hastighet (km/h)</td>
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<td>13,0</td>
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<tr>
<td>&gt;8000</td>
<td>13,0</td>
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</tbody>
</table>
Maintenance effect

\[ y = 0.0957x + 2.087 \]
\[ R^2 = 0.7381 \]

\[ y = 0.098x + 0.2498 \]
\[ R^2 = 0.9156 \]

40 mm Hot Mix 1996

670 vehicles/day 90 trucks/day
1163 m 7.0 m 90 km/h
Predicted unevenness before maintenance
Predicted rut depth before maintenance
Yearly change in condition

Yearly change in IRI after maintenance (mm/m/year)

Yearly change in Rut depth after maintenance (mm/year)

Traffic class

Traffic class
How much can different types of maintenance improve the surface condition?

CM=Cold Mix
HM=Hot Mix
SC=Seal Coat
SD=Surface Dressing
SHM=Semi-Hot Mix
P=Preparatory work

Ratio $\frac{\text{IRI}_{\text{after}}}{\text{IRI}_{\text{before}}}$

500-999 vehicles/day
Pavements for the road users

Comfort
Road Safety
Noise
External
Internal
Particles
PM10
PM2.5
Emission
CO2
Vehicle operating costs
Fuel
Tire
Repair
Travel time
Access

Vehicle operating costs
Fuel
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Pavements for the road users

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Repair
Travel time
Access
Condition
Evenness
Rut depth
Friction
Texture
Cross fall
etc.

Effects
Environment
Safety
Health
Comfort
Speed
Vehicle

Valuation

Cost
Environment
Safety
Health
Comfort
Speed
Vehicle
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<th>Influence</th>
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<td>Rut shape</td>
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<tr>
<td>Water permeability</td>
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<td>Stiffness</td>
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</tbody>
</table>
IRI vs Speed - Trucks

![Graph showing IRI vs Speed for trucks](image)
Fuel consumption
Tyre wear

- Number wore out tires per 1000 ftkm, TC
- Unevenness IRI (mm/m)
Parts consumption vs. evenness
Capital value vs. evenness

![Graph showing the relationship between capital value and unevenness IRI (mm/m)]
Comfort

Profile measurement → QC-model → IRI

Vibration measurement

Panel rating

- ISO 2631
- Speed 70 km/h
- Passenger car
Comfort

Profile measurement

IRI = 0.784

IRI_{20} = NaN

Panel rating

1 Very poor
2 Poor
3 Fair
4 Good
5 Very good

© Peter Andrén
Comfort

Profile measurement → QC-model → IRI → Panel rating

Vibration measurement → Vibration

Profile measurement
Comfort

IRI vs. Panel rating

\[ y = -0.3162x + 4.0667 \]
\[ R^2 = 0.786 \]

\[ y = -1.3275 \ln(x) + 4.2543 \]
\[ R^2 = 0.9034 \]
Road user opinion, main roads, unsatisfied %


- Car ruts
- Car roughness
- Car markings
- Car ice
- Truck ruts
- Truck roughness
- Truck markings
- Truck ice
Road user requirements on road condition

Five reports (in swedish, summary in english)

1. Literature review
   • Many countries are making road user opinion studies but few have find a good connection between rod user opinion and condition measurements

2. Focusgroup discussions
   • Surface drainage is important
   • Important condition variables: rut depth, potholes, patches, roughness and cracks
   • Critical condition: If a driver must react to avoid a damage eg a pothole
   • Truckdrivers don’t like narrow road with weak edges
   • Good understanding of shortage of money

3. Questionnarie
4. Driving simulator
5. Summary
Driving simulator study

Road with water filled ruts

- Variation in image, vibration and noise
- Questions about experienced safety and comfort
- Clear indicator of poor safety at waterfilled ruts
  - Speed reduction
Rolling resistance vs. texture

\[ y = 0.0028x + 0.0098 \]

\[ R^2 = 0.7599 \]
Old road after maintenance
Old road in need of maintenance
PMS - Overview

Road Inventory

Pavement information

Database

Evaluation models

Condition monitoring

Project identification

Follow-up contracts

PMS Components

Road condition

Longitudinal unevenness

Transversal unevenness

Budget needs

Change in roughness 1989 - 2000
Percentage IRI > 5mm/m

89 90 91 92 93 94 95 96 97 98 99 00
Year

Percentage of network

< 2000 AADT > 2000 AADT
HDM-4 Highway Development and Management

HDM-III  Highway Design and Maintenance Standards Model
HDM-4  Highway Development and Management

First developed by the World Bank

Today managed by PIARC (The World Road Association)
HDM-4 Highway Development and Management

Datahantering
- Vägnät
- Fordon
- Åtgärder
- HDM Konfig.

Analysverktyg
- Projekt
- Program
- Strategi

Filkonverterare
- Överföra data till externa system

Grunndata
- Vägnät
- Fordon
- Åtgärder
- Projekt
- Program
- Strategier

Modeller
- RDWE
- RUE
- SEE

Externa system
- Databaser, PMS, etc.

RDWE: Road Deterioration and Works Effects (Nedbrytning och åtgärdseffekter)
RUE: Road User Effects (Trafikanteffekter)
SSE: Safety, Energy and Environmental Effects (Trafiksäkerhet, energi och miljö)
PMS: Pavement Management Systems
Resultat

Average Roughness by Section (Graph)

Study Name: MY3 Hdm_2012_300_10
Run Date: 18-04-2013

<table>
<thead>
<tr>
<th>Section</th>
<th>8210024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>No Sensitivity Analysis Conducted</td>
</tr>
</tbody>
</table>

NPV/Cost = \( \frac{\text{UCbase} - \text{UCalt} - (\text{ACalt} - \text{ACbase})}{(\text{ACalt} - \text{ACbase})} \)
Roughness: Average for Road Network by Budget Scenario (Graph)

Surface Class: Bituminous

Annual Average Roughness for each Surface Class of the Optimised Work Programme (weighted by length)