Pavement Management Systems

Johan Lang

UNITED BY OUR DIFFERENCE WSP

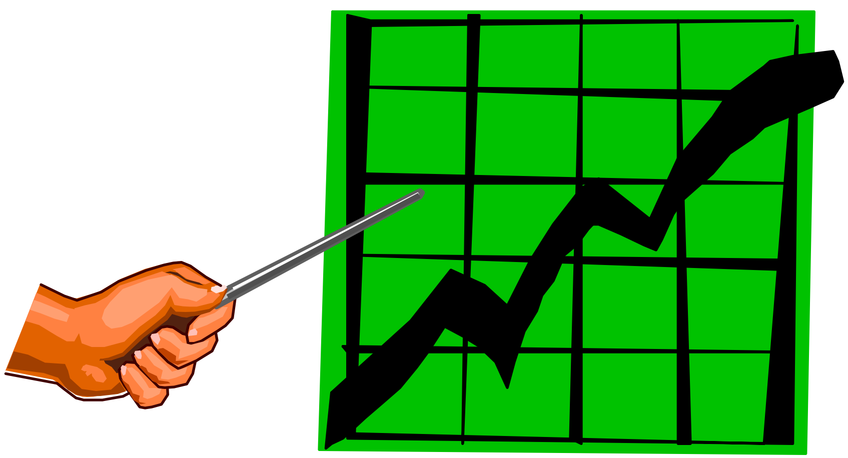
2013-05-07

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

PMS - Pavement Management Systems

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

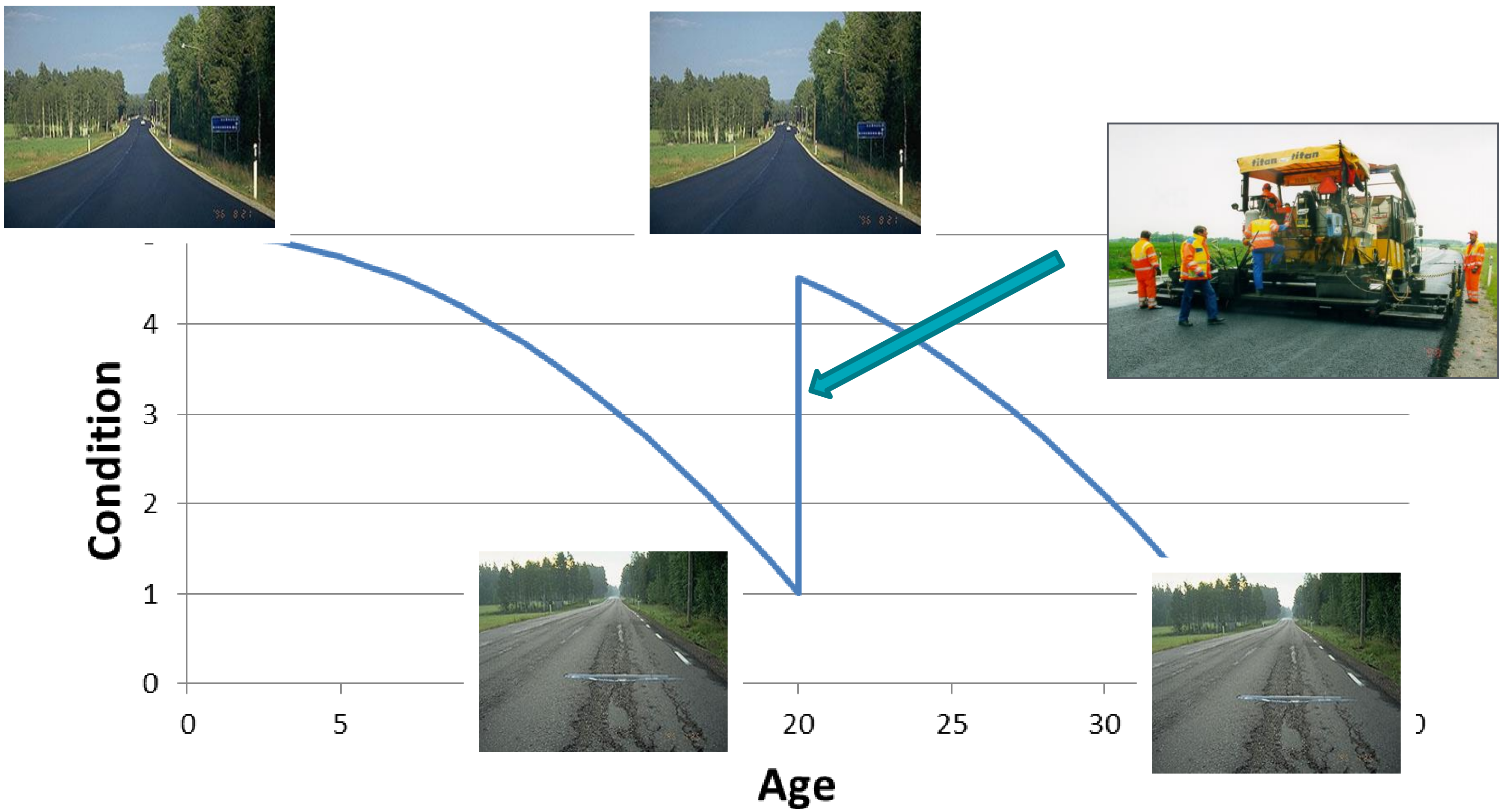
New Zealand

Spain

Sweden

Sweden

A pavements life cycle



Roads for the users

Pavements for the road users

Comfort

Road Safety

Noice

Internal

External

Fuel

Vehicle operating costs

Tire

Rep-air

Particles

PM10 PM2.5l

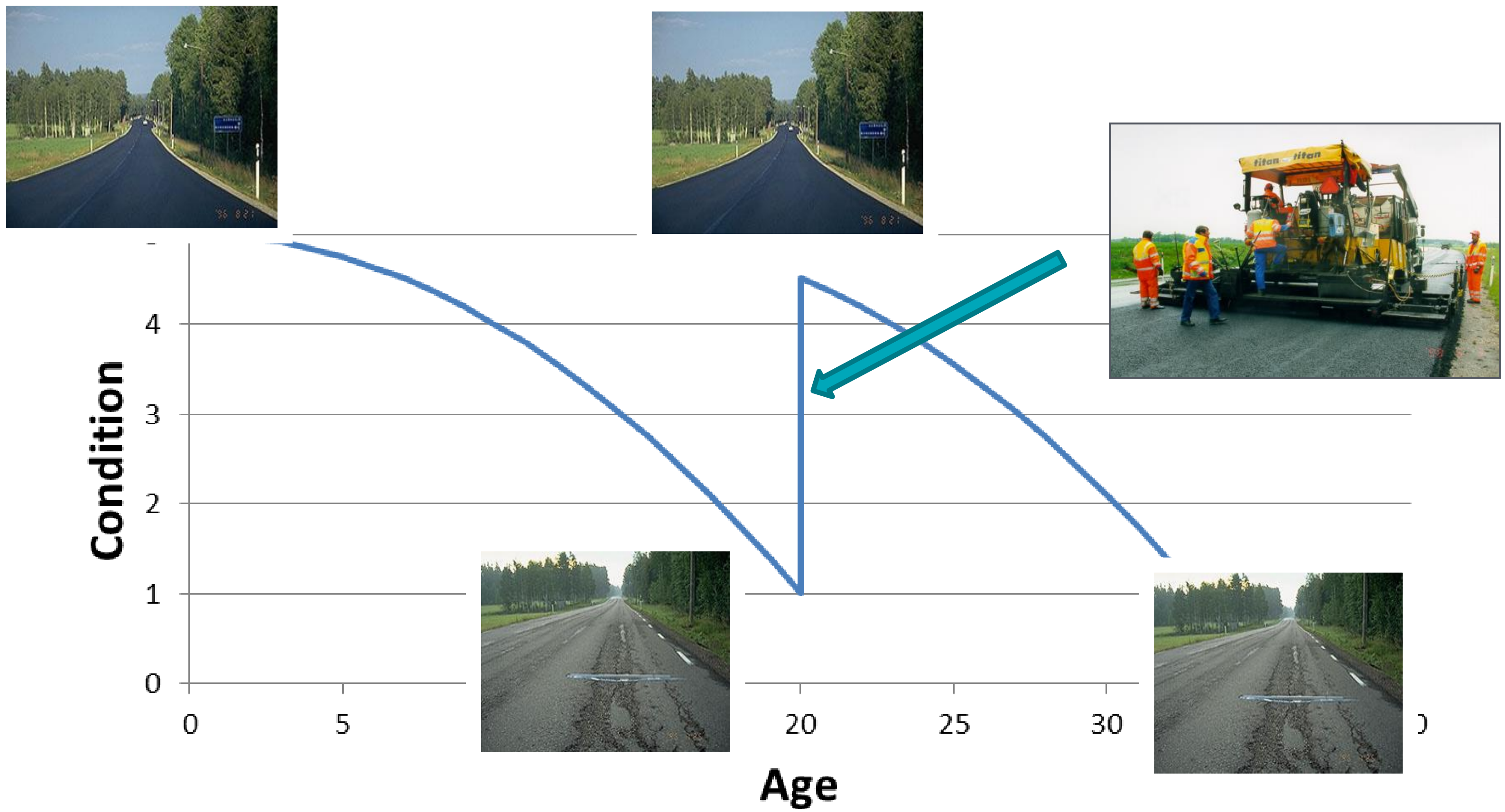
Emission

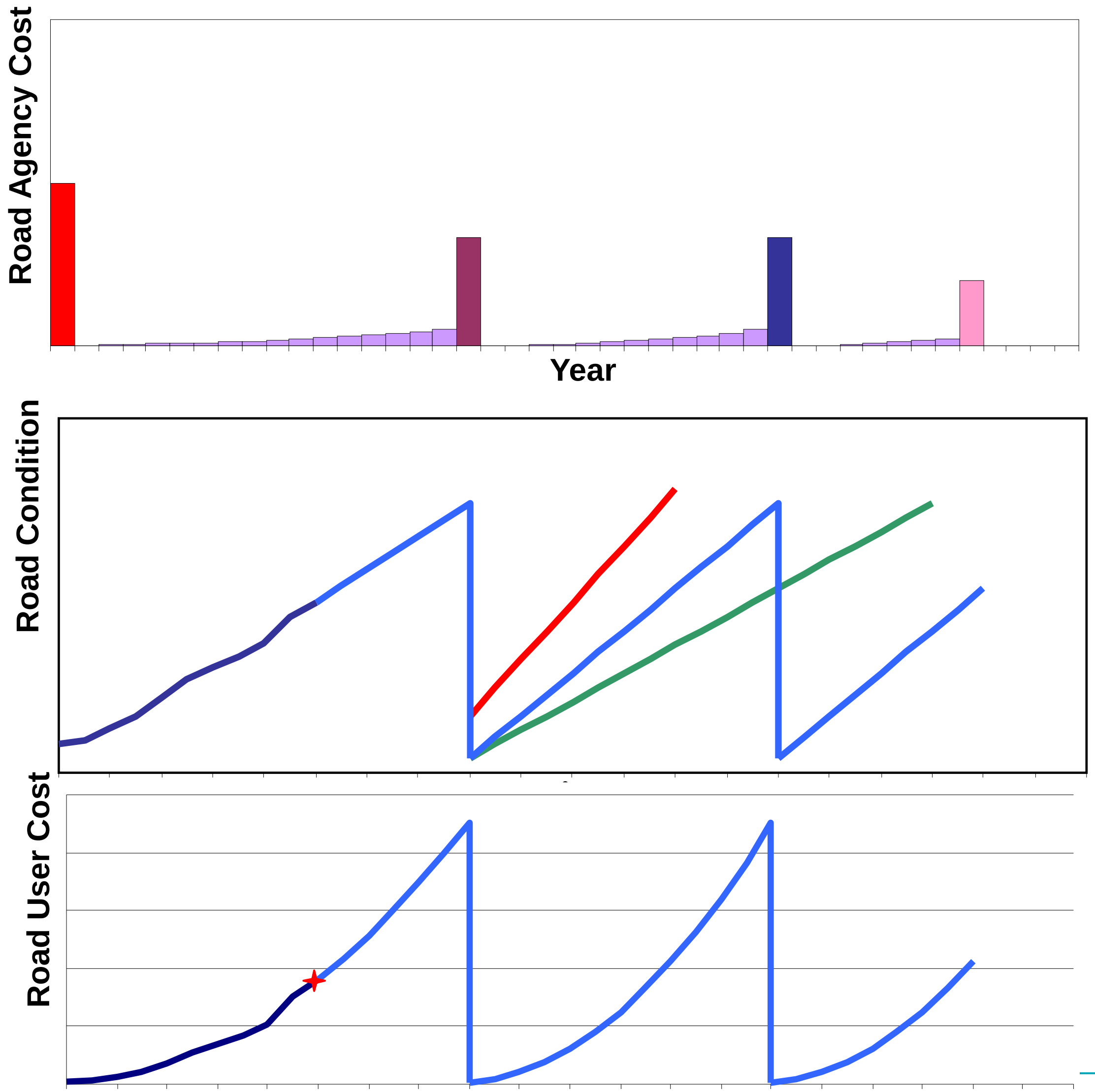
CO2

Travel time

Access

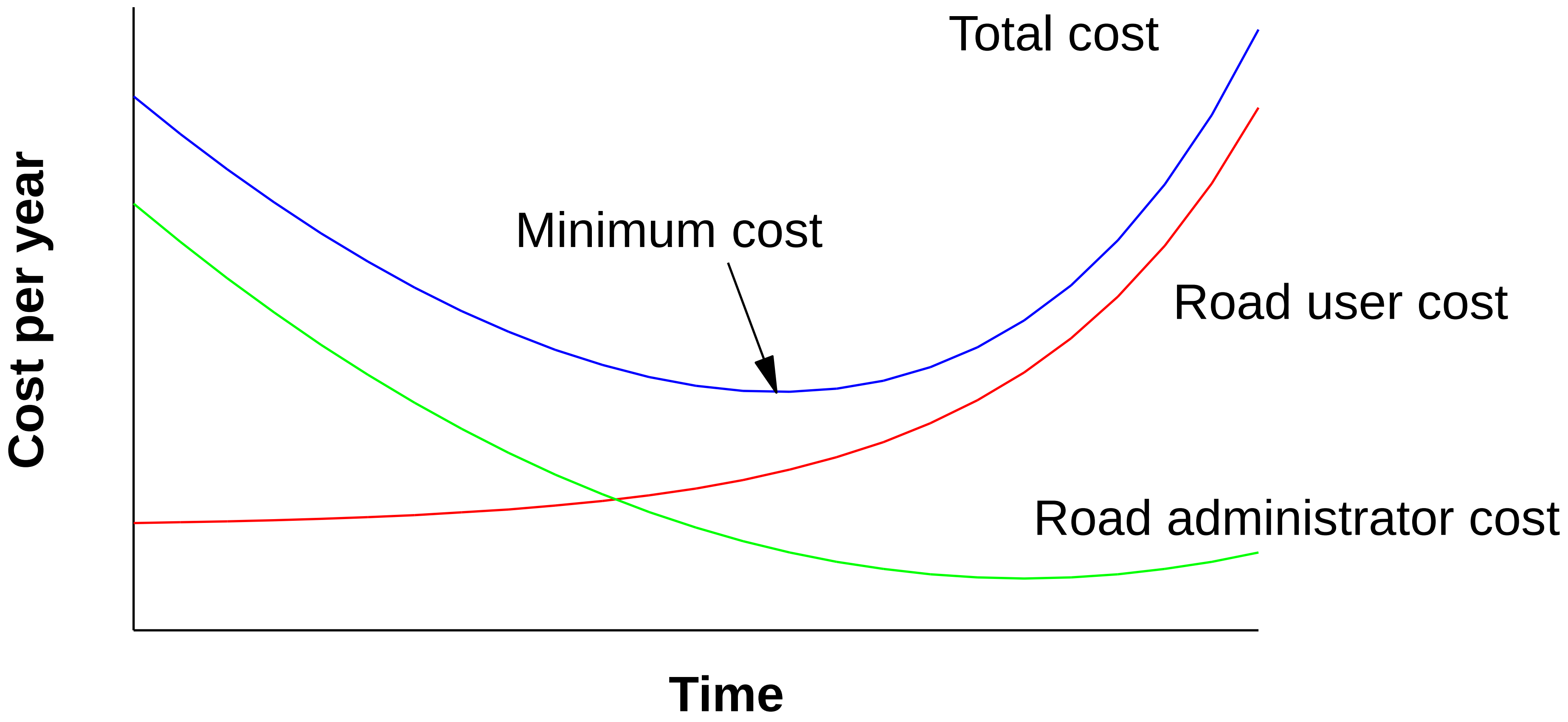
A pavements life cycle





Pavement Life Cycle Cost

Optimizing



Total cost
Minimum cost
Road user cost
Road administrator cost
Cost per year
Time

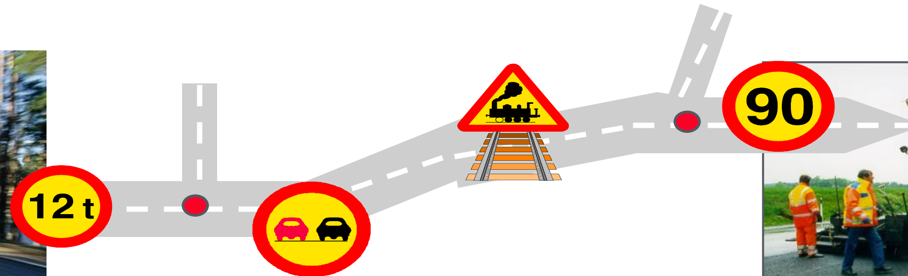
Pavement Management Systems is multidiciplinary

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

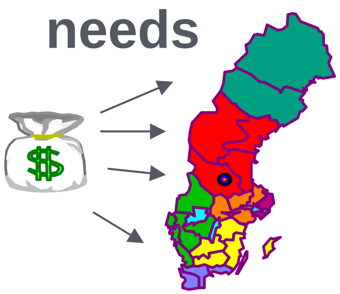
Road Inventory

Pavement information

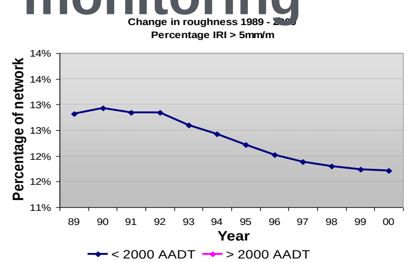
Database

Evaluation models

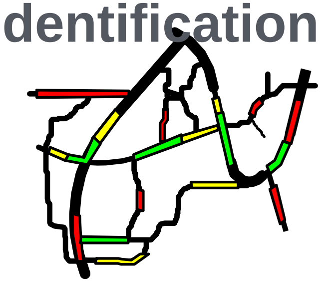
Budget needs



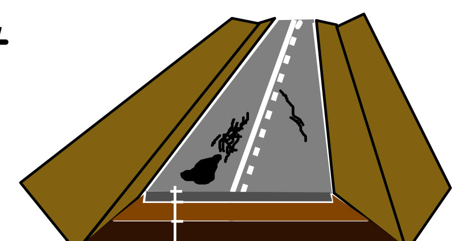
Condition monitoring



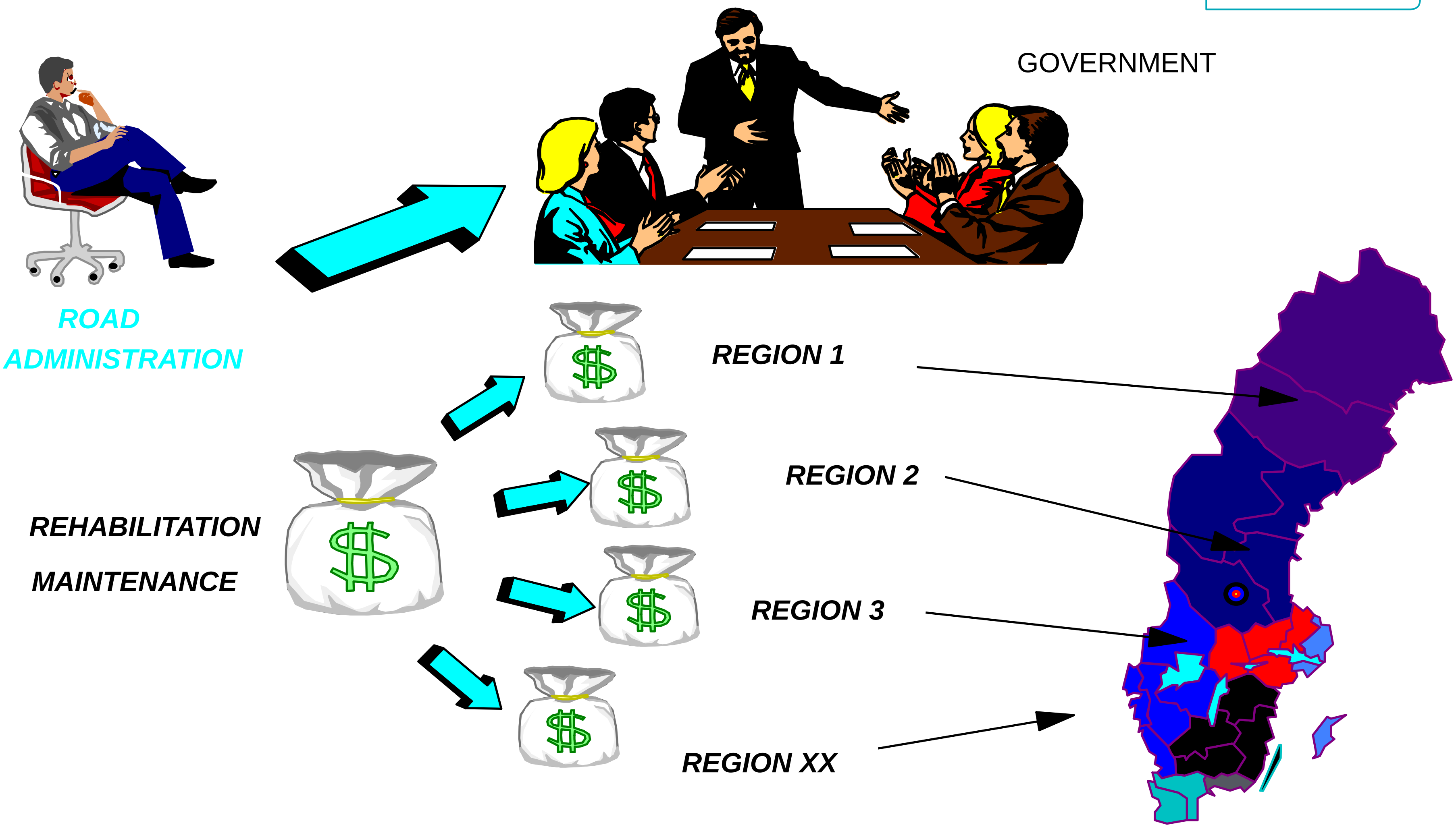
Project identification



Follow-up contracts

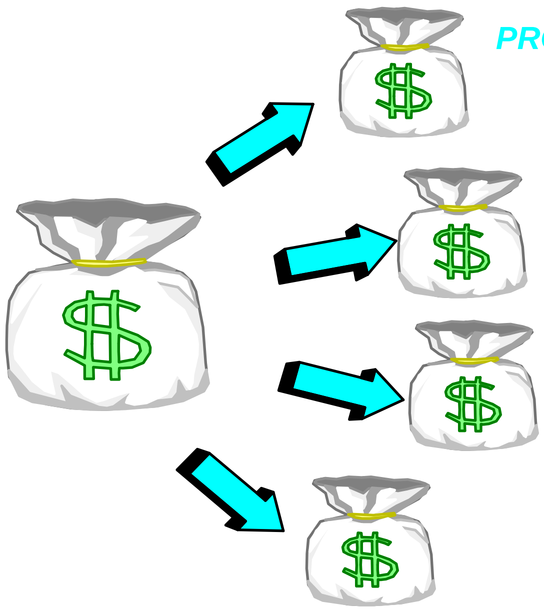


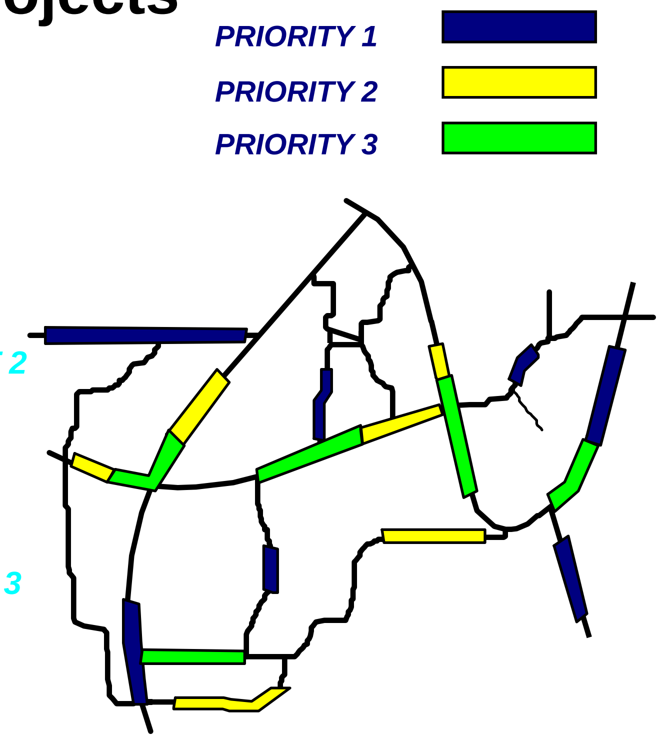
Network level - Overview



Network to project level

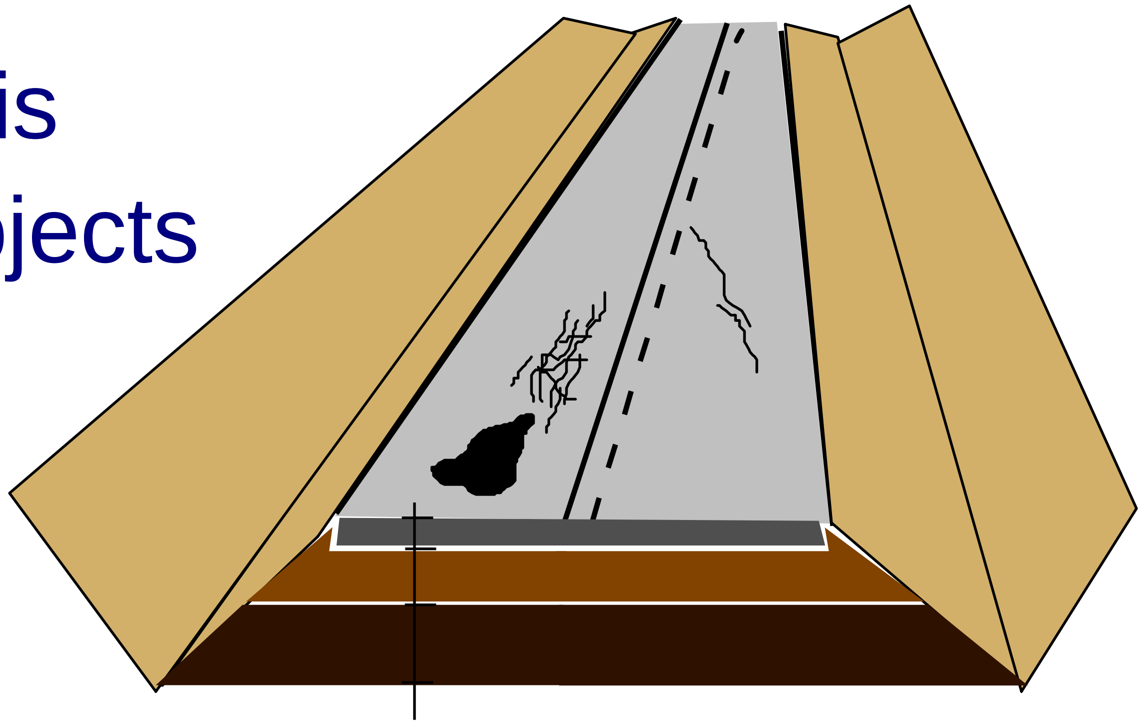
Network - identification of projects

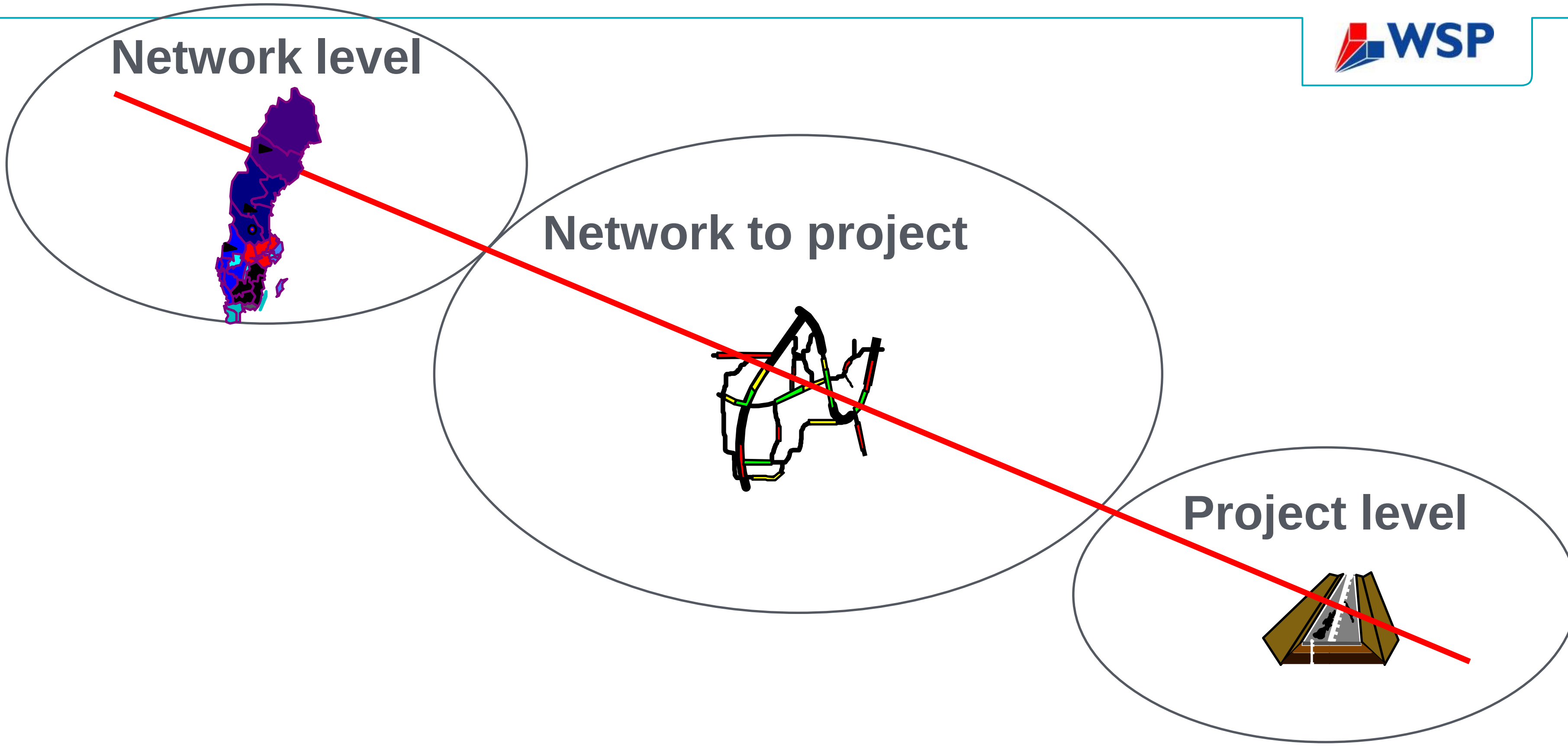




PMS - Project Level

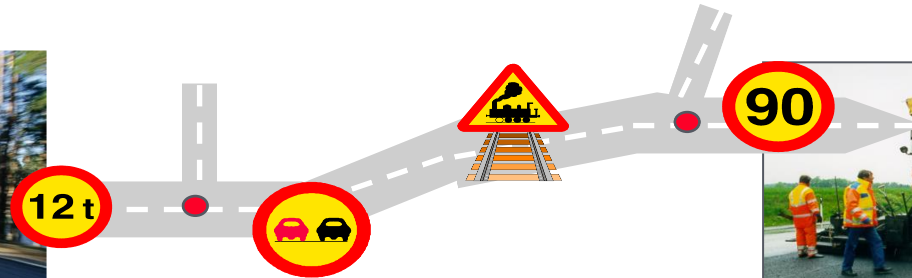
Detailed analysis
of individual projects




Network level
Network to project
Project level

PMS - Overview

PMS Components



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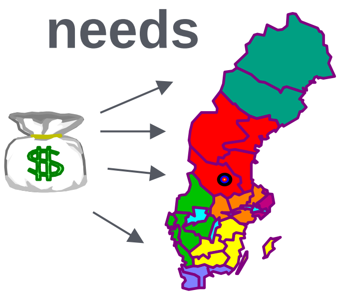

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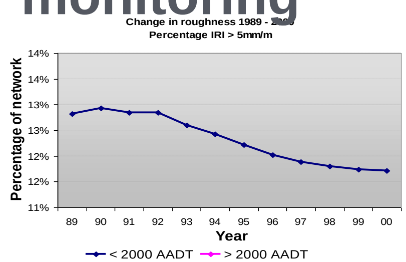

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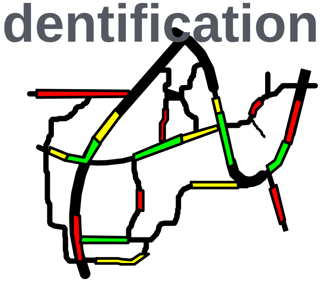

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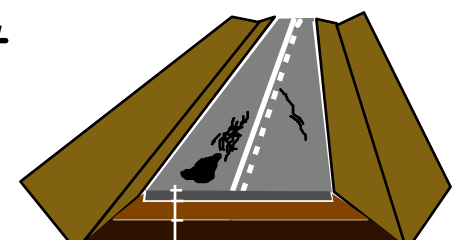
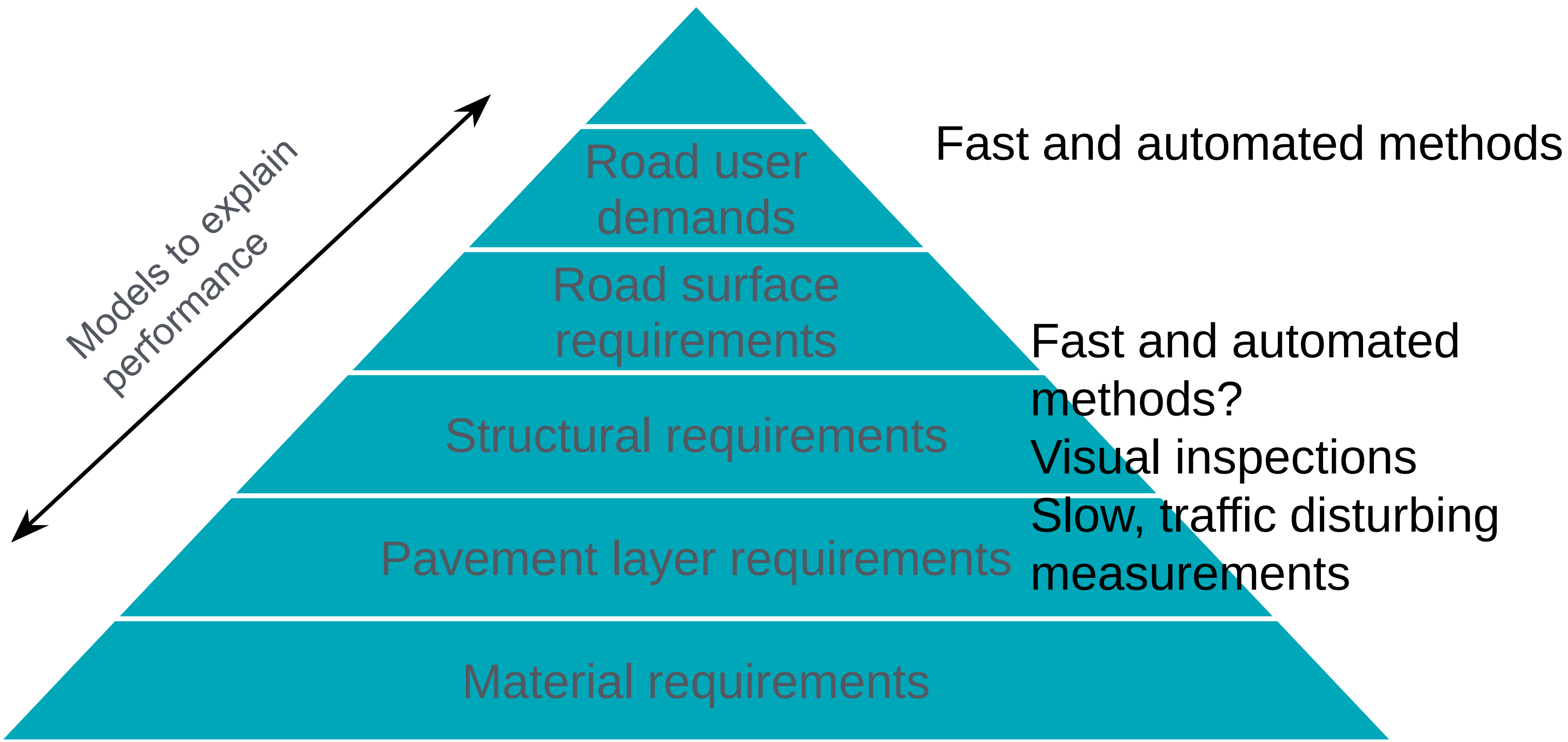
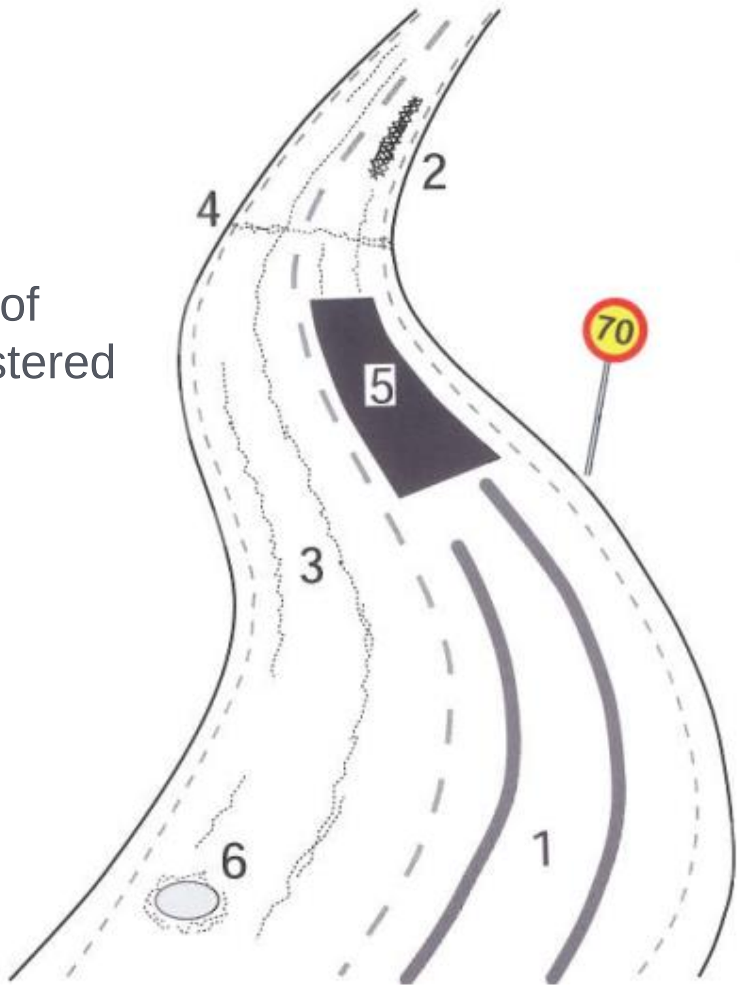


Need of information



Visual inspection

Severity and extension of different damages are registered



Unevenness – Roughness - Smoothness

Local uneveness 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

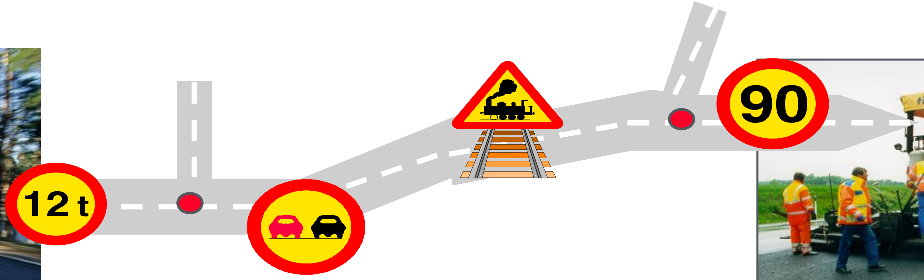
Ravelling

Surface dressing where stones get loose

Patching and local repair

PMS - Overview

PMS Components



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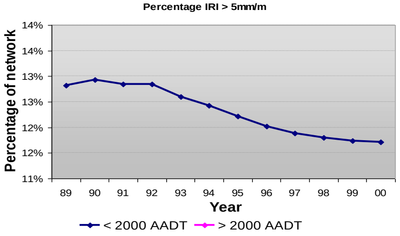

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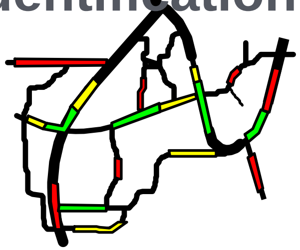

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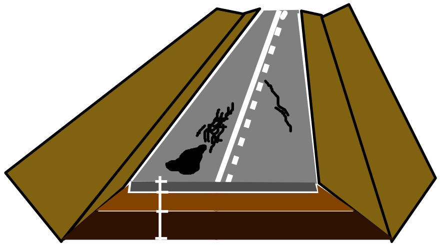
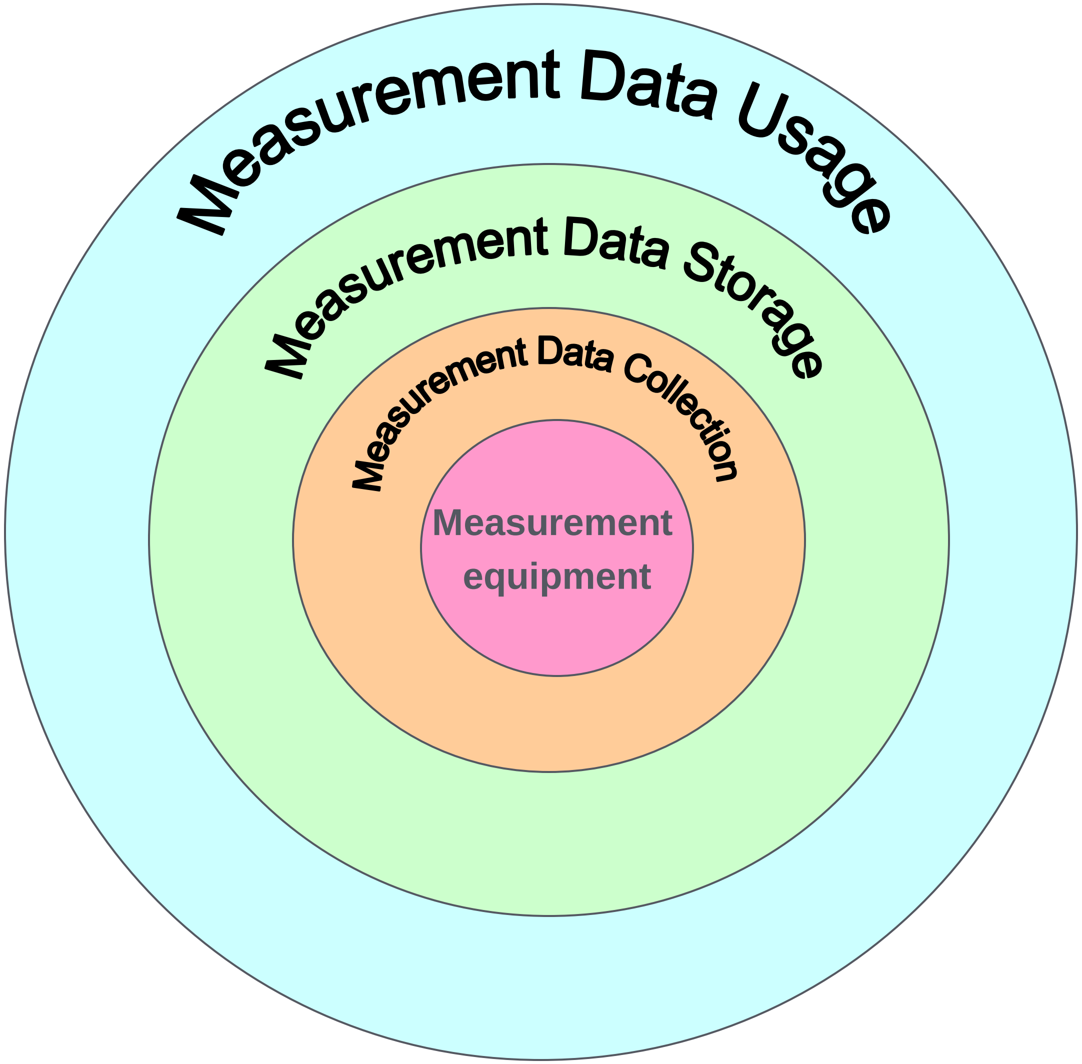


Automated measurements



Measurement Data Usage
Measurement Data Storage
Measurement Data Collection
Measurement equipment

Measurement quality

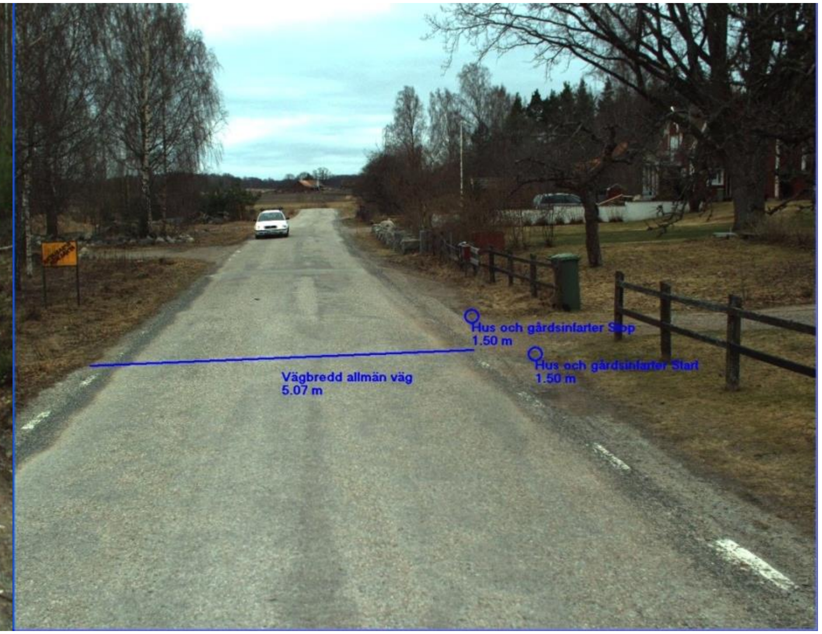
Repeatability

Measure again and get the same results.

Validity

Measure what is intended to measure

Visual inspection by using images



Inspection of damages

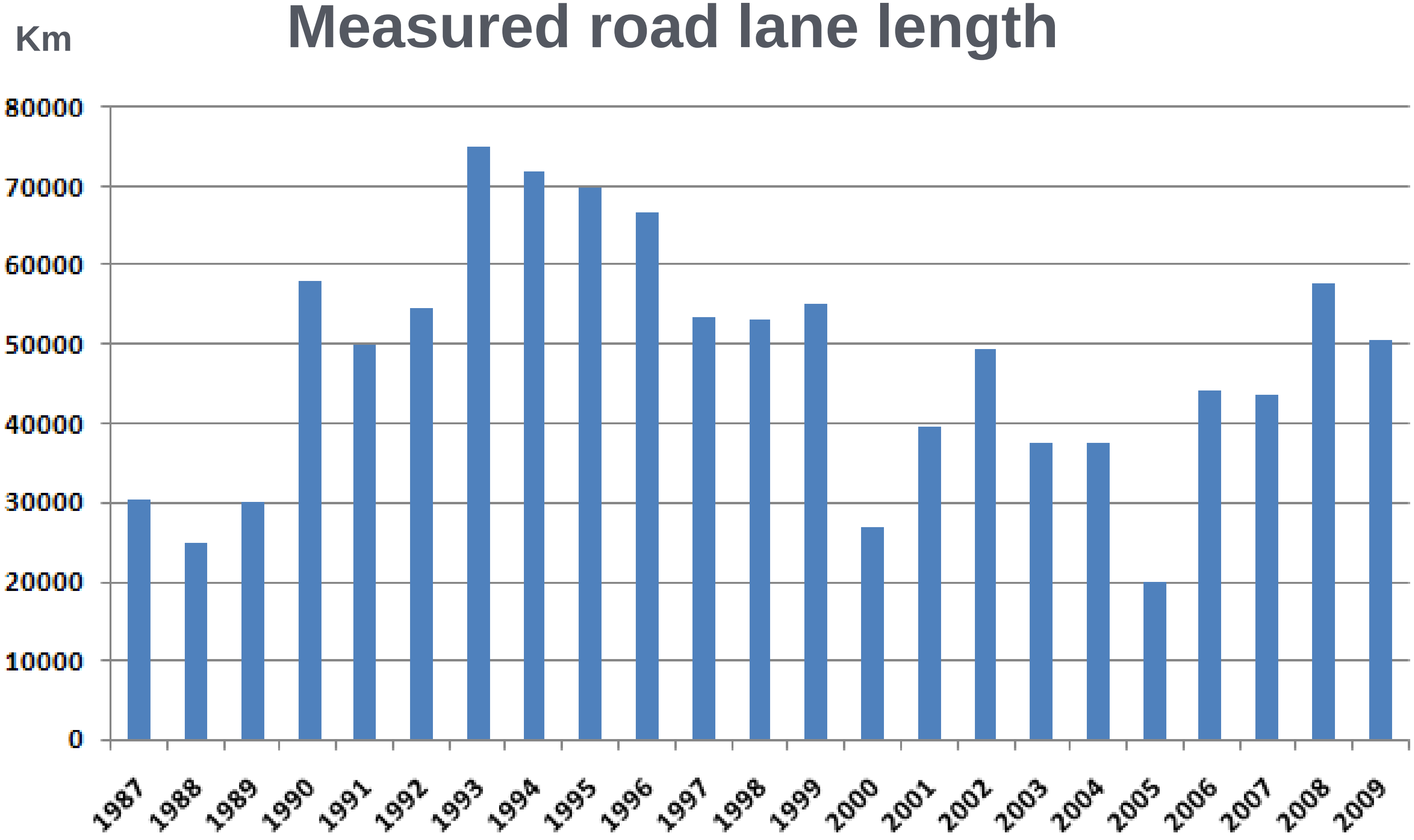
Measurement in stereo images

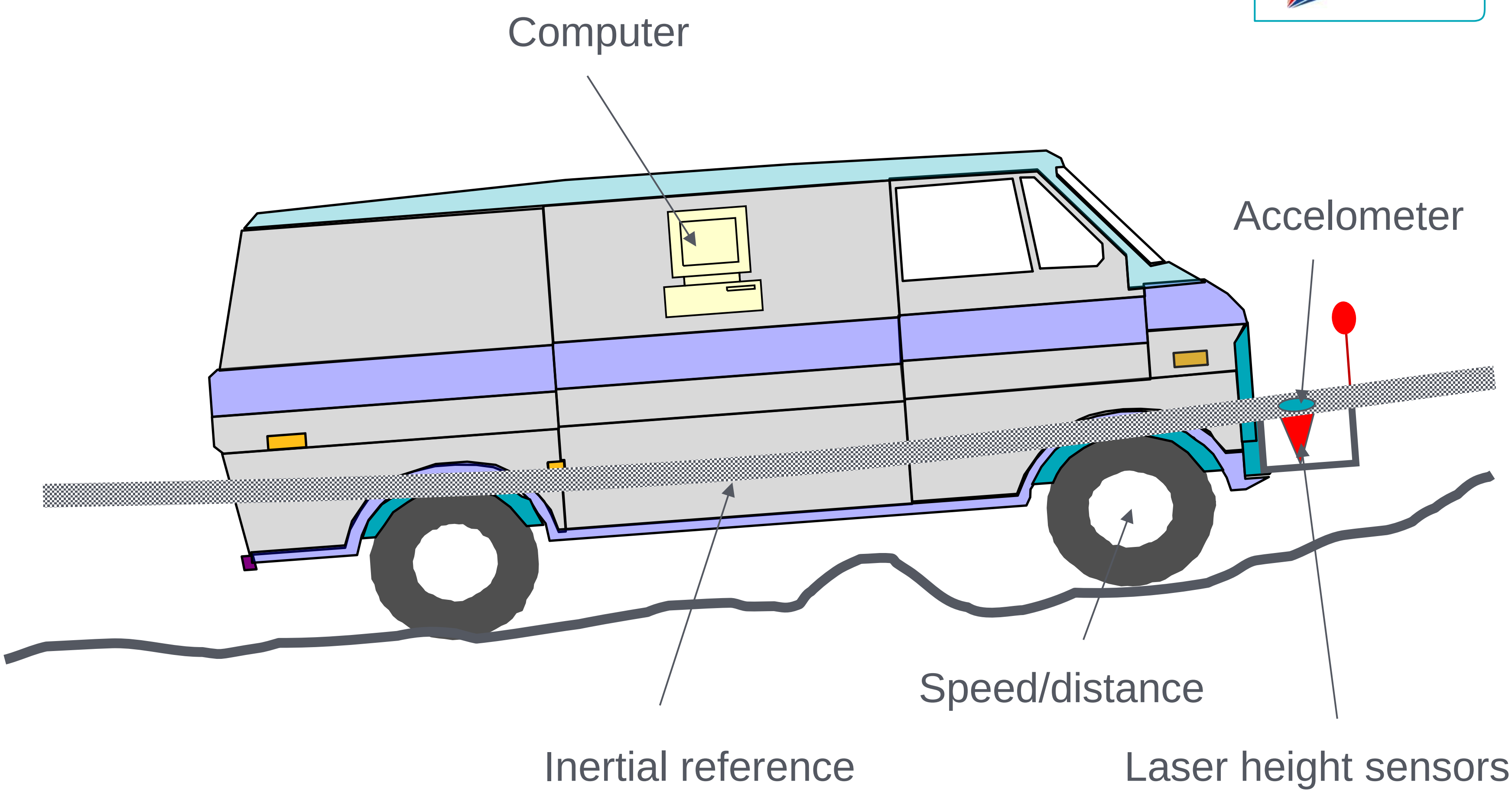
Automated measurements

Condition data

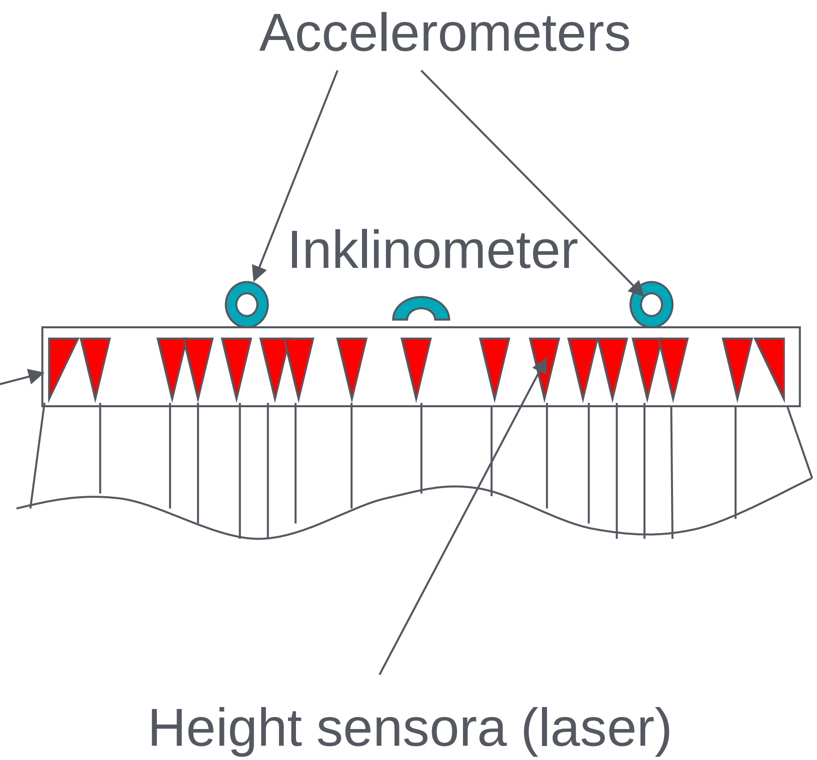
- Rut depth (1987)
- Unevenness IRI (1987)
- Cross fall, curvature, hilliness (1991)
- Cross profile
- Texture (2005)
- Edge deformation (2002)
- Longitudinal profile
- Cracks (not yet)
- Pictures

Measured road lane length

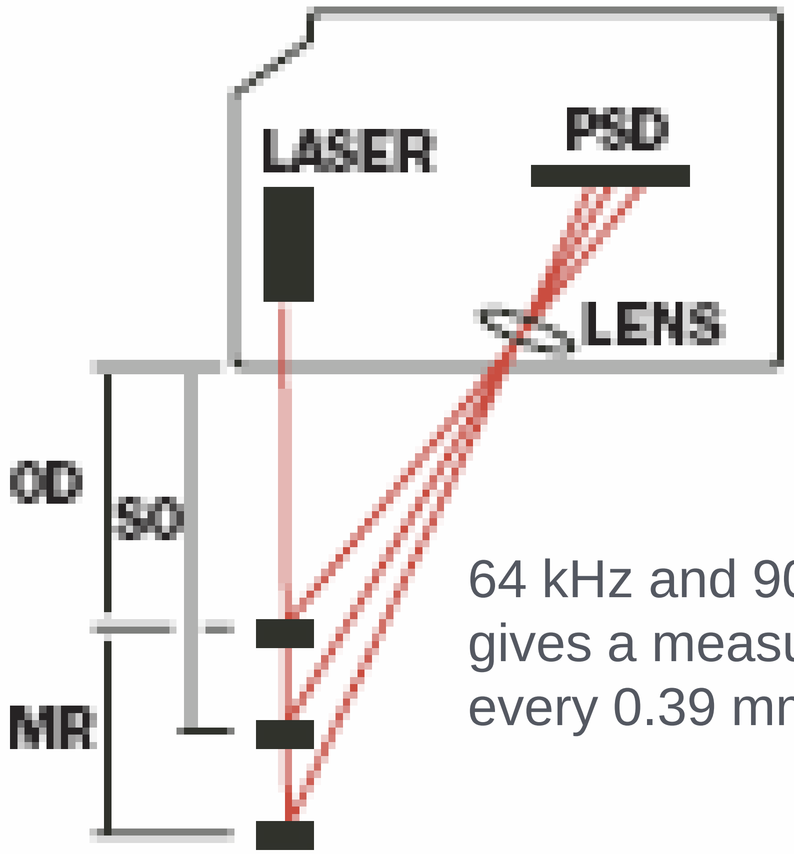



Computer
Accelometer
Speed/distance
Inertial reference
Laser height sensors

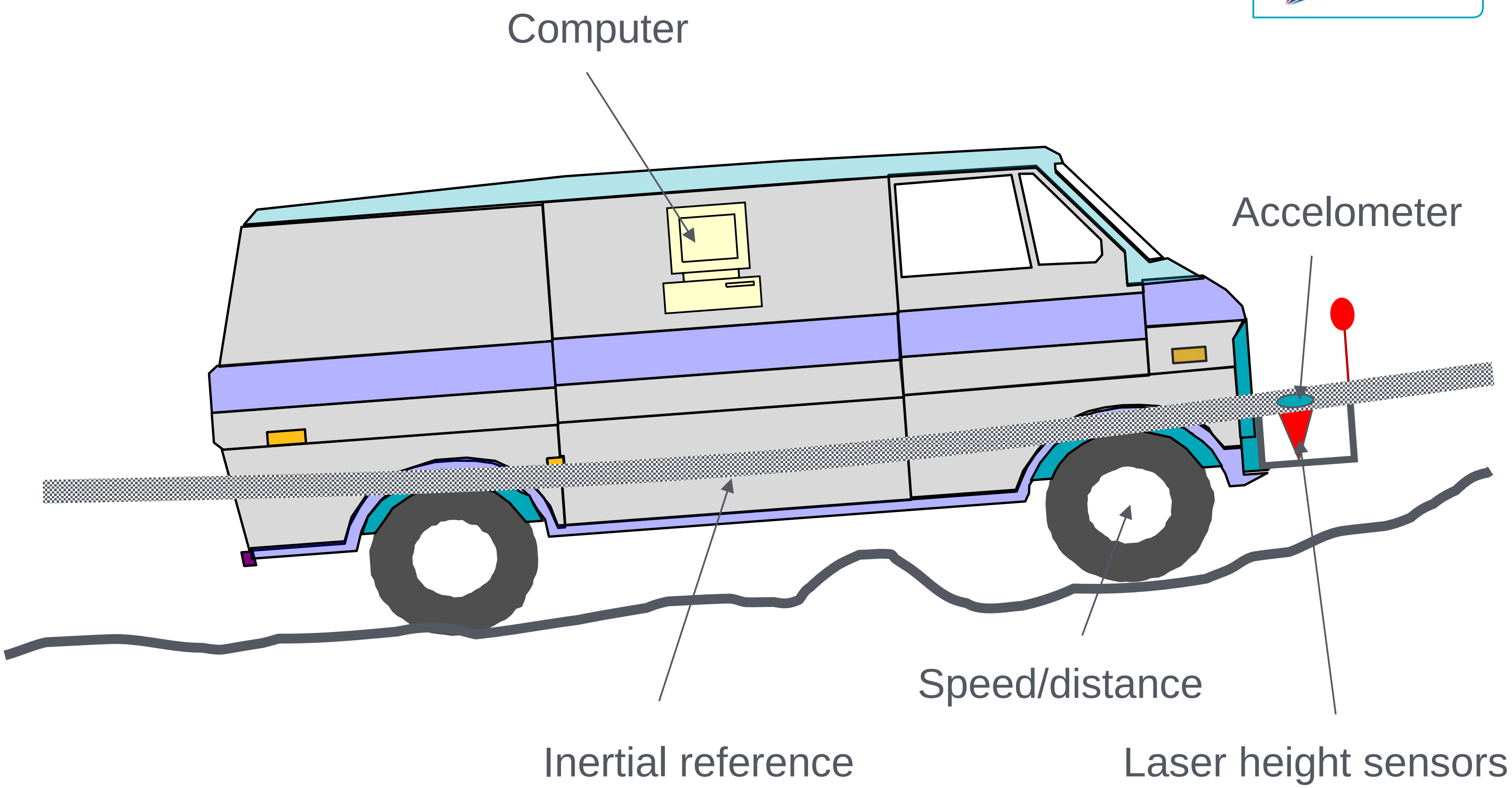
Profile measurements



Principle - Height Measurement



64 kHz and 90 km/h gives a measurement every 0.39 mm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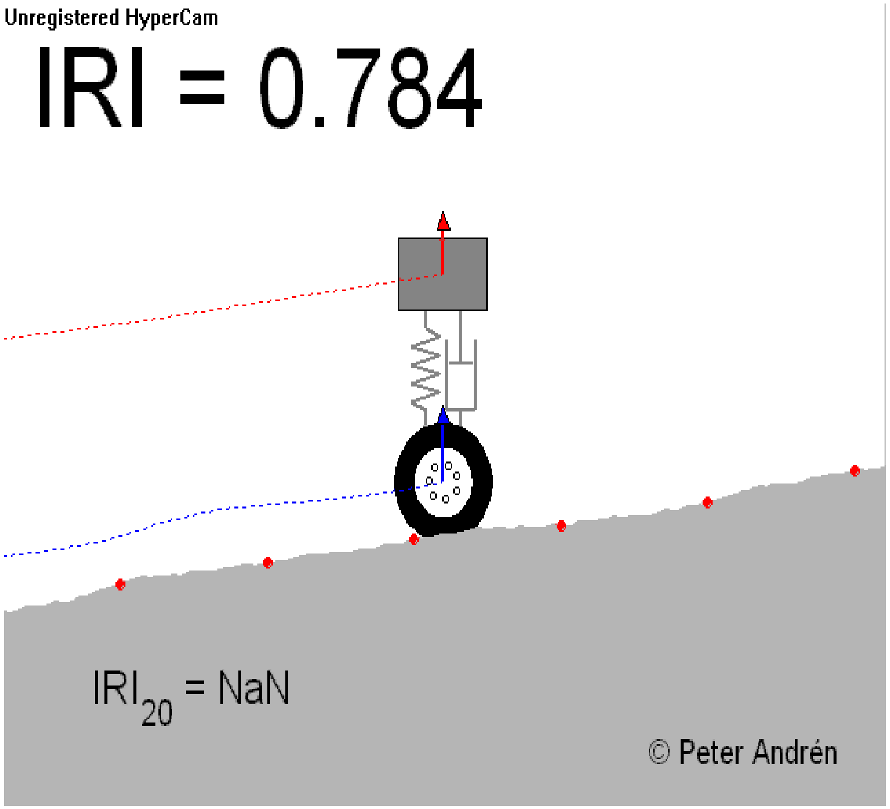
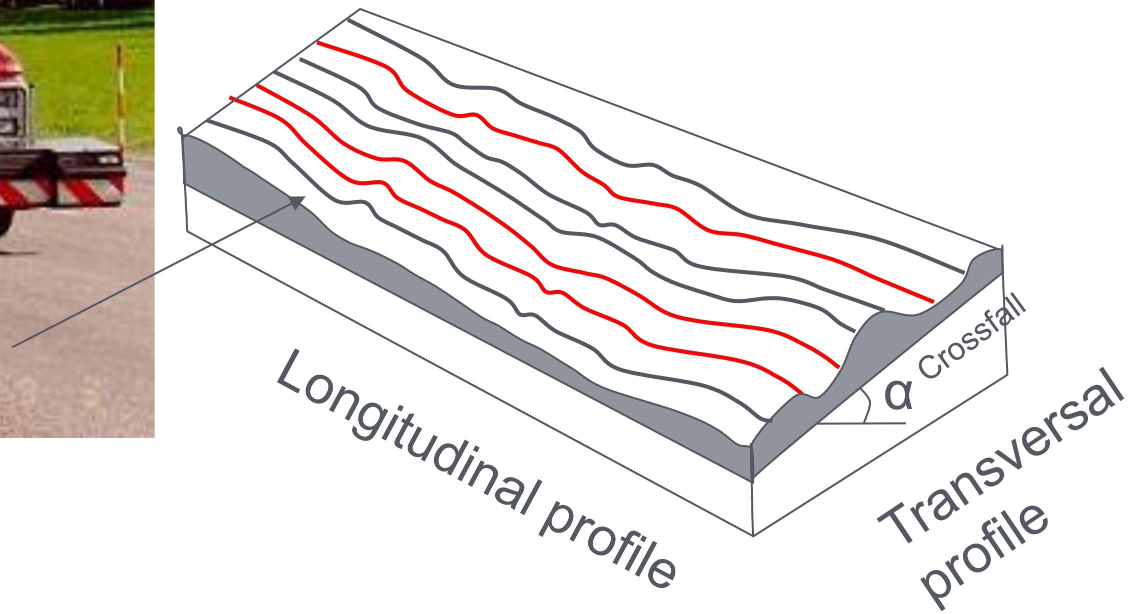
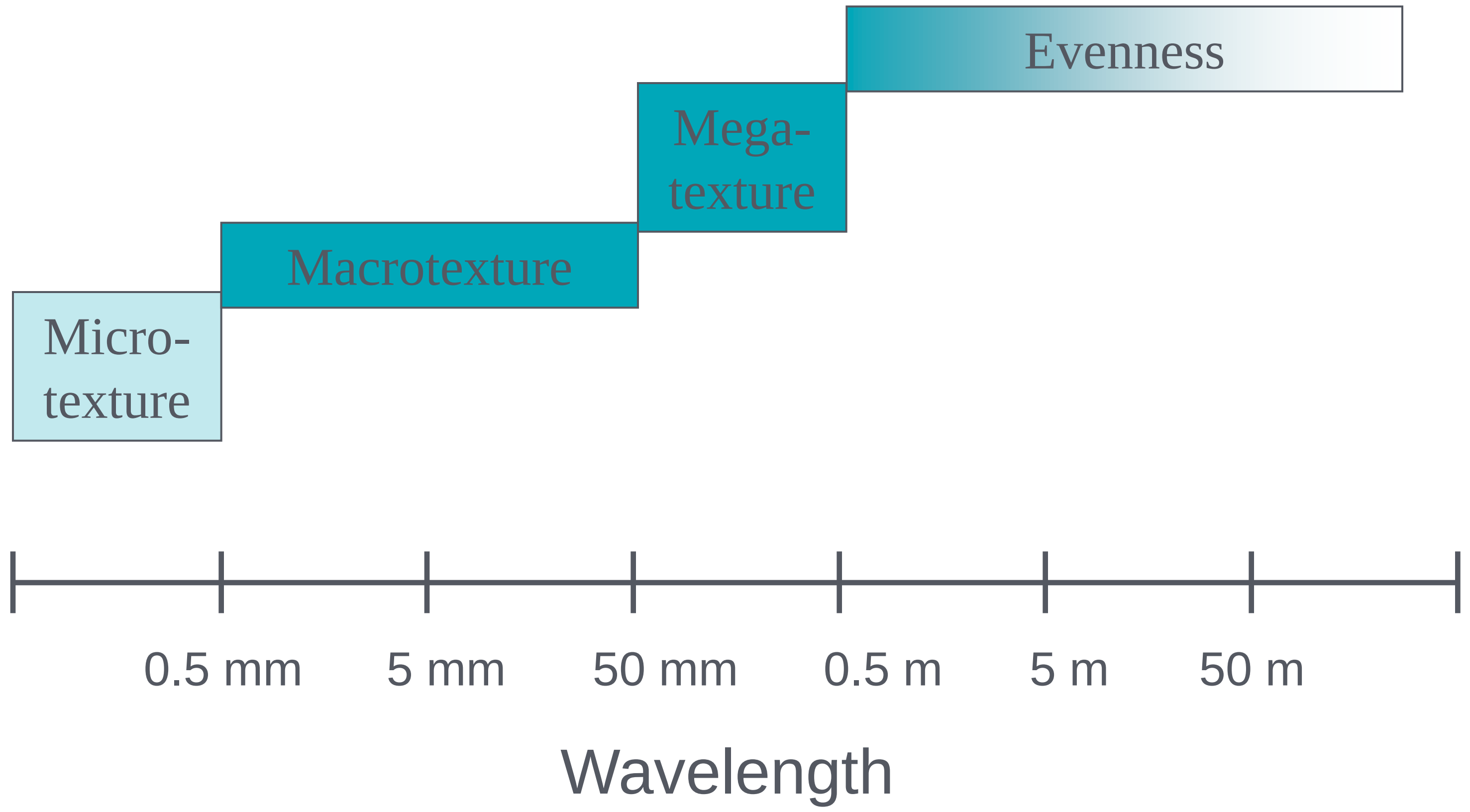
IRI – International Roughness Index



- •Measurement of three longitudinal profiles
- •Development of full-car model
- •Intepretation of vibration (ISO2631 and EU directive 2002/44/EG)



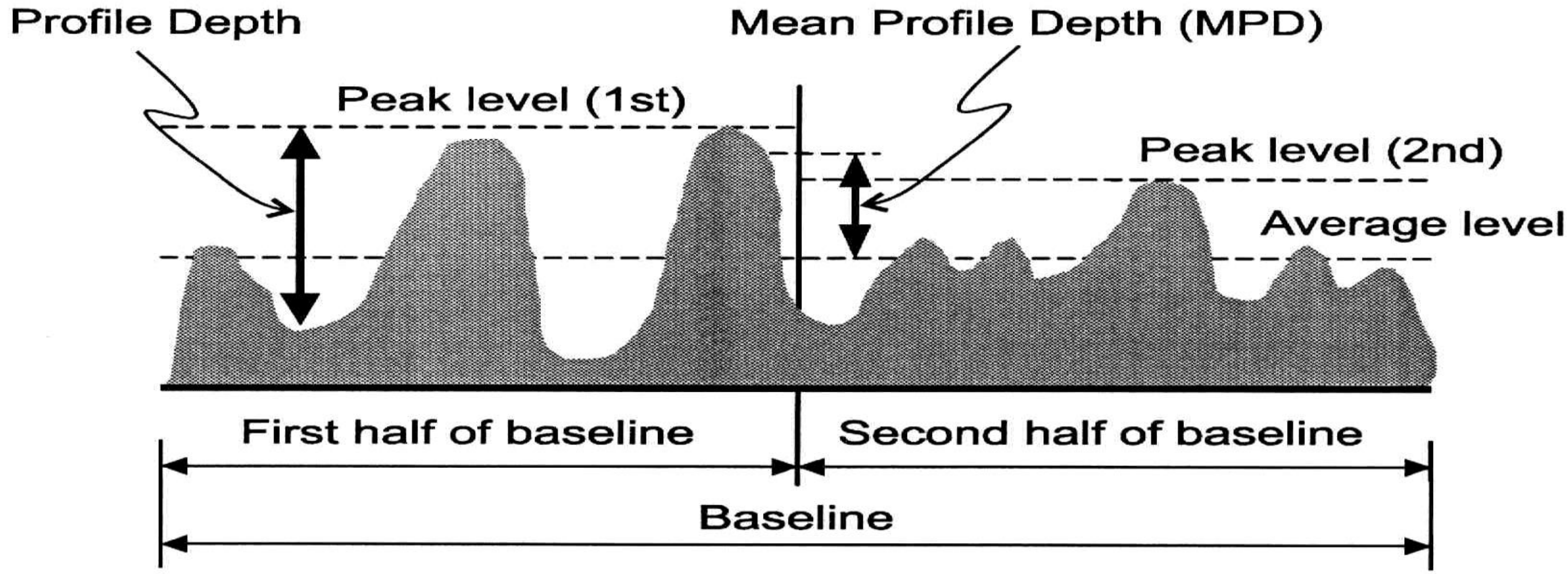
Types of evenness



Macrotextur-Mean Profile Depth

Beräkning av makrotextur från profil

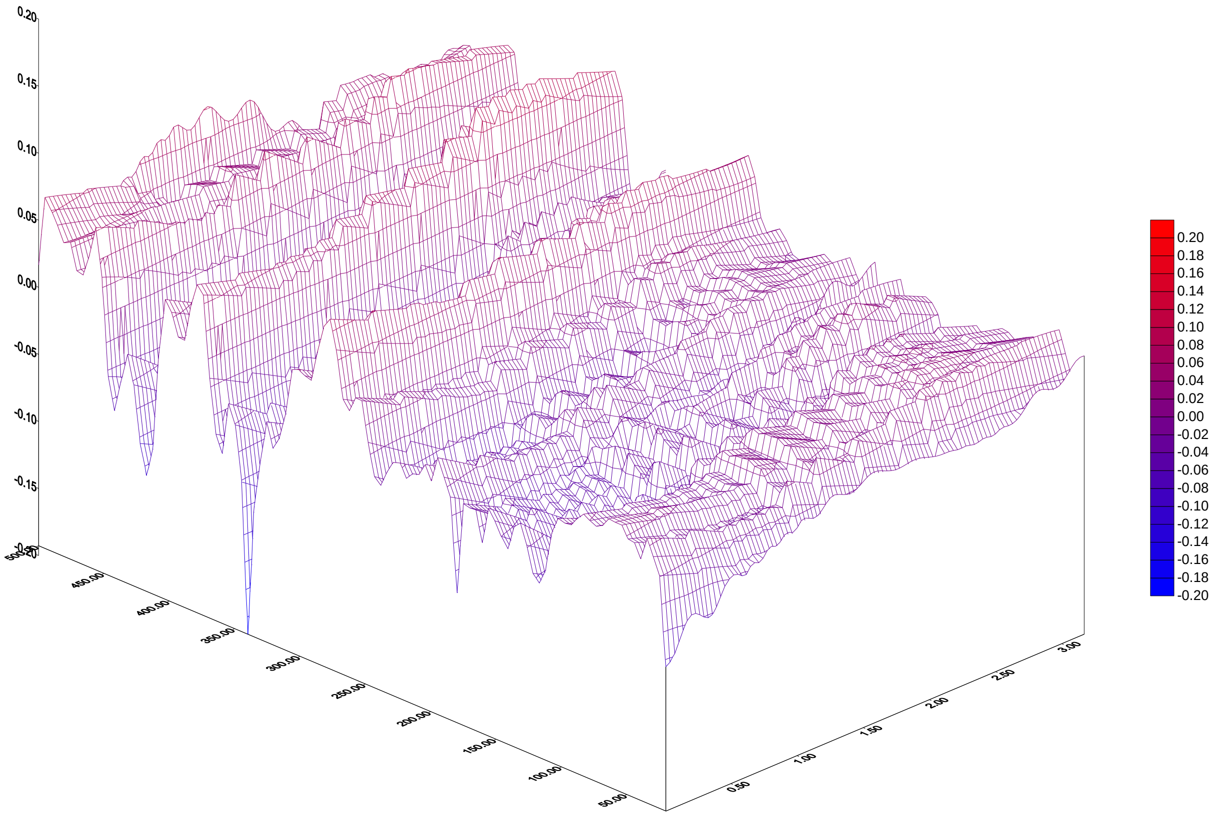
$$MPD = \frac{Peak1 + Peak2}{2} - average$$



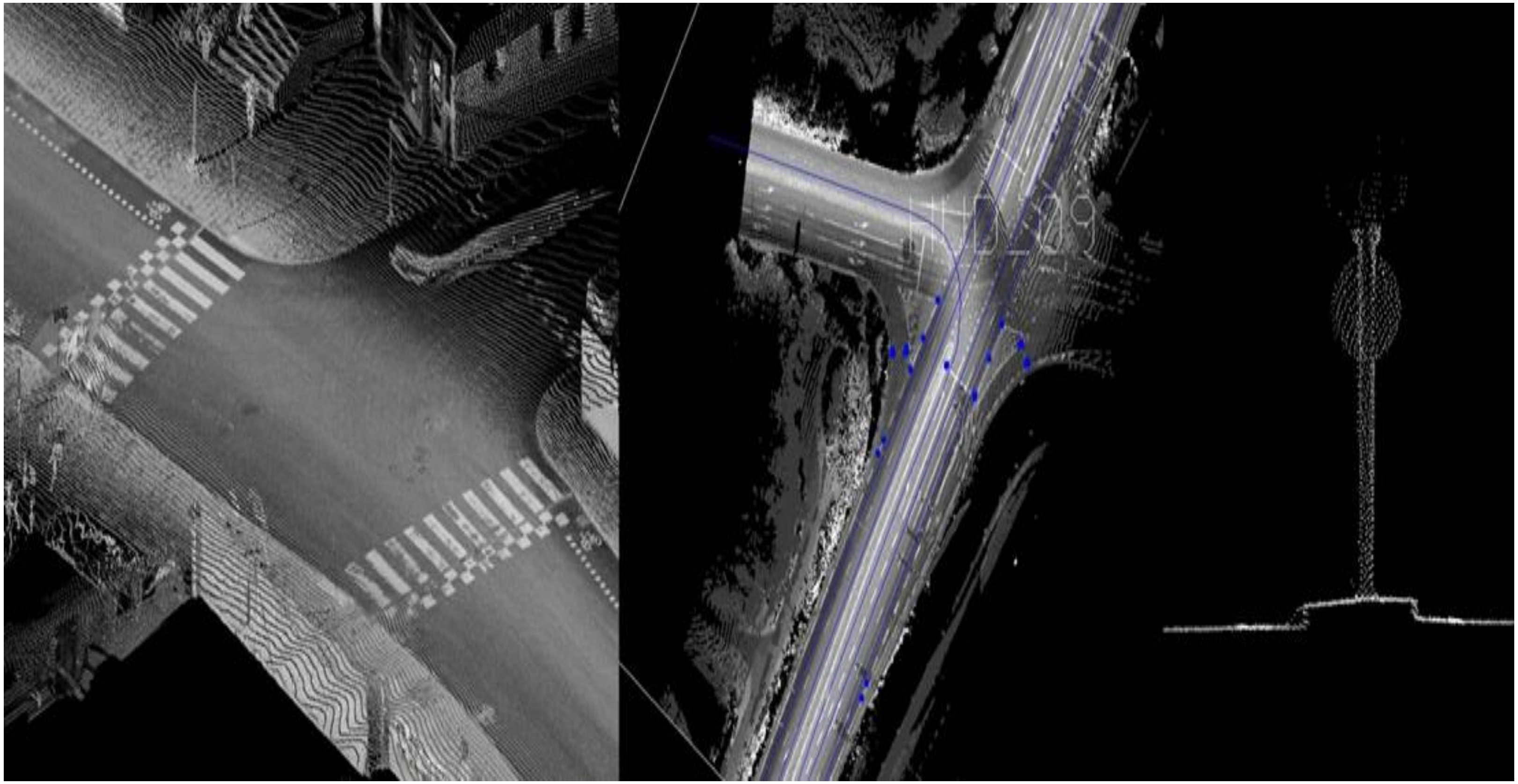
ETD=0.2 + 0.8 MPD

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

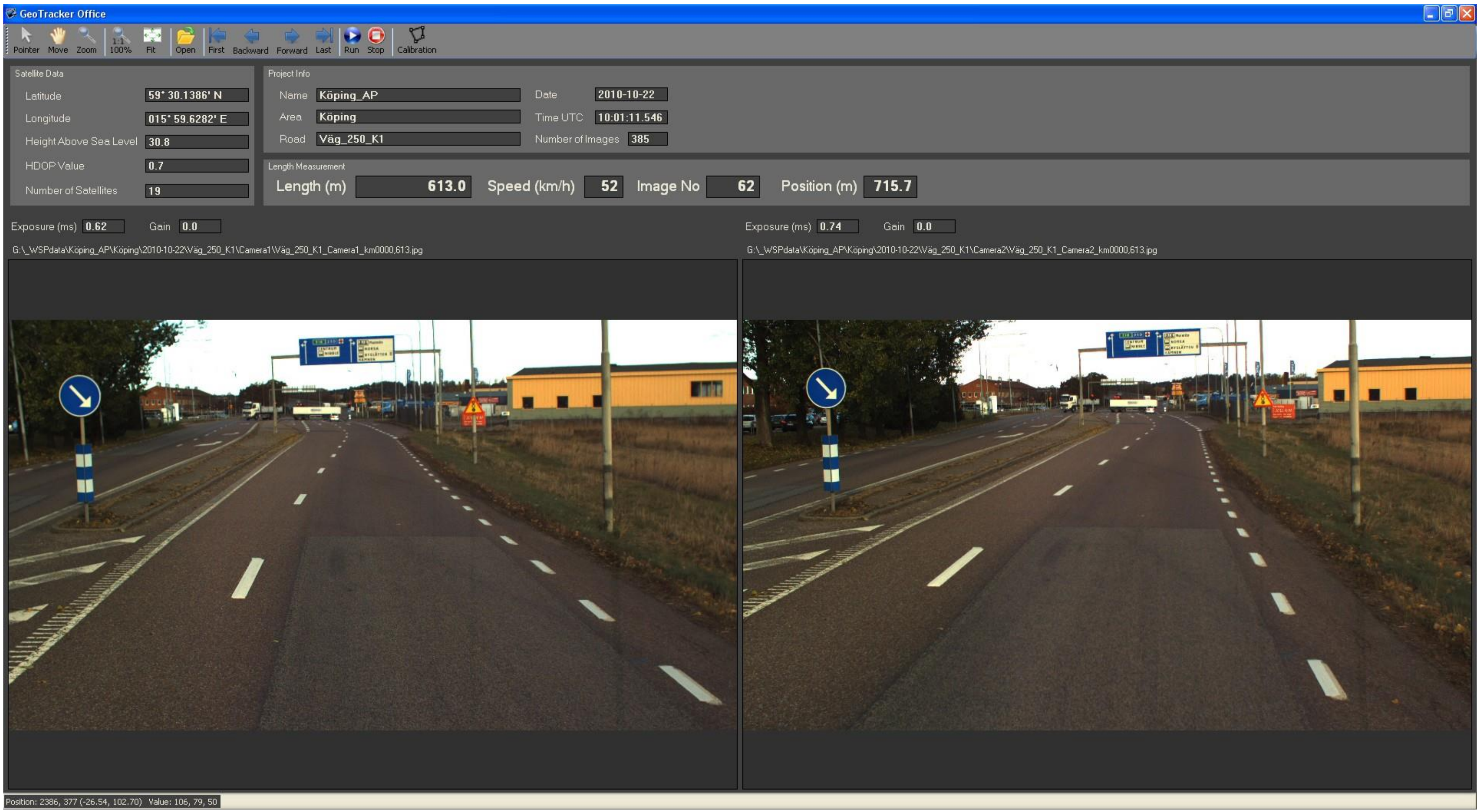


Collection of images

WSP

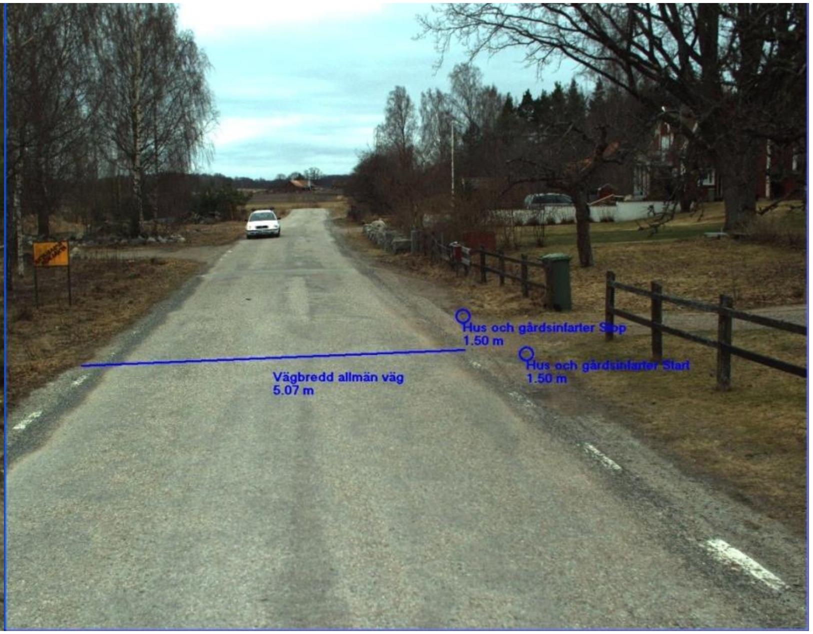
- Collection of high resolution images in traffic speed
- Processing at the office

Stereo images



360-pictures

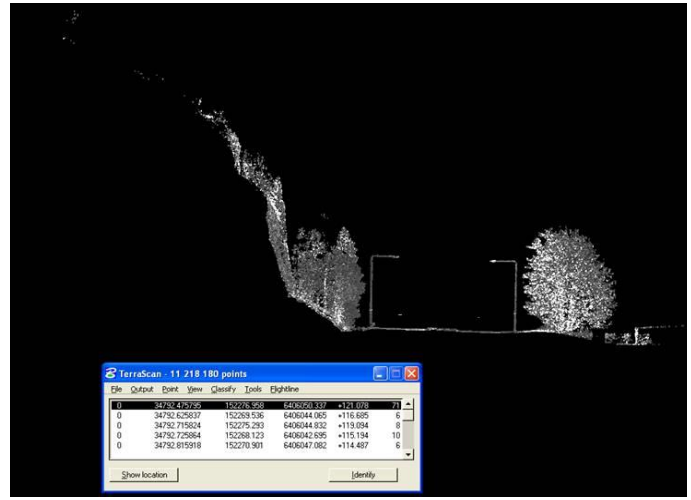
Visual inspection by using images

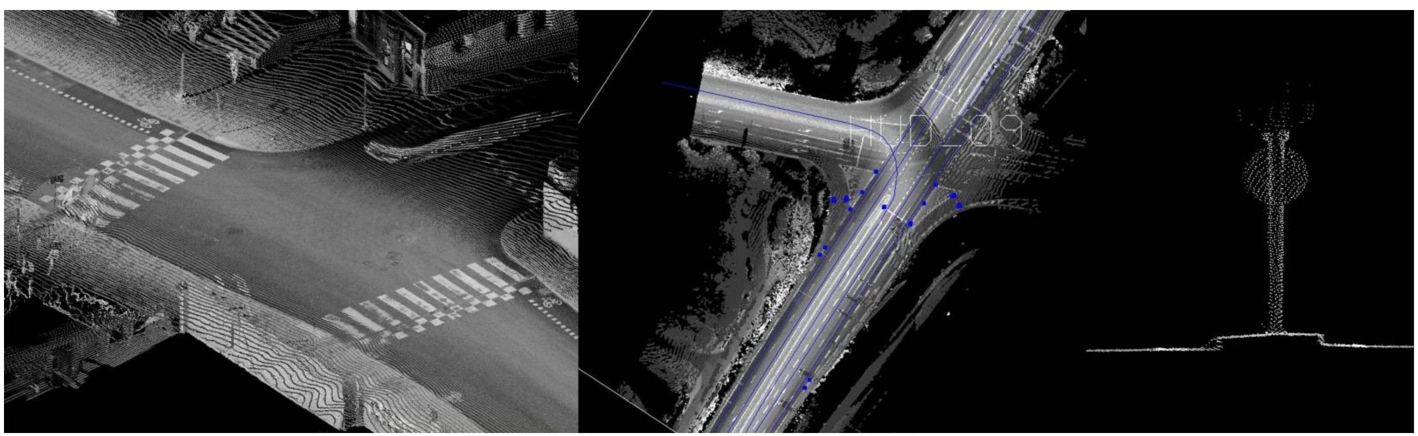


Inspection of damages

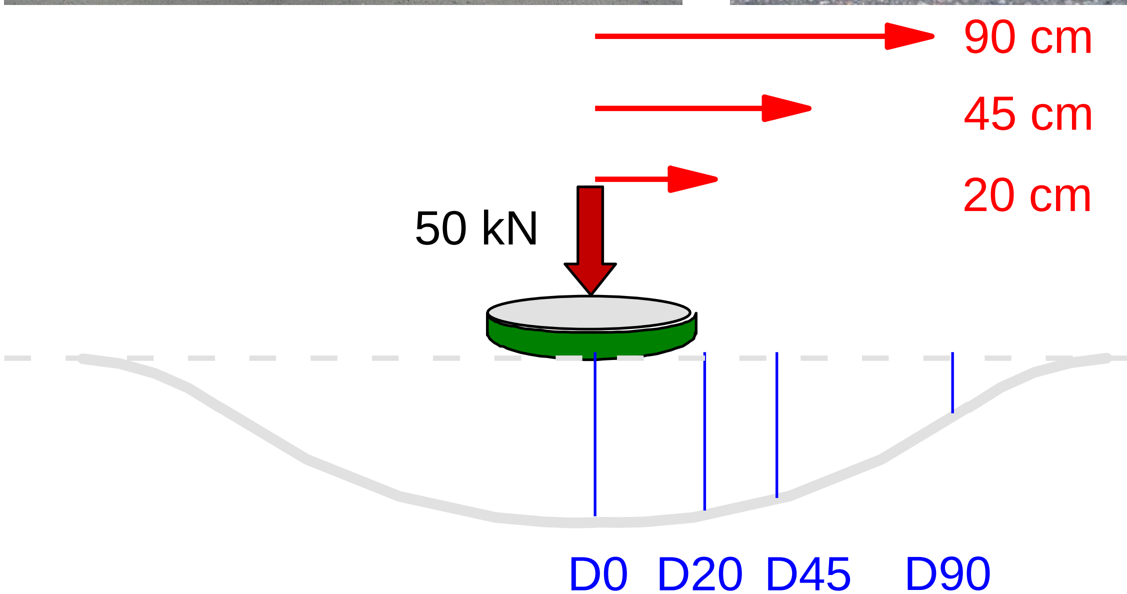
Measurement in stereo images

Laser scanning





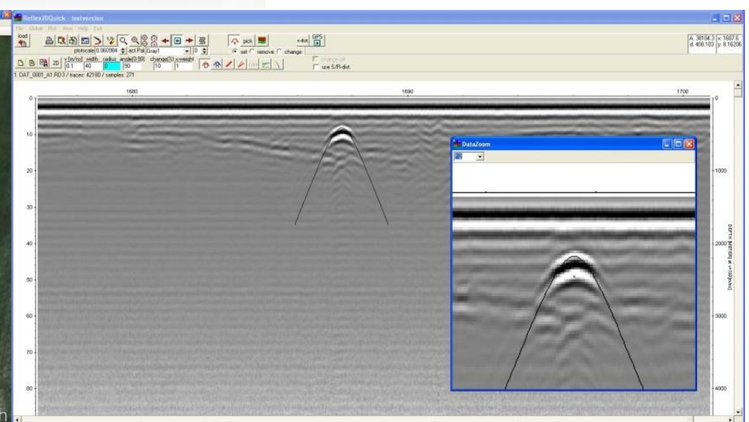
Falling Weight Deflectometer - FWD



Bearing Capacity

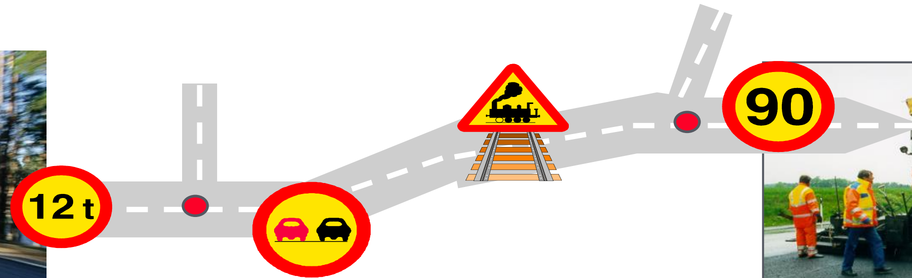
Ground Penetrating Radar (GPR)

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



PMS - Overview

PMS Components



Road condition

Longitudinal unevenness

Transversal unevenness

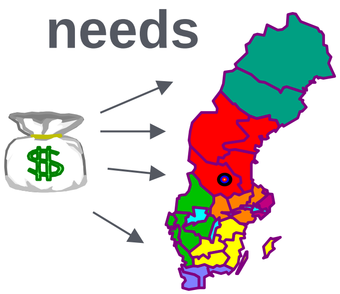
Road Inventory

Pavement information

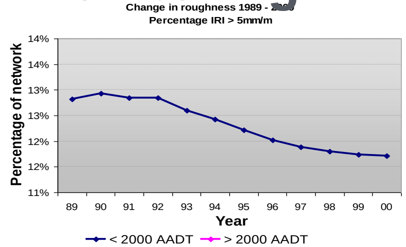
Database

Evaluation models

Budget needs



Condition monitoring



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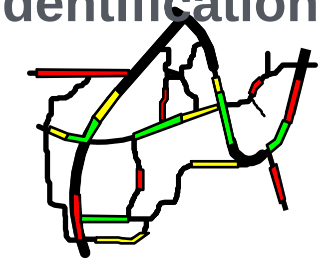
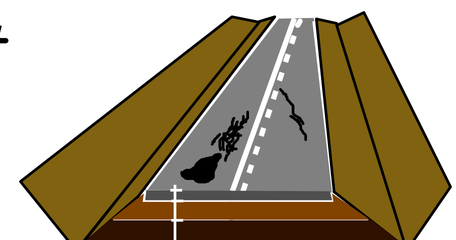
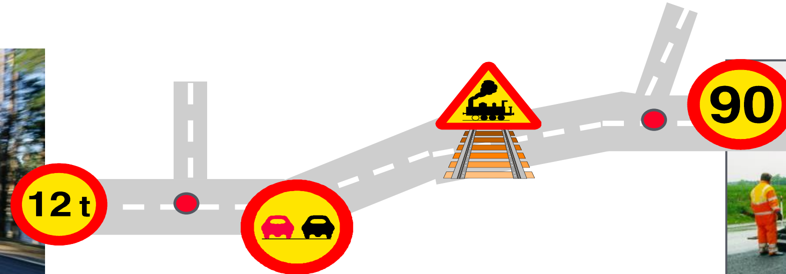


Follow-up contracts





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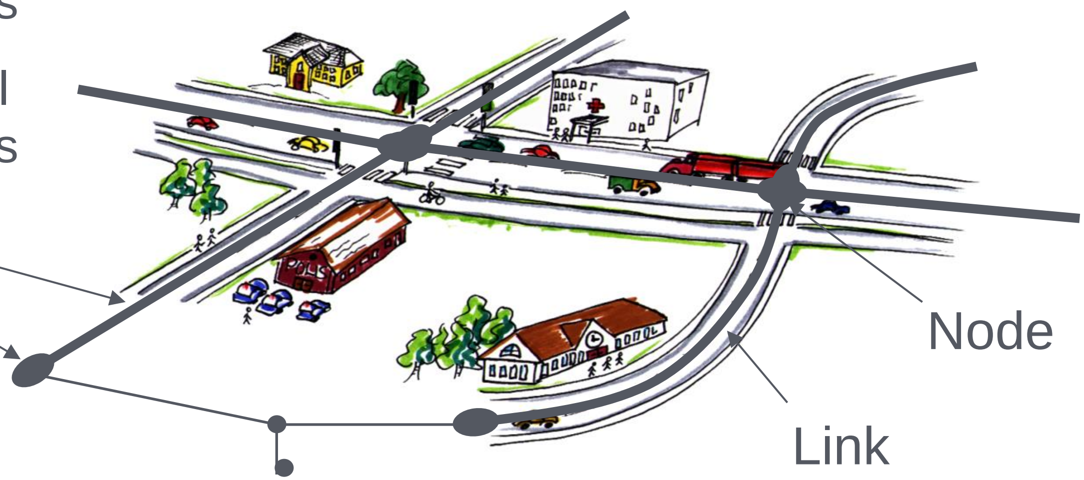
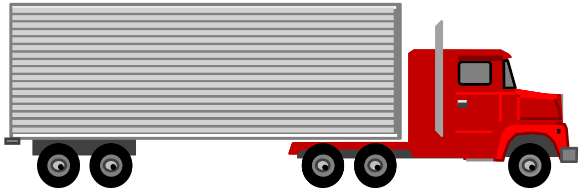
Coordinates x, y, z



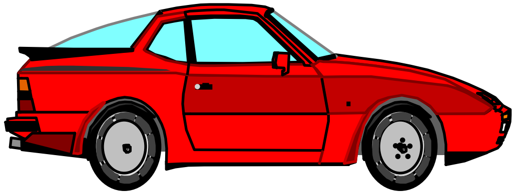
Node

Link

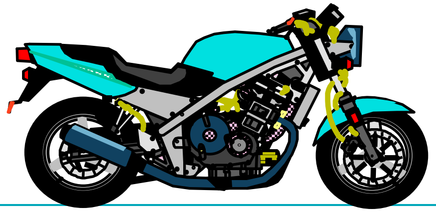
Traffic numbers are collected in the "Traffic Measurement System"



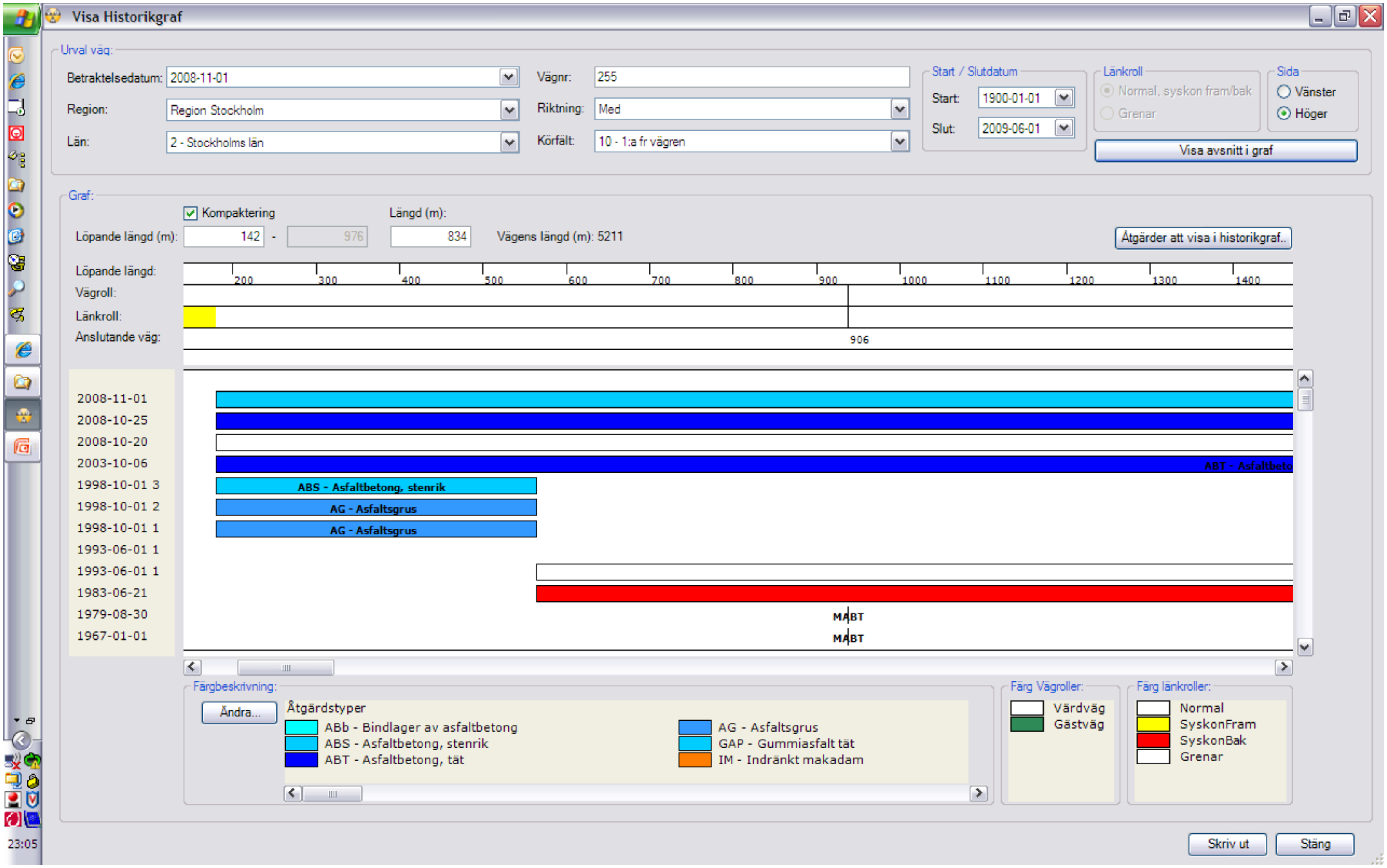
- Number of vehicles
- Number of axles
- Vehicle type



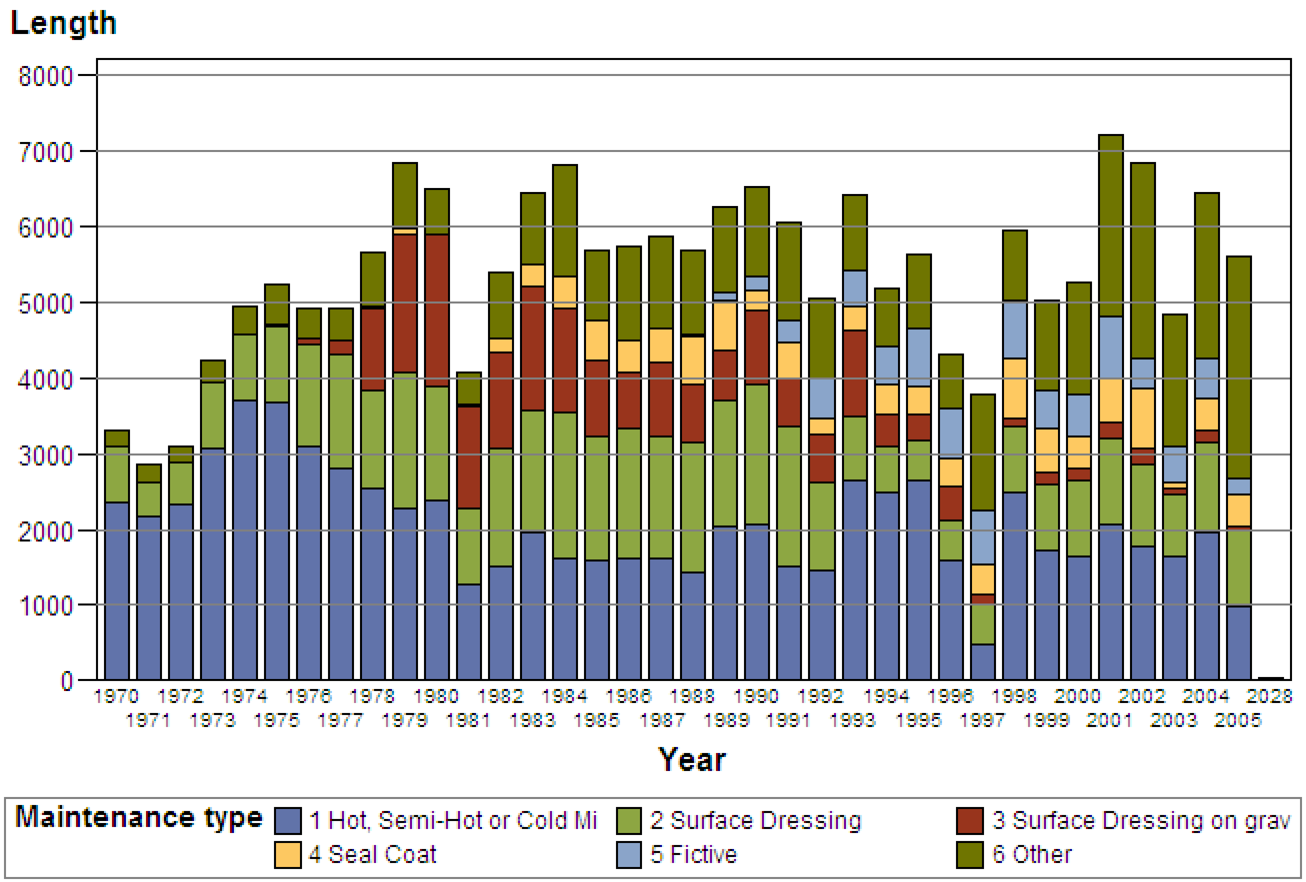
Based on traffic measurements Equivalent Standard Axle Loads is calculated



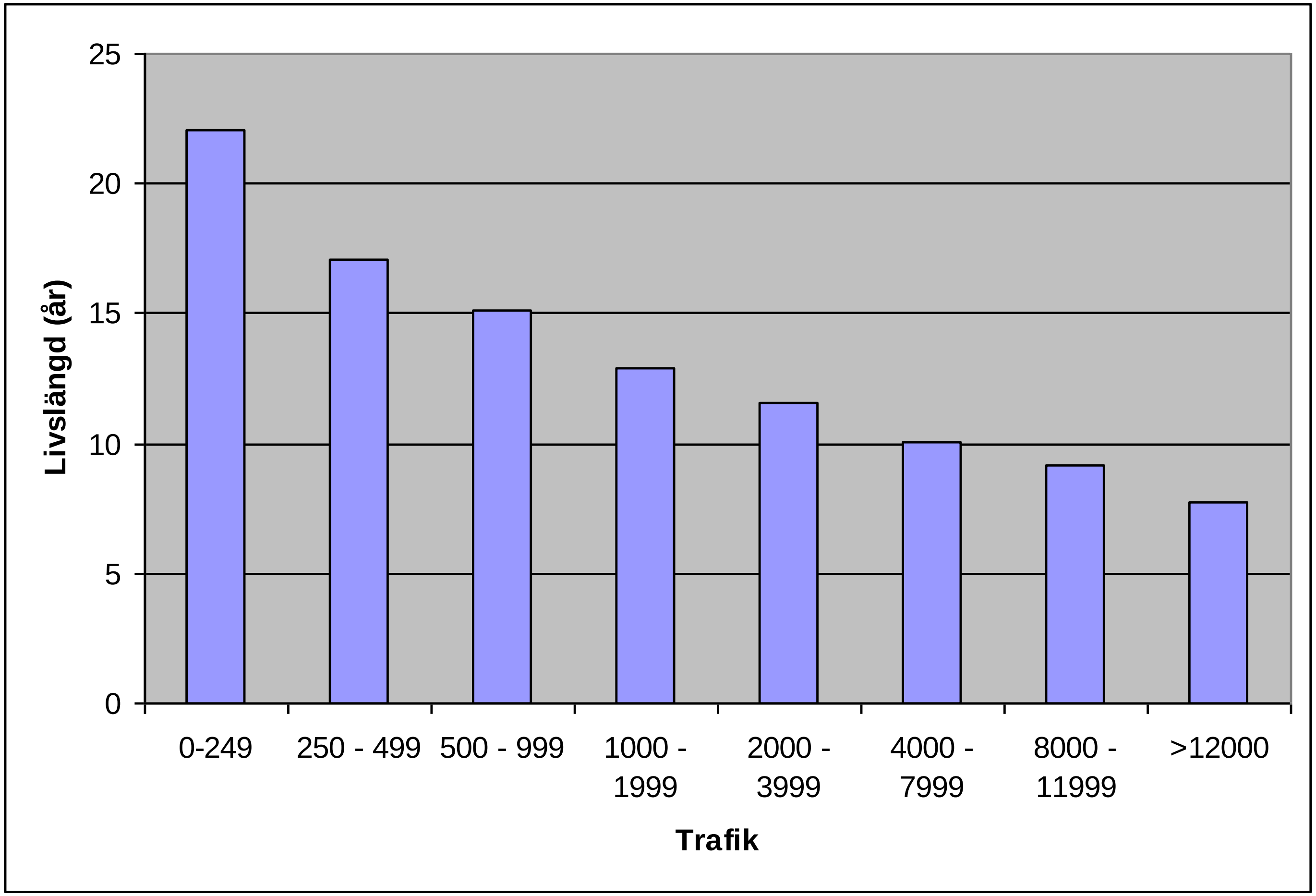
Example of output from the maintenance treatment database



The maintenance treatment database covers a long period



Expected durability



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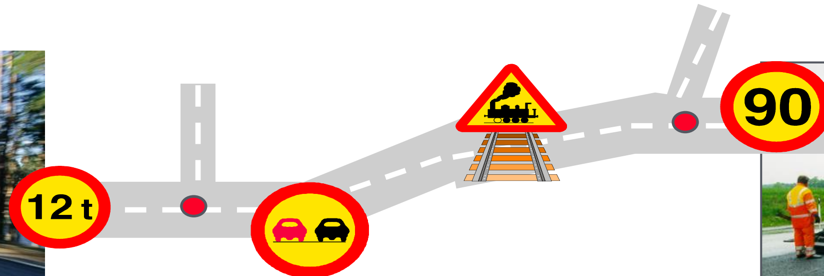

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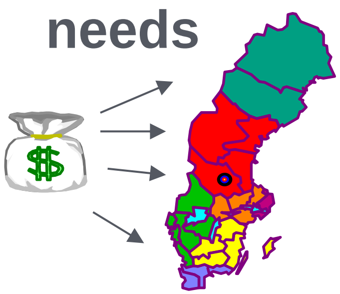

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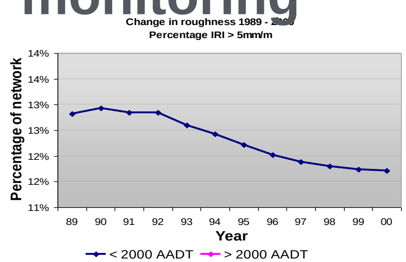

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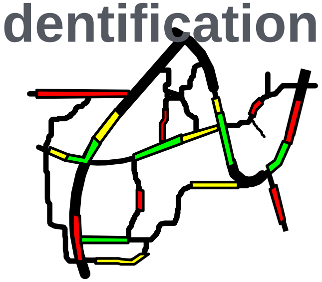
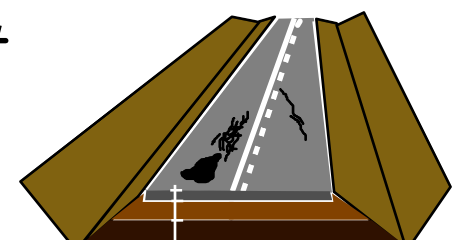


Follow-up contracts



PMS - Pavement Management Systems

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

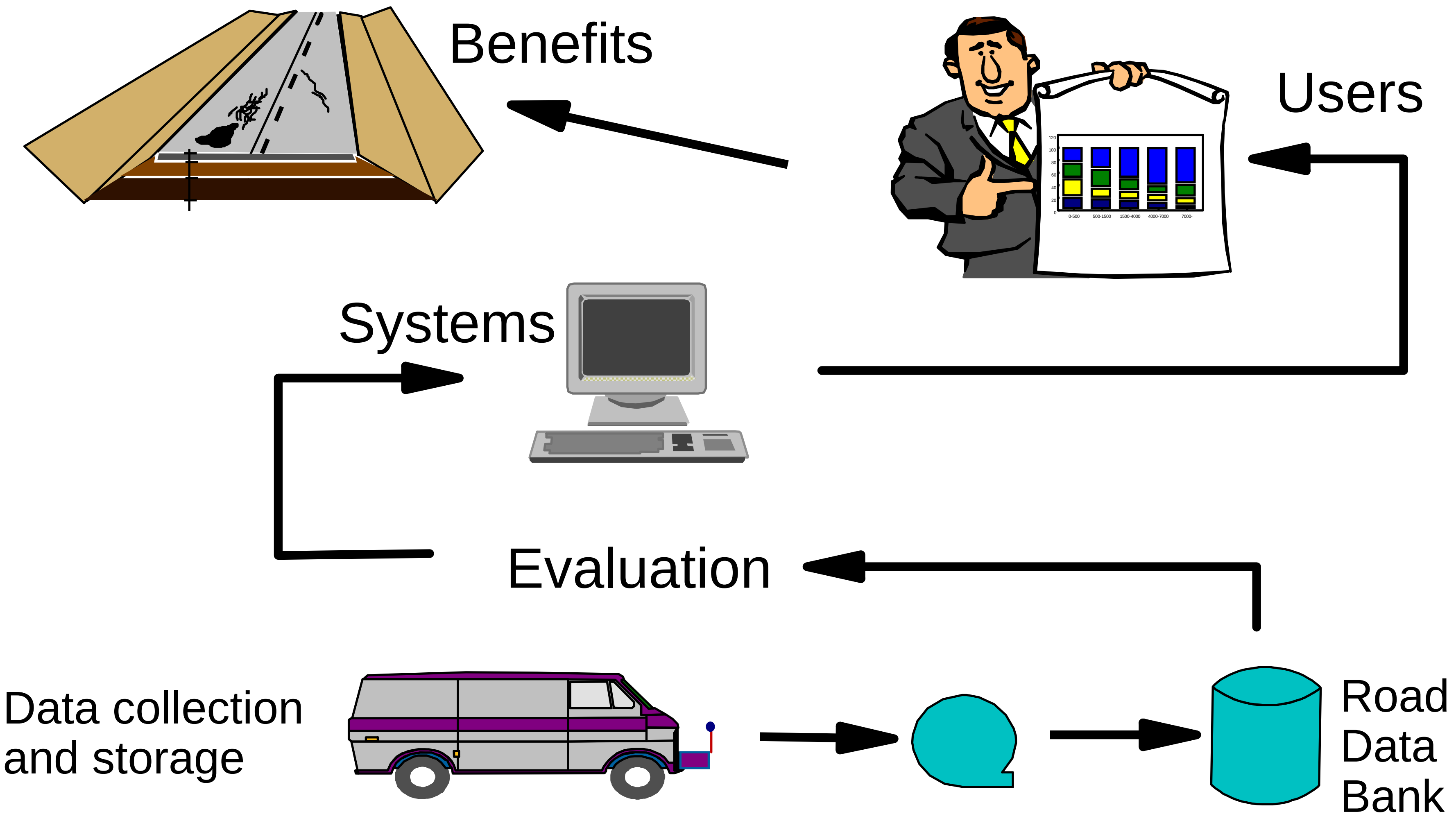
- Uses the results of the system
- Managers

PMS is a

Decision

Support

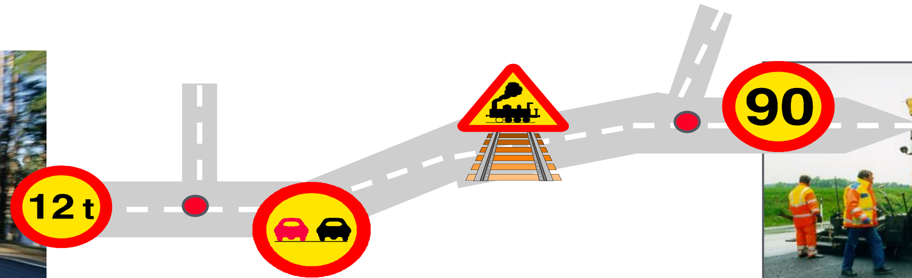
System



Benefits
Users
Systems
Evaluation
Data collection and storage
Road Data Bank

PMS - Overview

PMS Components



Road condition

Longitudinal unevenness

Transversal unevenness

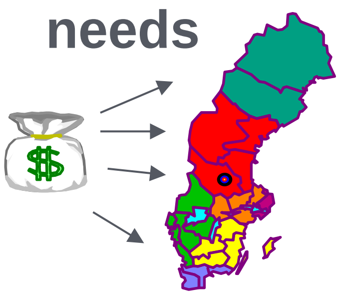
Road Inventory

Pavement information

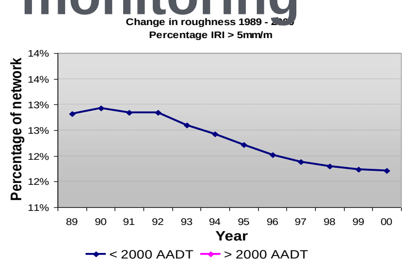
Database

Evaluation models

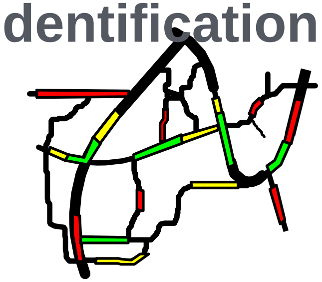
Budget needs



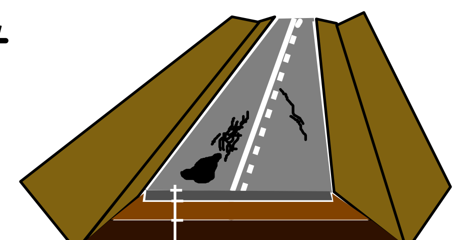
Condition monitoring



Project identification



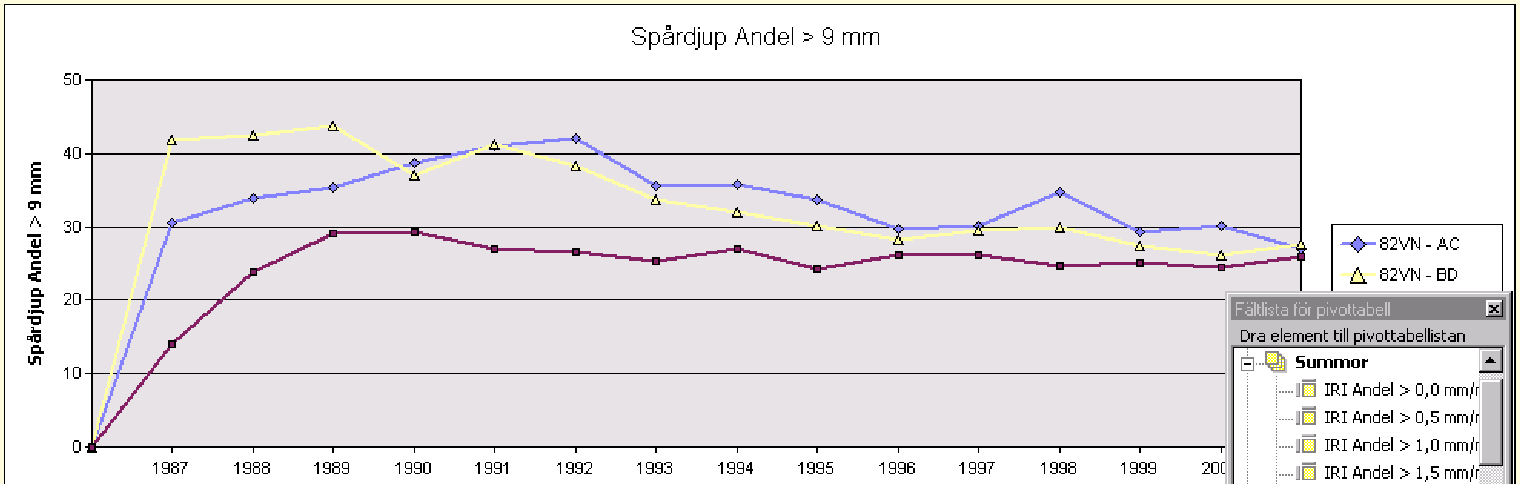
Follow-up contracts



Vägverket

Uppföljning PMS Vägnät

Tillståndsförändring Spårdjup



IRI_Spar

Hastighet	Hastighetsklass	Trafikklass 1	Trafikklass 2	Trafikklass 3
All Hastighet	All Hastighetsklass	All Trafikklass 1	All Trafikklass 2	All Trafikklass 3

Region	Lan	(tom) Spårdj	1987 Spårdj	1988 Spårdj	1989 Spårdj	1990 Spårdj	1991 Spårdj	1992 Spårdj	1993 Spårdj	1994 Spårdj	1995 Spårdj	1996 Spårdj	1997 Spårdj	1998 Spårdj	1999 Spårdj	2000 Spårdj	2001 Spårdj
⊟ 82VN	AC	#####	31	34	35	39	41	42	36	36	34	30	30	35	29	30	27
	BD	#####	42	42	44	37	41	38	34	32	30	28	30	30	27	26	28
⊞ 85VVAE		#####	14	24	29	29	27	27	25	27	24	26	26	25	25	24	26

Fältlista för pivottabell

Dra element till pivottabellistan

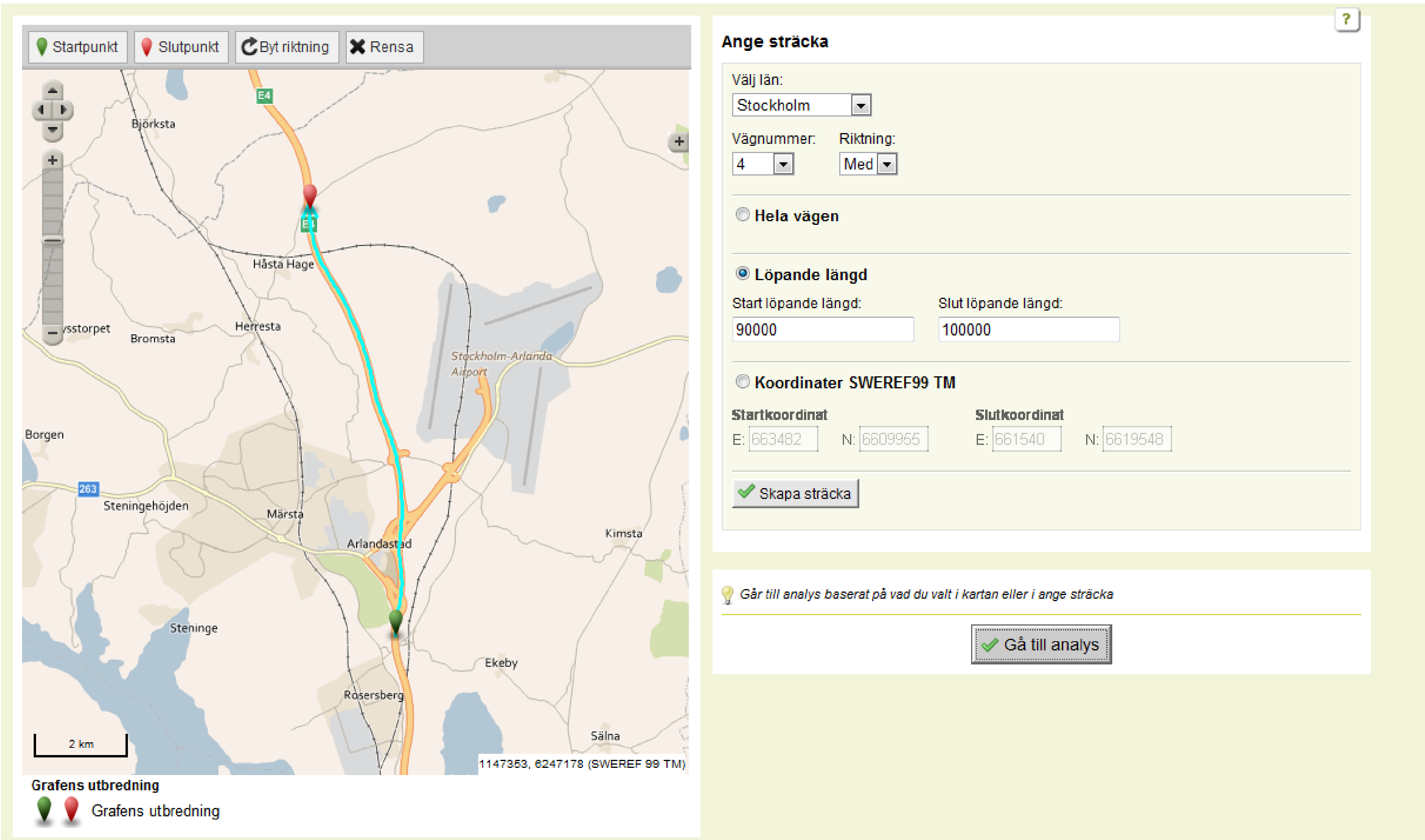
Summor

- IRI Andel > 0,0 mm/r
- IRI Andel > 0,5 mm/r
- IRI Andel > 1,0 mm/r
- IRI Andel > 1,5 mm/r
- IRI Andel > 2,0 mm/r
- IRI Andel > 2,5 mm/r
- IRI Andel > 3,0 mm/r
- IRI Andel > 3,5 mm/r
- IRI Andel > 4,0 mm/r
- IRI Andel > 4,5 mm/r
- IRI Andel > 5,0 mm/r
- IRI Andel > 5,5 mm/r
- IRI Andel > 6,0 mm/r
- IRI Andel > 6,5 mm/r
- IRI Andel > 7,0 mm/r

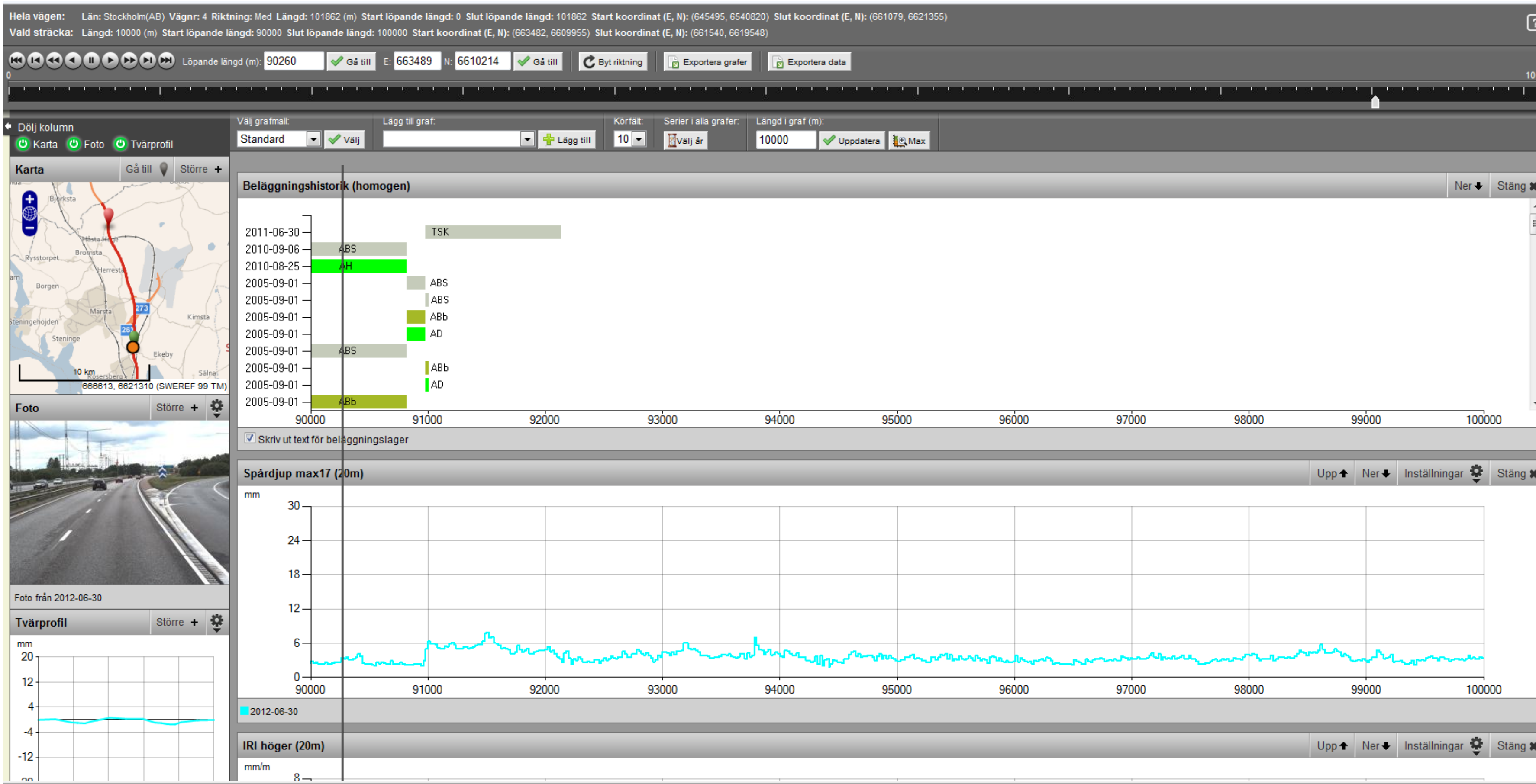
Lägg till | Radområde

Fel på sidan.

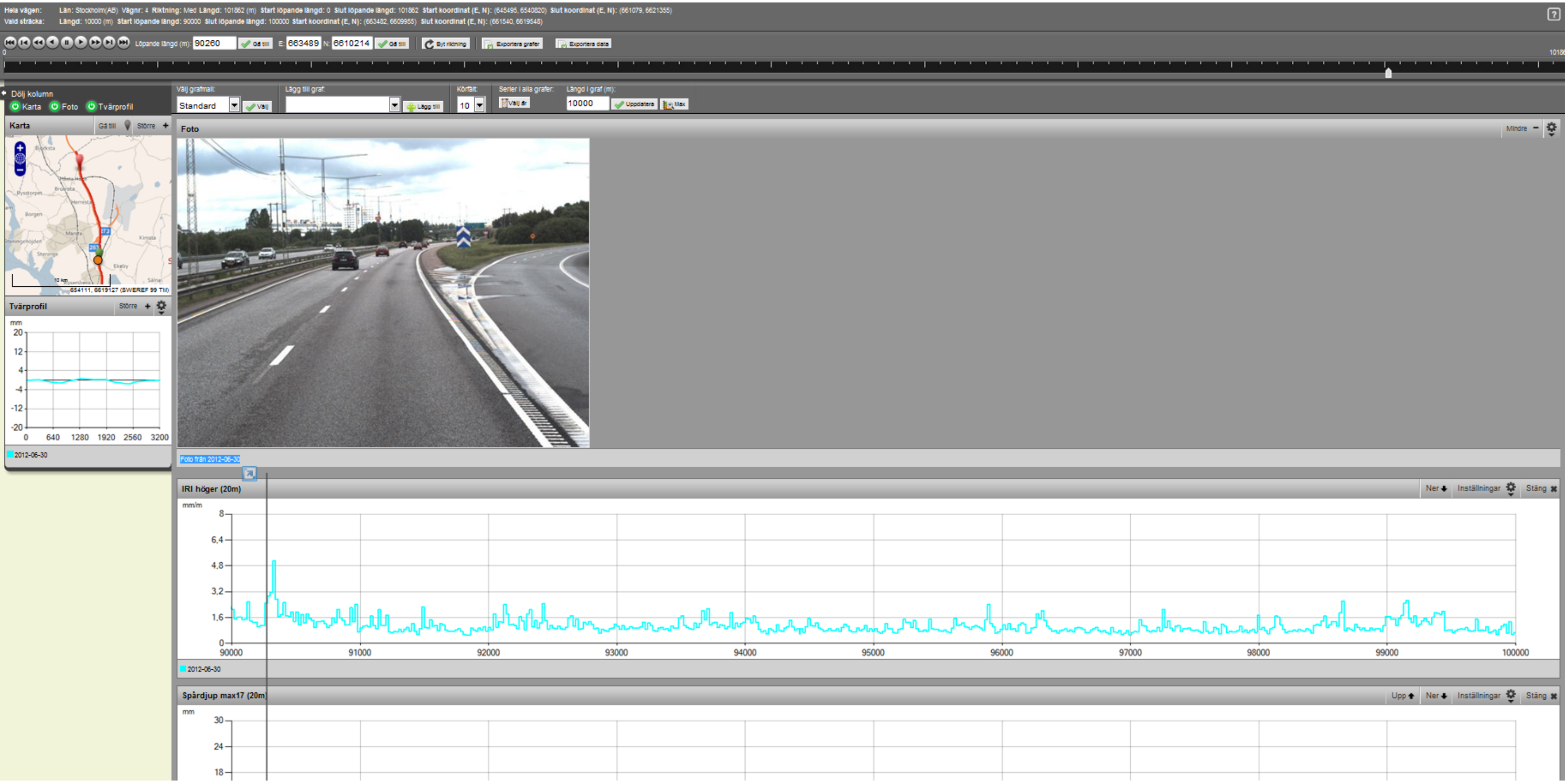
Output example from the New Swedish PMS



Output example from the New Swedish PMS

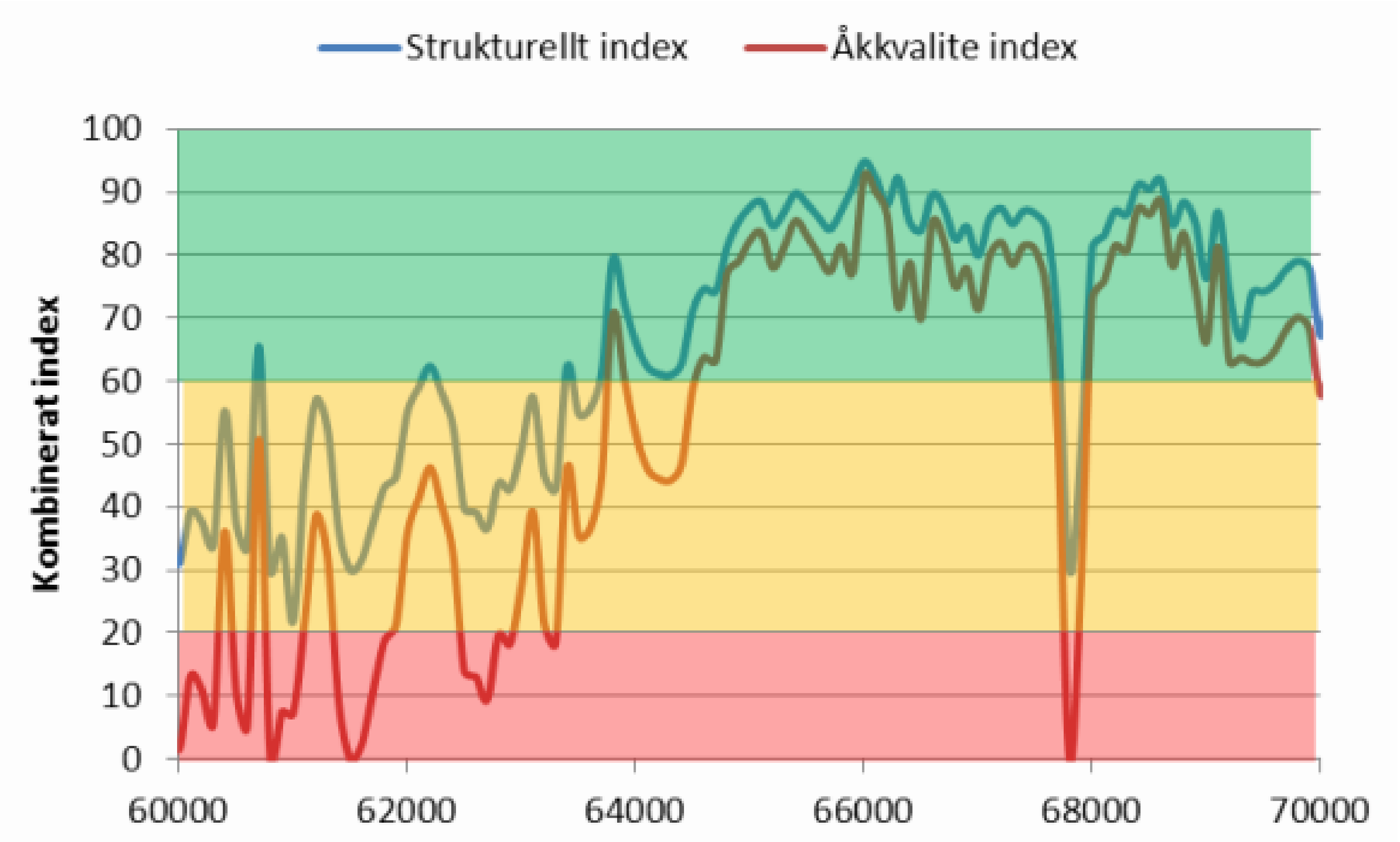


Output example from the New Swedish PMS



Output index

Output index



VÄGVERKET
PMS
20000531, 13.12

Road Surface Condition

Dalarnas län , Väg: 60.00

Sträcka: 0 - 5000, Körfält: 10, Riktning: Framåt, Sida för vägdata: 1

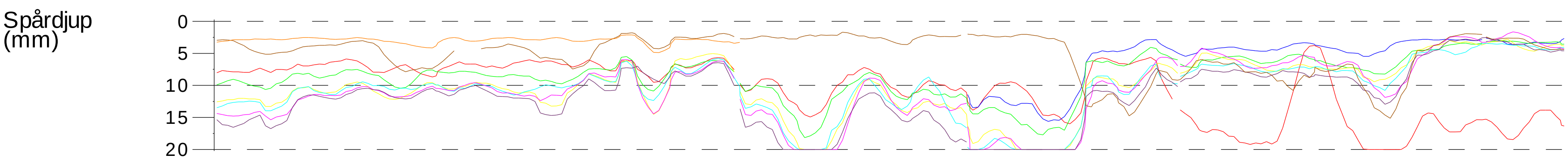
Vägversion: 19991205

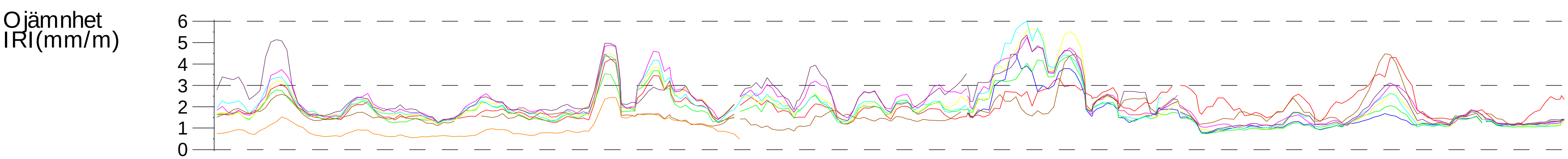
600.00 617.00 604.00 618.00

0 1000 2000 3000 4000 5000

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

1)32MABT1285, 2)24MABT1279, 3)32MABT1285,

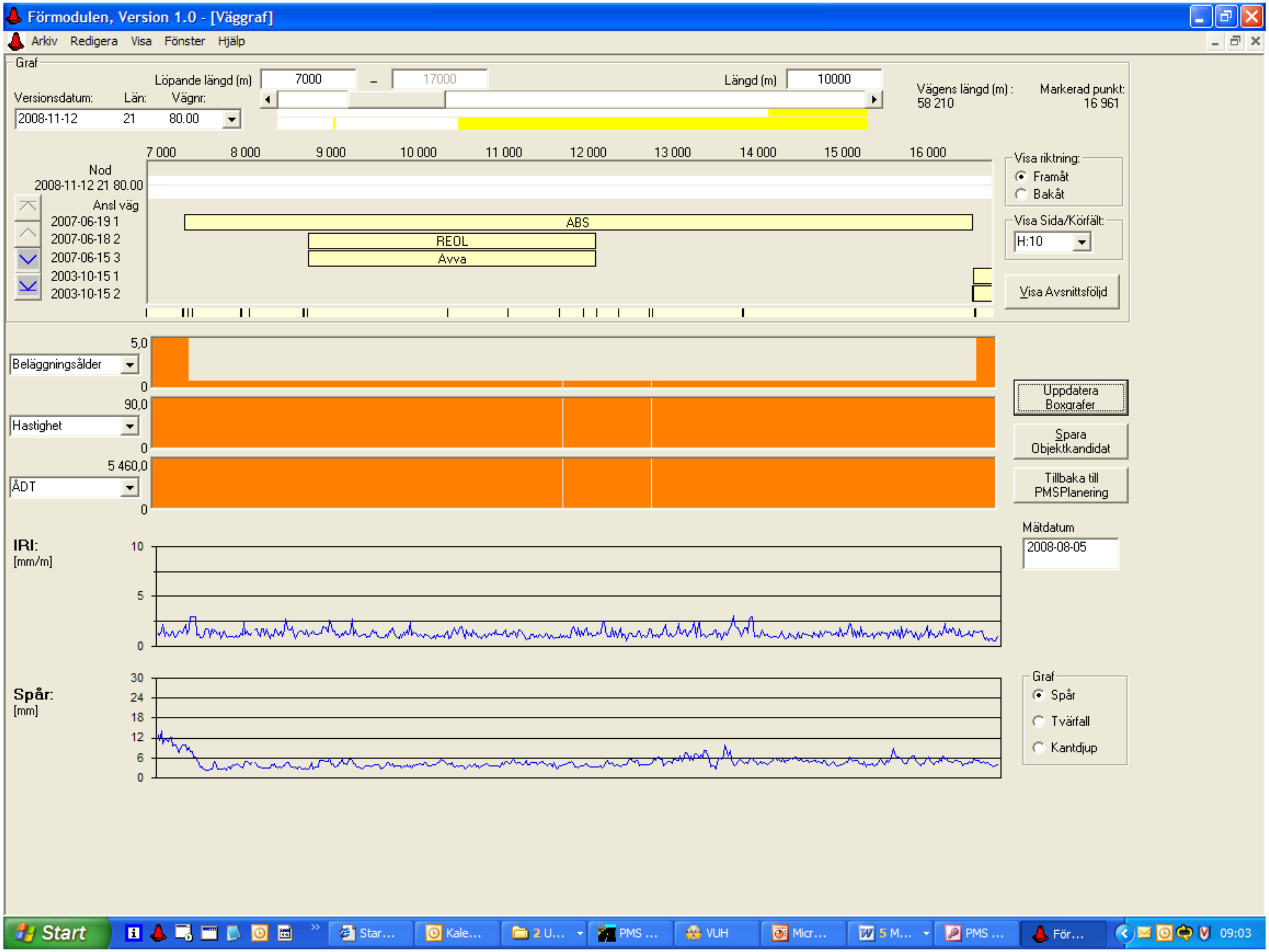


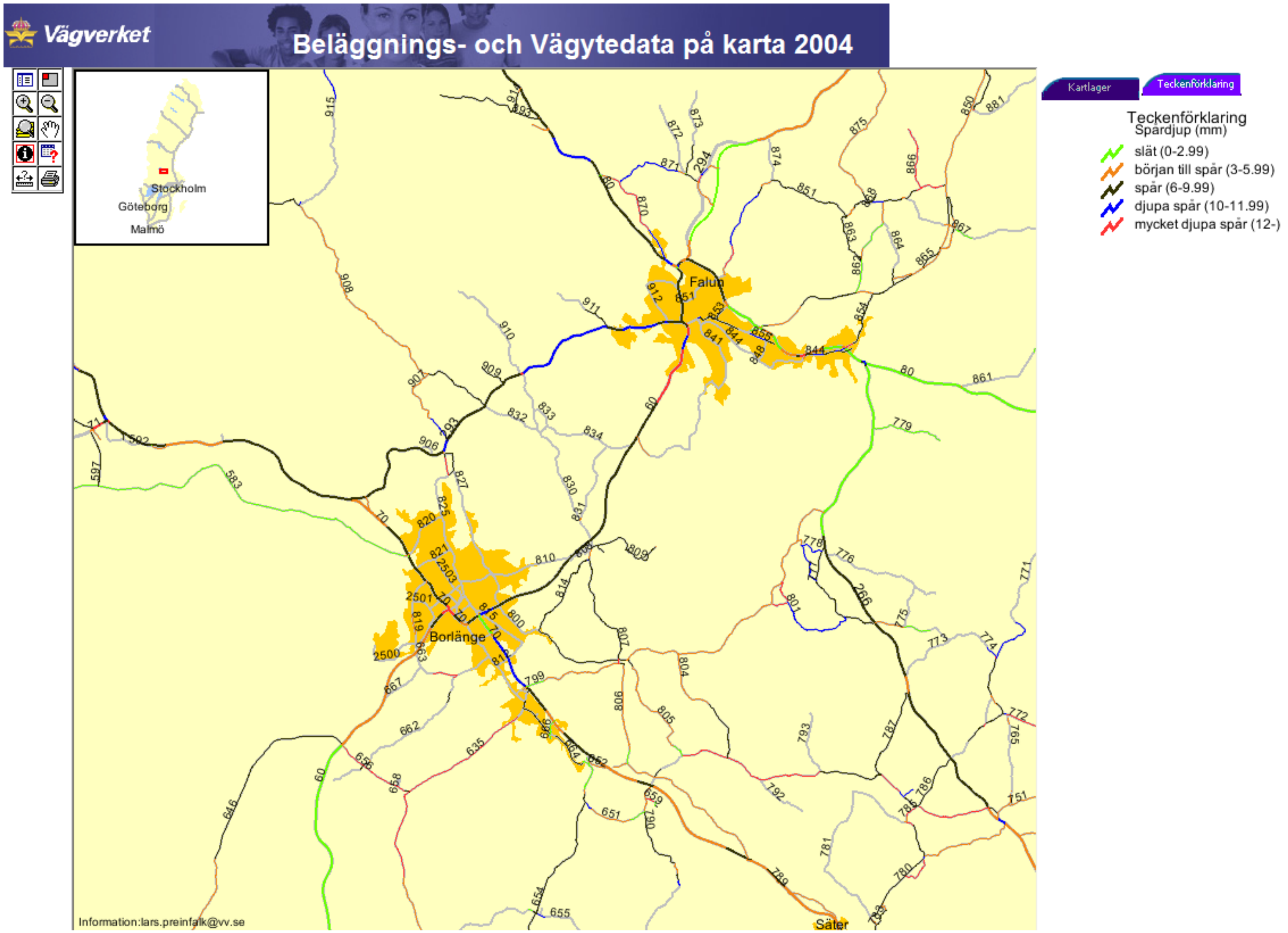


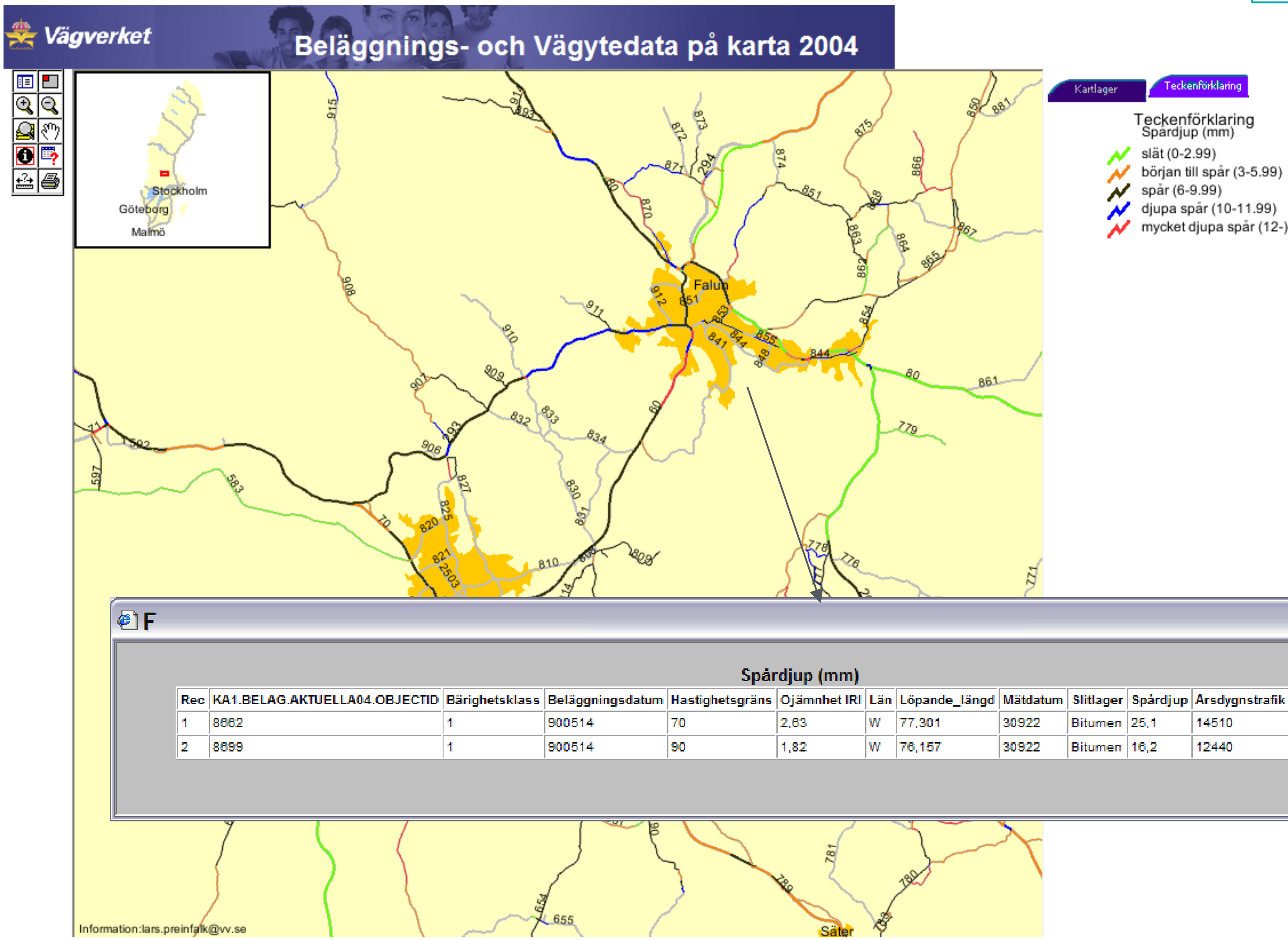
— 930601 — 930721 — 940530 — 950607 — 960609 — 970605
— 980627 — 990617 — 991023

Best1

Example PMS planning module – Road graph




Vägverket
Beläggnings- och Vägytedata på karta 2004
Stockholm
Göteborg
Malmö
Kartlager
Teckenförklaring
Teckenförklaring
Spårdjup (mm)
slät (0-2.99)
början till spår (3-5.99)
spår (6-9.99)
djupa spår (10-11.99)
mycket djupa spår (12-)
Falun
Borlänge
Säter
Information:lars.preinfalk@vv.se

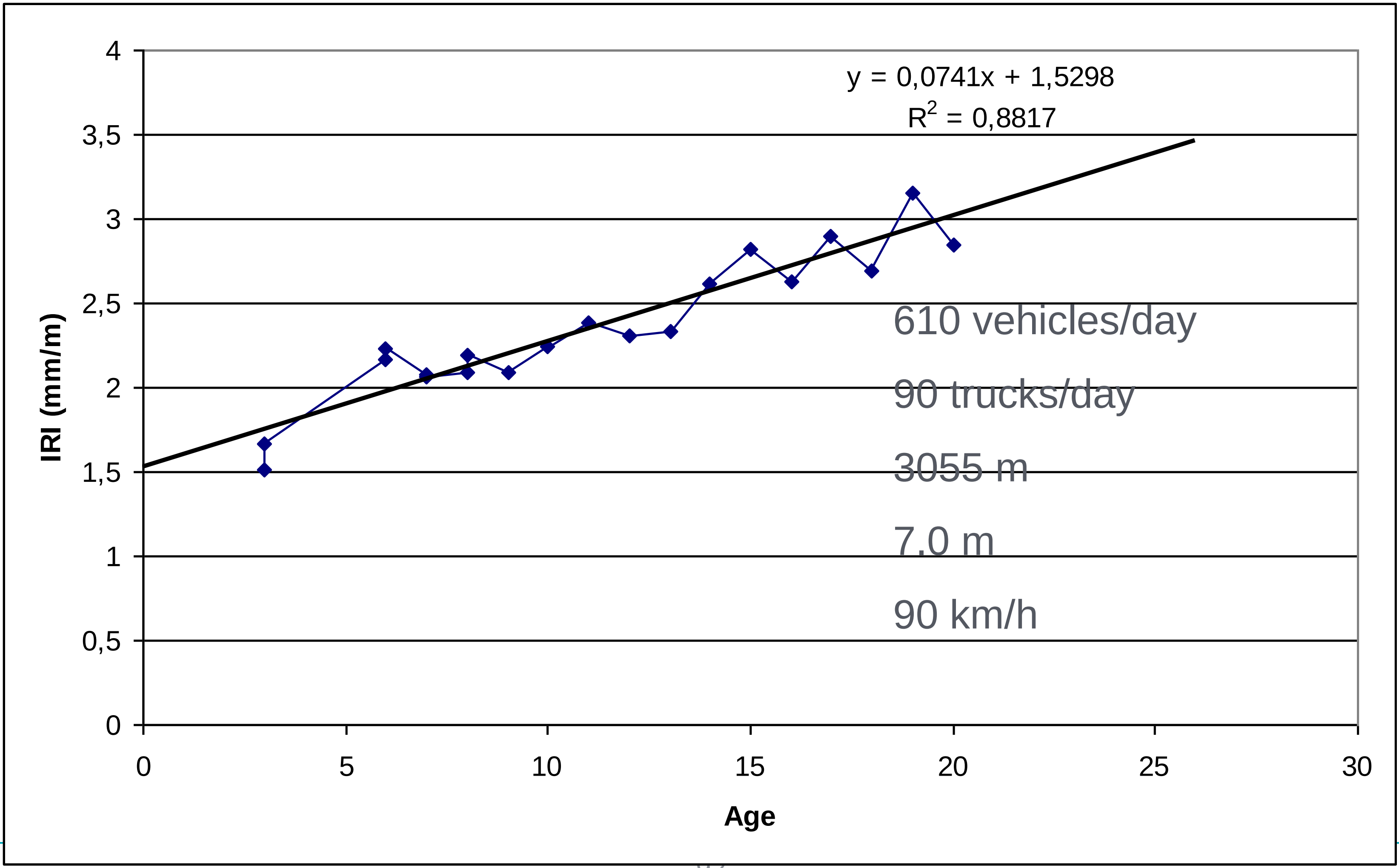


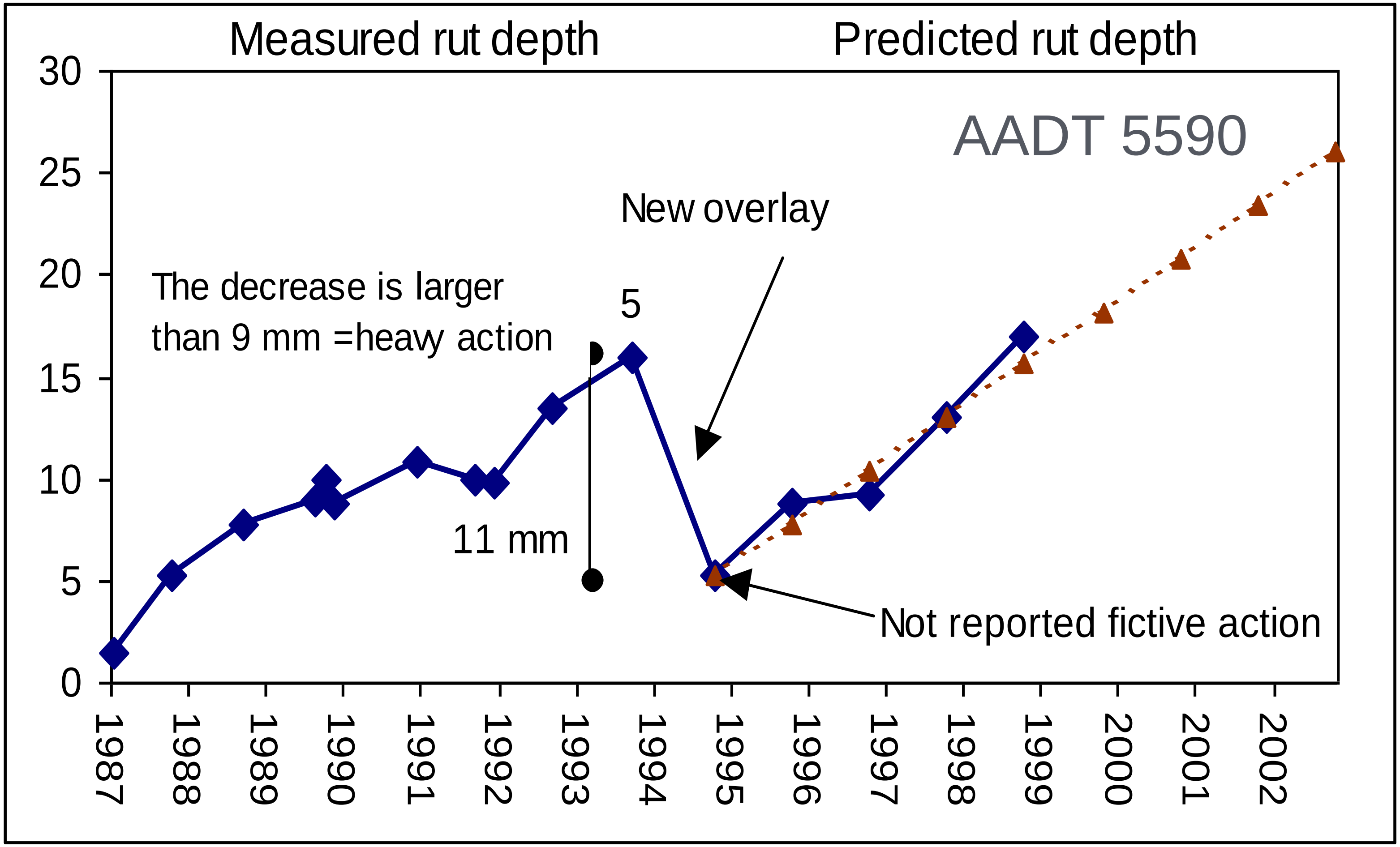
F

Spårdjup (mm)

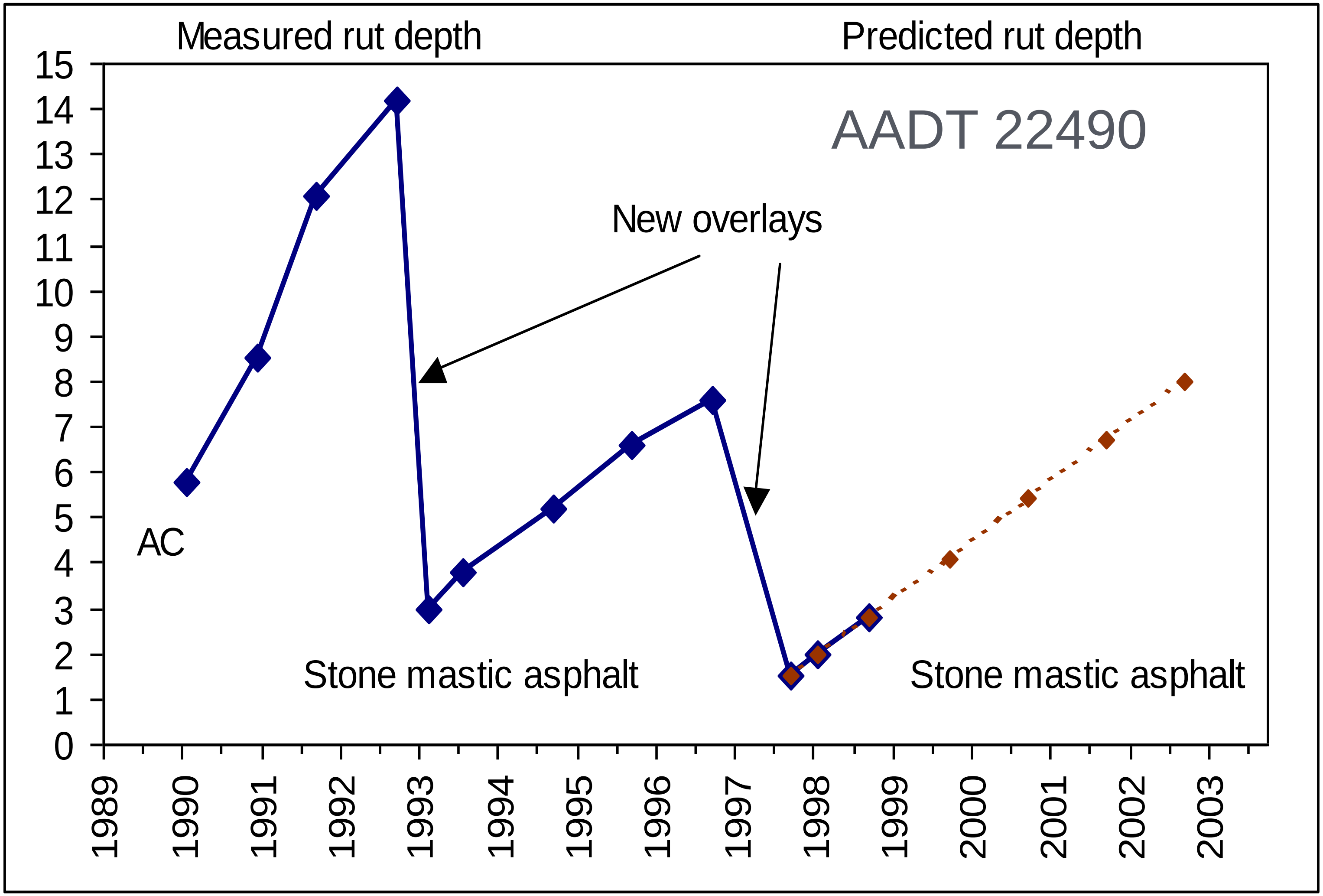
Rec	KA1.BELAG.AKTUELLA04.OBJECTID	Bärighetsklass	Beläggningsdatum	Hastighetsgräns	Ojämnhet IRI	Län	Löpande_längd	Mätdatum	Slitlager	Spårdjup	Årsdygnstrafik	Vägnummer	Vägtyp
1	8662	1	900514	70	2,63	W	77,301	30922	Bitumen	25,1	14510	50	Vanl
2	8699	1	900514	90	1,82	W	76,157	30922	Bitumen	16,2	12440	50	Vanl

Change in condition





Measured rut depth
Predicted rut depth
AADT 5590
New overlay
The decrease is larger
than 9 mm =heavy action
5
11 mm
Not reported fictive action
0
5
10
15
20
25
30
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


Measured rut depth
Predicted rut depth
AADT 22490
New overlays
AC
Stone mastic asphalt
Stone mastic asphalt
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

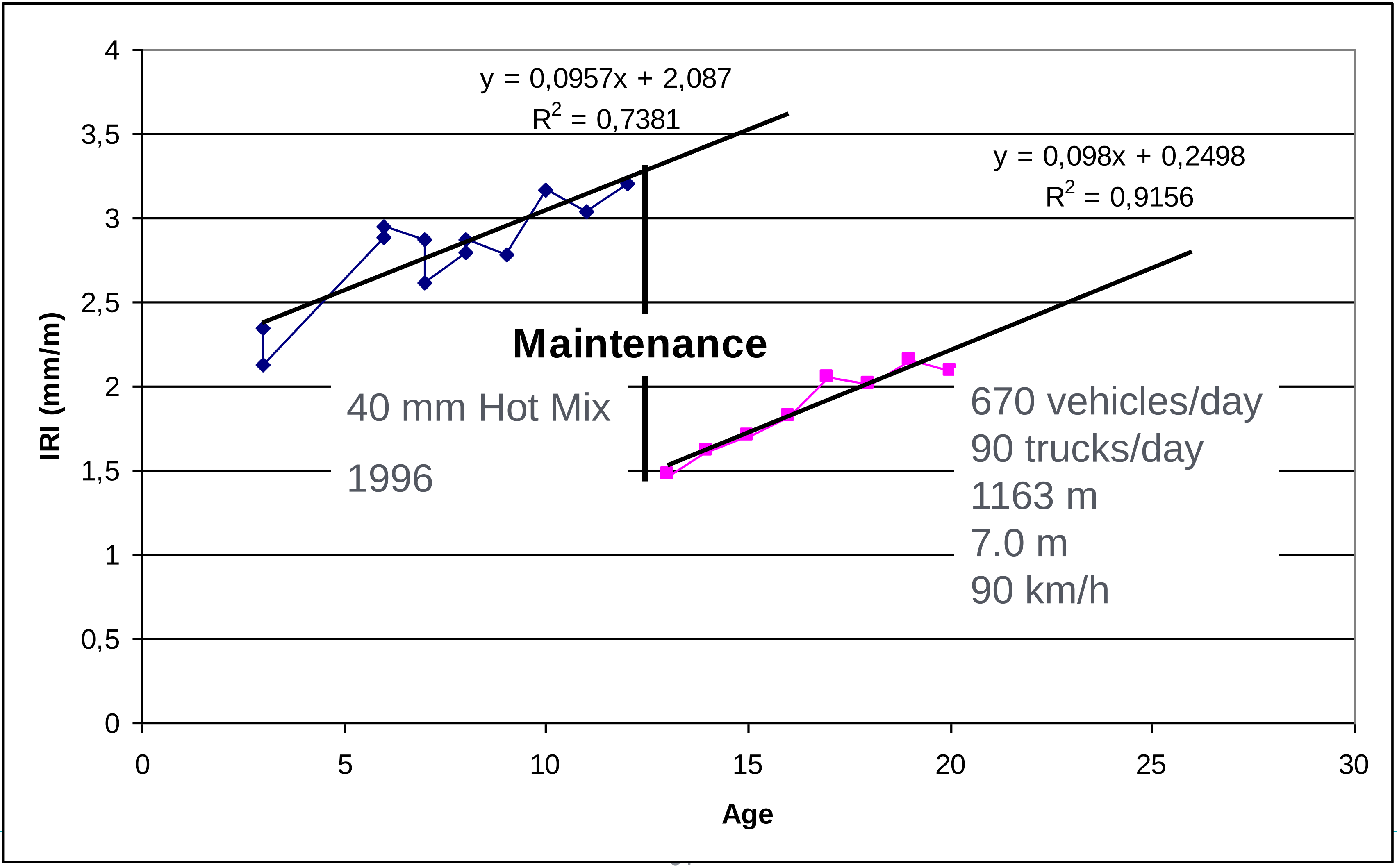
Maintenance standard IRI

Trafik (fordon/dygn)	Skyltad hastighet (km/h)							
	120	110	100	90	80	70	60	50
0-250		4,3	4,7	5,2	5,9	6,7	6,7	6,7
250-500		4,0	4,4	4,9	5,5	6,3	6,3	6,3
500-1000		3,7	4,1	4,5	5,1	5,8	5,8	5,8
1000-2000		3,0	3,3	3,7	4,2	4,8	5,2	5,2
2000-4000	2,4	2,6	2,9	3,2	3,6	4,1	4,9	4,9
4000-8000	2,4	2,6	2,9	3,2	3,6	4,1	4,9	4,9
>8000	2,4	2,6	2,9	3,2	3,6	4,1	4,9	4,9

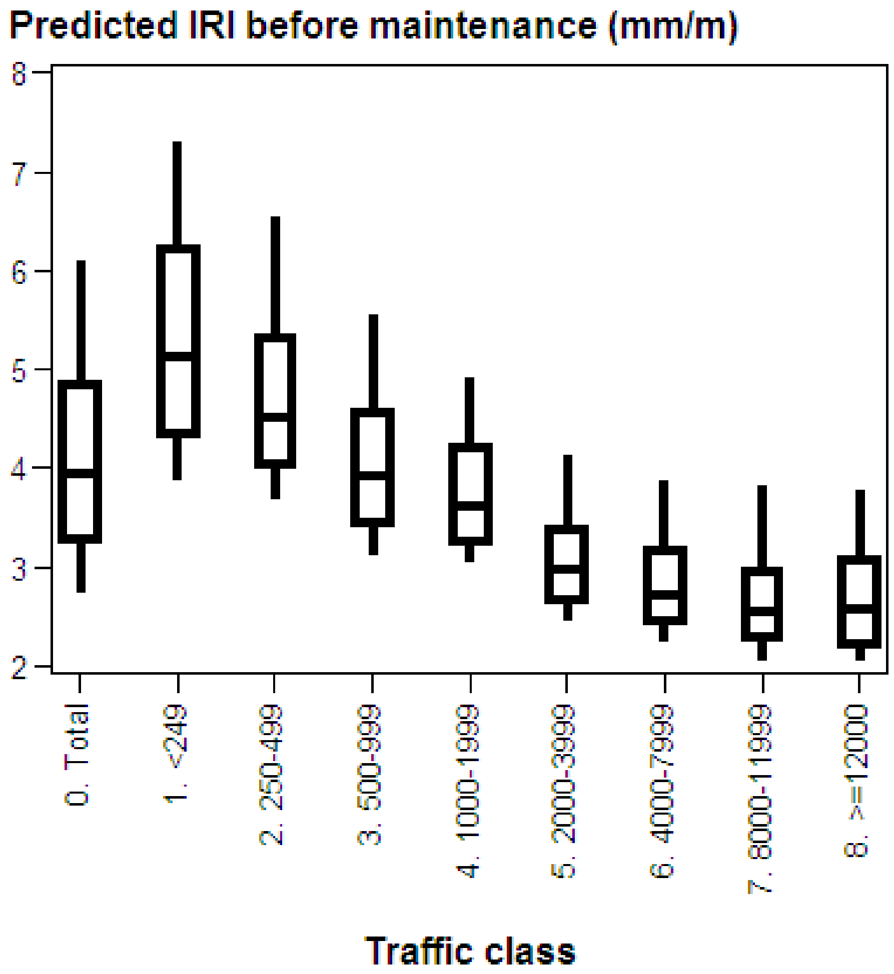
Maintenance standard rut depth

Trafik (fordon/dygn)	Skyltad hastighet (km/h)							
	120	110	100	90	80	70	60	50
0-250		18,0	18,0	24,0	24,0	30,0	30,0	30,0
250-500		18,0	18,0	22,0	22,0	27,0	27,0	27,0
500-1000		18,0	18,0	20,0	20,0	24,0	24,0	24,0
1000-2000		15,0	16,0	17,0	18,0	20,0	21,0	21,0
2000-4000	13,0	13,0	14,0	14,0	16,0	16,0	18,0	18,0
4000-8000	13,0	13,0	14,0	14,0	16,0	16,0	18,0	18,0
>8000	13,0	13,0	14,0	14,0	16,0	16,0	18,0	18,0

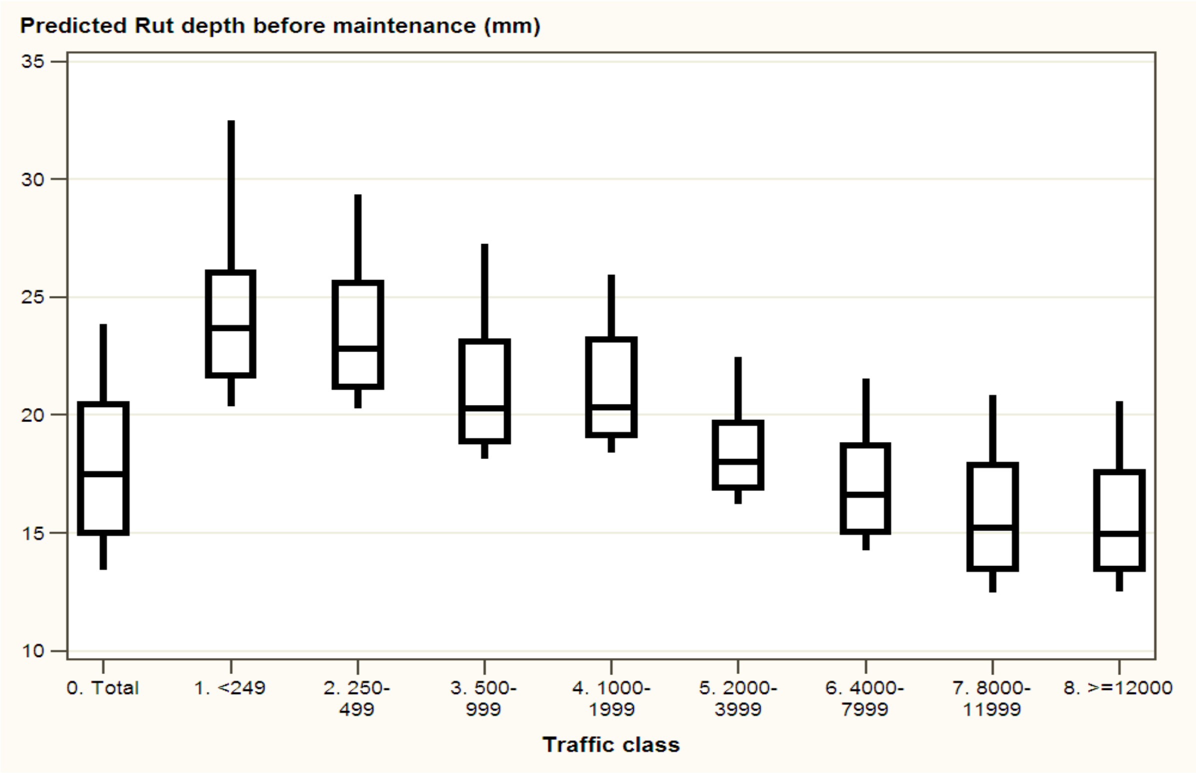
Maintenance effect



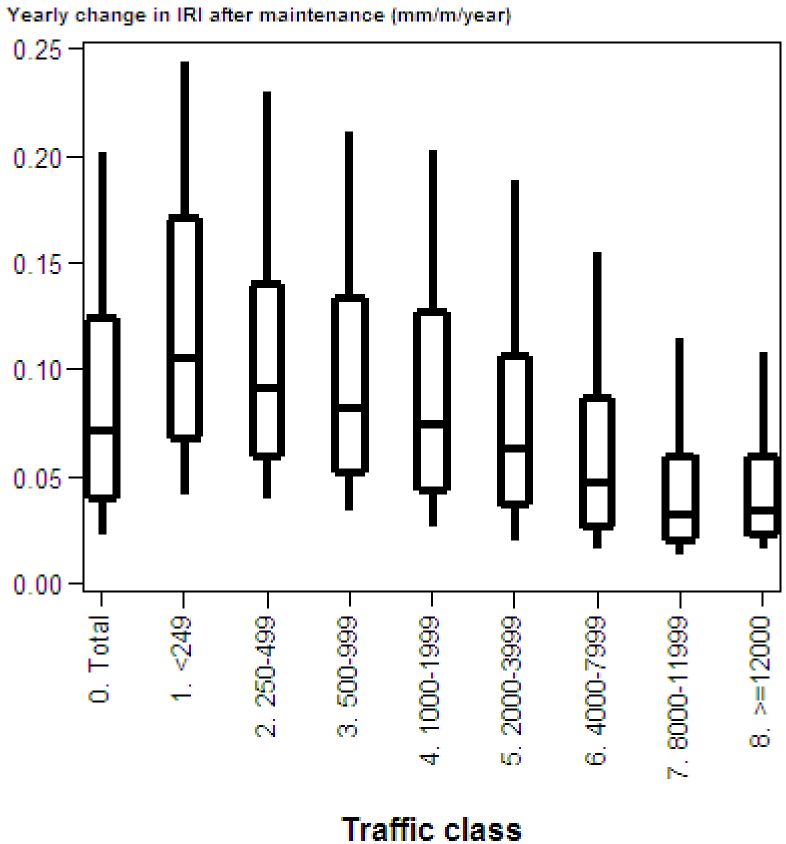
Predicted unevenness before maintenance

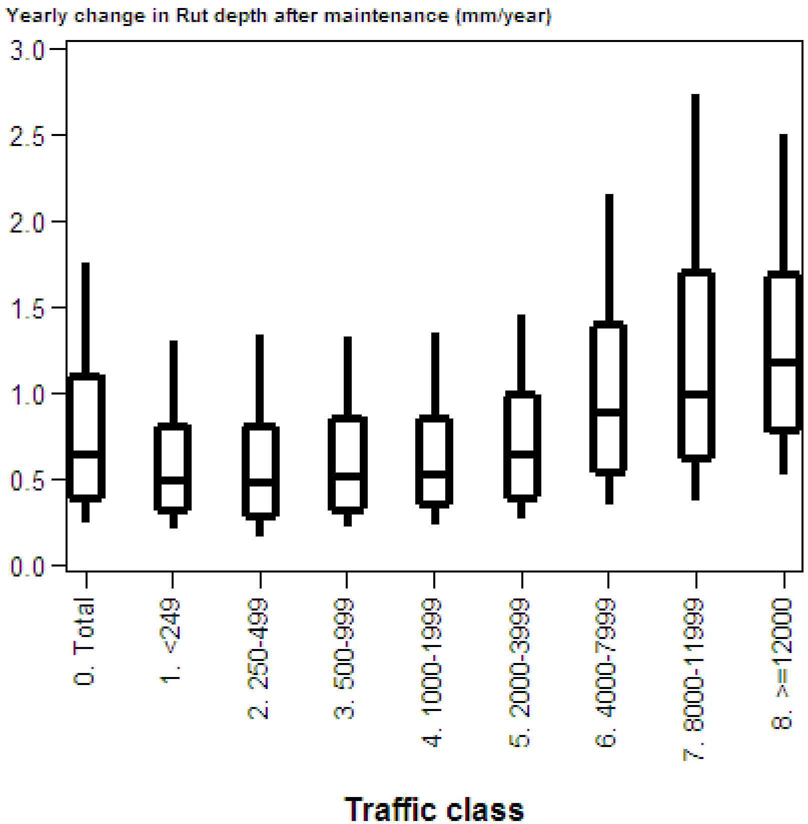


Predicted rut depth before maintenance



Yearly change in condition





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

CM=Cold Mix

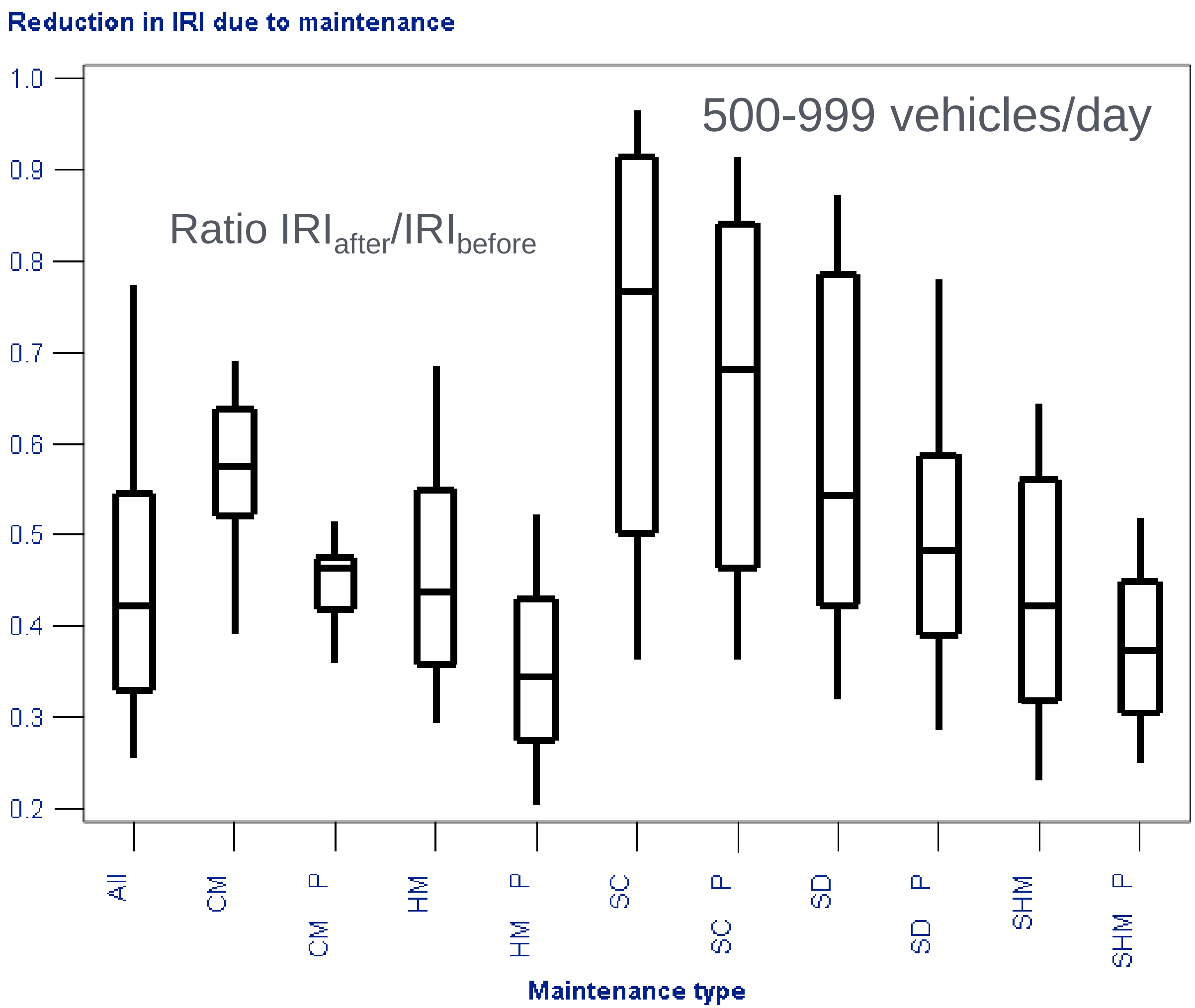
HM=Hot Mix

SC=Seal Coat

SD=Surface Dressing

SHM=Semi-Hot Mix

P=Preparatory work



Pavements for the road users

Internal

Comfort

Road Safety

Noice

External

Fuel

Vehicle operating costs

Tire

Rep-air

Particles

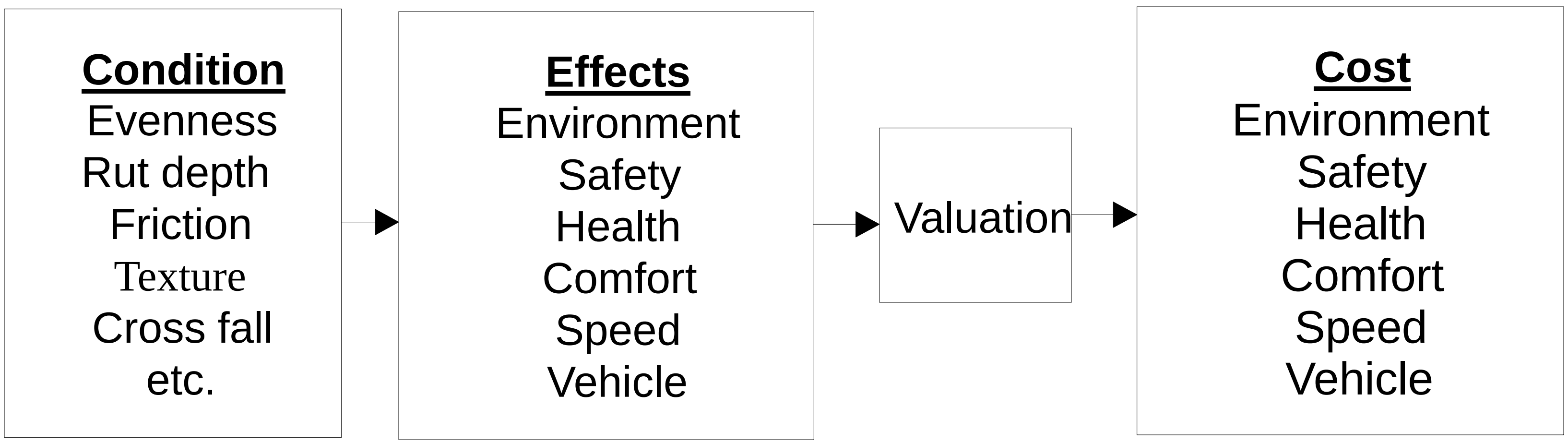
PM10 PM2.5l

Emission

CO2

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

Influence

Big

Fair

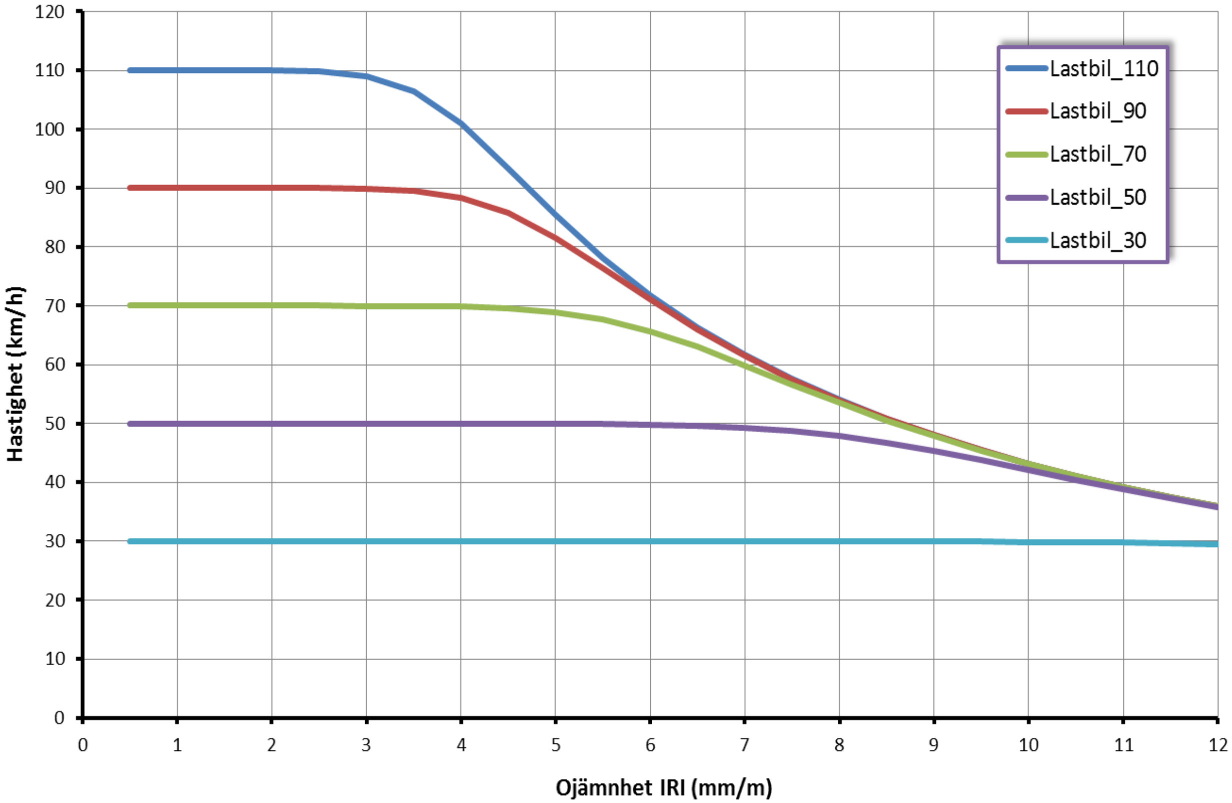
Low

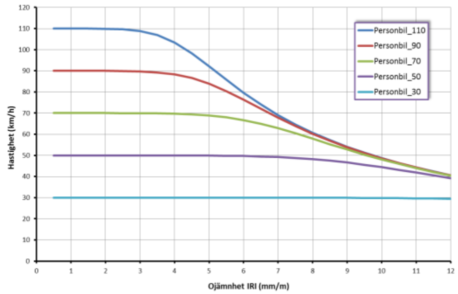
None

	Speed	Safety	Comfort	Vehicle damage	Tyre wear	Fuel consumption	Choice of road	Transport damage	Noice	Pollution	Longevity	Winter maintenance
Rut Depth	2	1	2	1	1	1	1	1	1	2	3	2
Rut shape	2	?	2	1	1	1	1	1	1	0	0	2
Roughness	3	2	3	3	2	3	3	3	2	1	3	2
Megatexture	2	2	3	3	2	3	2	3	3	1	2	2
Macrotexture	0	0	2	1	3	3	0	0	3	1	0	2
Microtexture	0	0	0	0	3	1	0	0	1	0	0	0
Friction	3	3	2	0	0	0	2	0	0	0	0	0
Retroreflection	2	2	2	0	0	0	1	0	0	0	0	0
Crossfall	1	1	1	1	1	1	0	0	0	1	2	0
Water permeability	2	2	2	0	0	1	1	0	1	3	1	2
Bearing Capicity	0	0	0	0	0	1	3	0	0	0	3	0
Stiffness	0	0	0	0	0	2	0	0	1	0	0	0

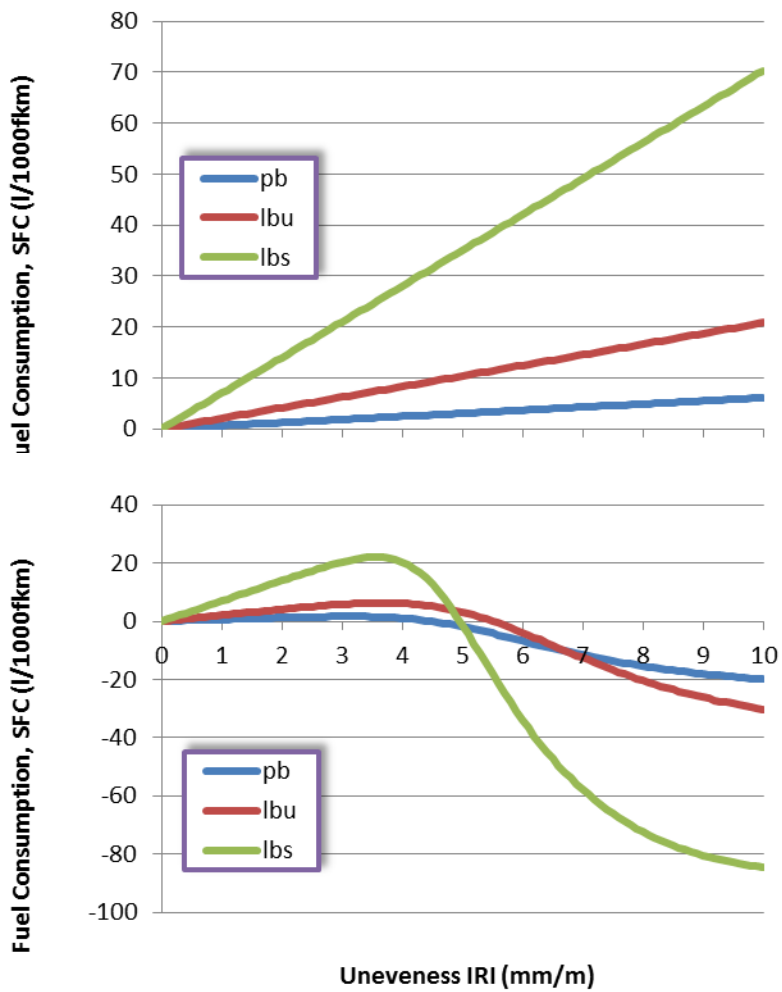
Importance ■ Large ■ Fair	Primary functional properties								Secondary functional properties		
Material- and construction properties	Friction	Rolling resistance	Tyre wear	Noise and sound	Vibration	Krängningar	Surface dewatering	Retro-reflection	Water depth	Ice on the road	Snow on the road
Microtexture	++	+	++								
Macrotexture	++	++	++	++			++	++		+	
Megatexture	+	++	+	++	++	+	+		++		
Roughness		+	+	+	++	++	+		+	+	+
Crossfall						++	++		++		
Edge drop						+					
Alignment						+			+		
Rut depth			+			+	++		++	++	++
Rut shape			+			+					+
Water permeability							++	++	++	+	
Stiffness		+									

IRI vs Speed - Trucks

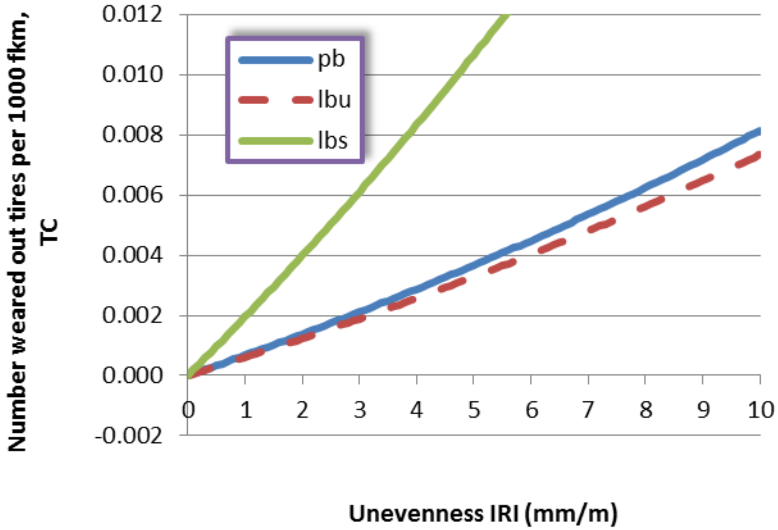


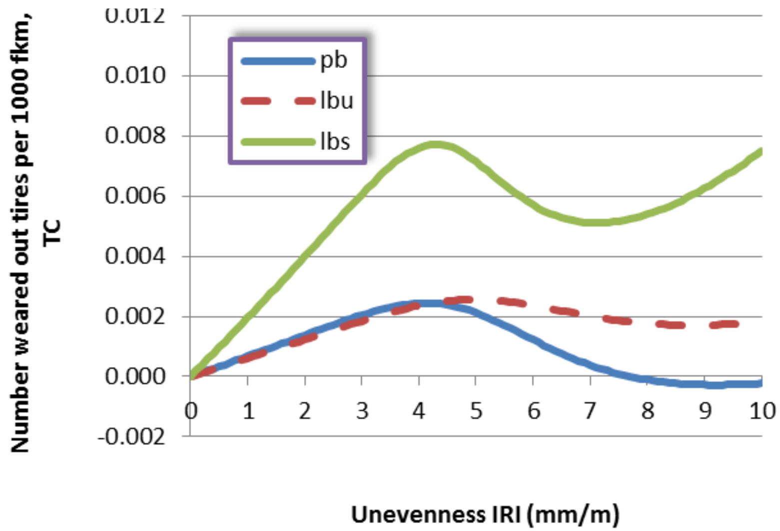


Fuel consumption

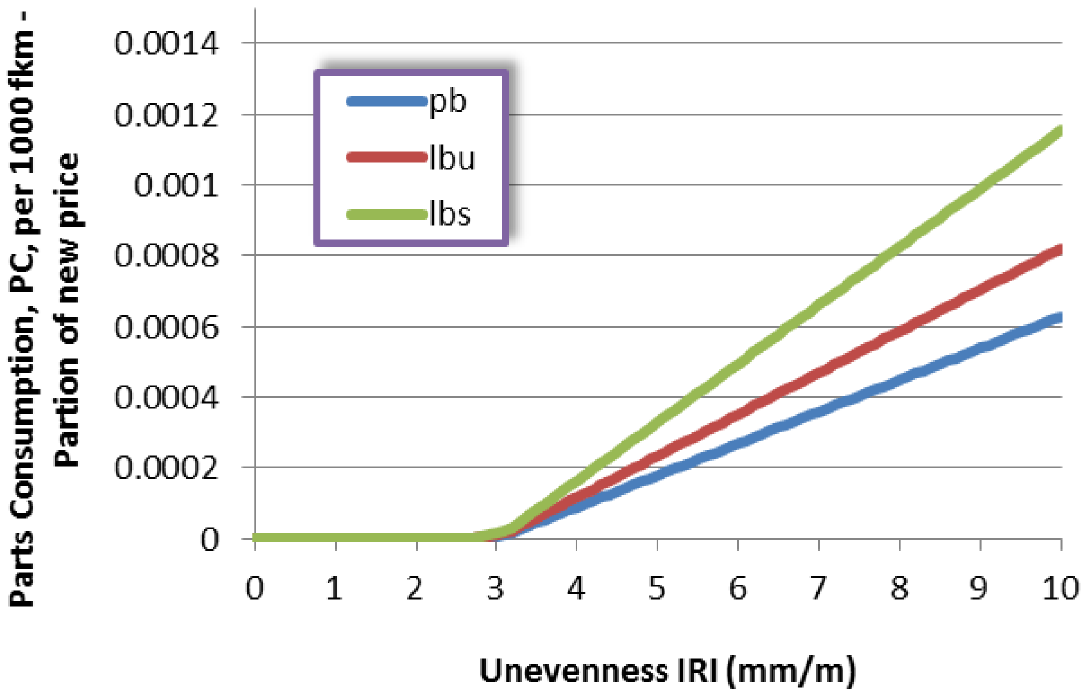


Tyre wear

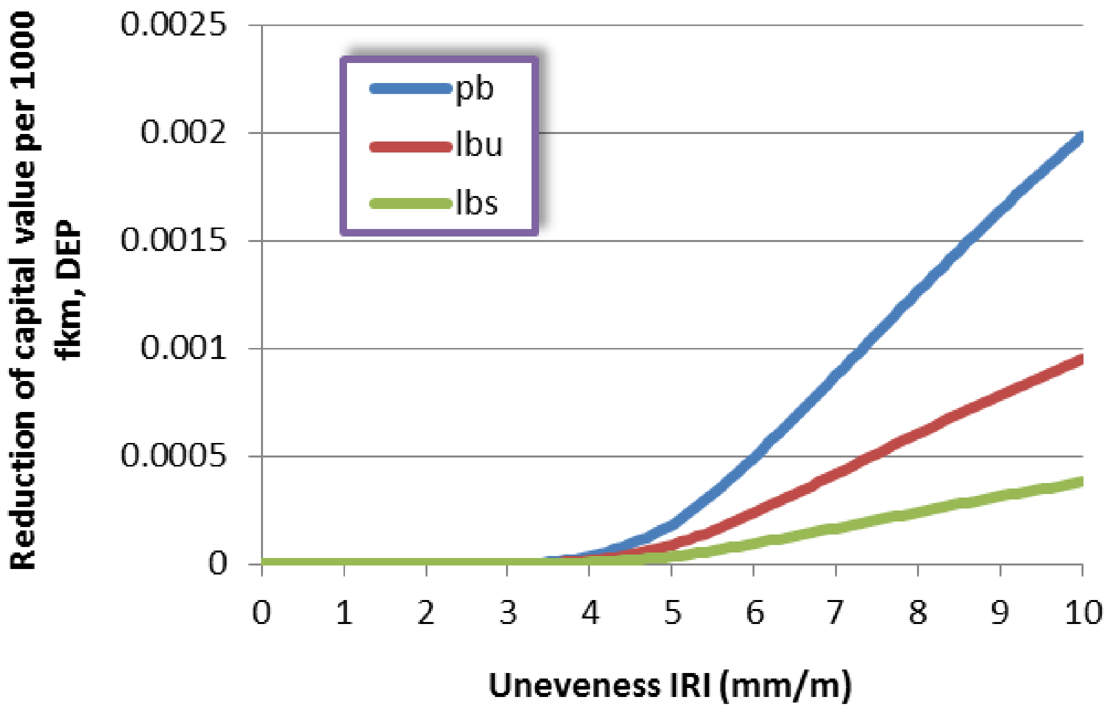

0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
0 1 2 3 4 5 6 7 8 9 10
pb
lbu
lbs
Number weared out tires per 1000 fkm, TC
Unevenness IRI (mm/m)


0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
0 1 2 3 4 5 6 7 8 9 10
pb
lbu
lbs
Number weared out tires per 1000 fkm, TC
Unevenness IRI (mm/m)

Parts consumption vs. evenness



Capital value vs. evenness



Comfort

Profile measurement → QC-model → IRI

IRI ↔ Vibration measurement

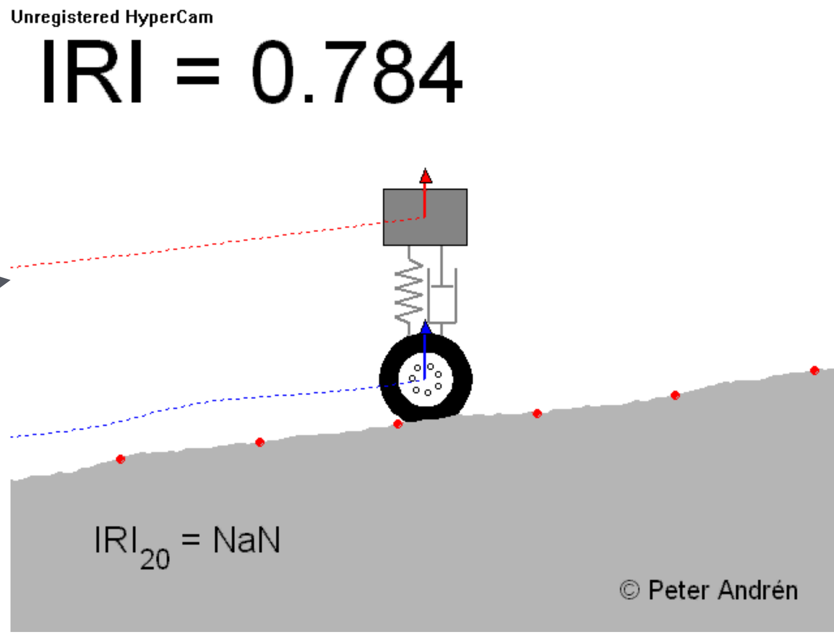
Vibration measurement →

→ Panel rating

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

Comfort

Profile measurement



IRI

Panel rating

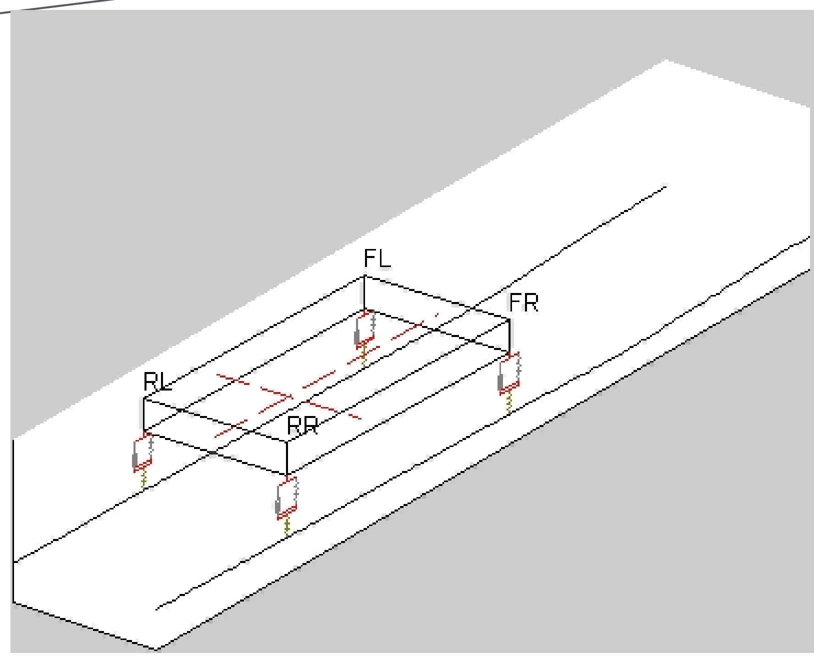
1 Very poor
2 Poor
3 Fair
4 Good
5 Very good

Comfort

Profile measurement → QC-model → IRI → Panel rating

Vibration measurement → Panel rating

Profile measurement →

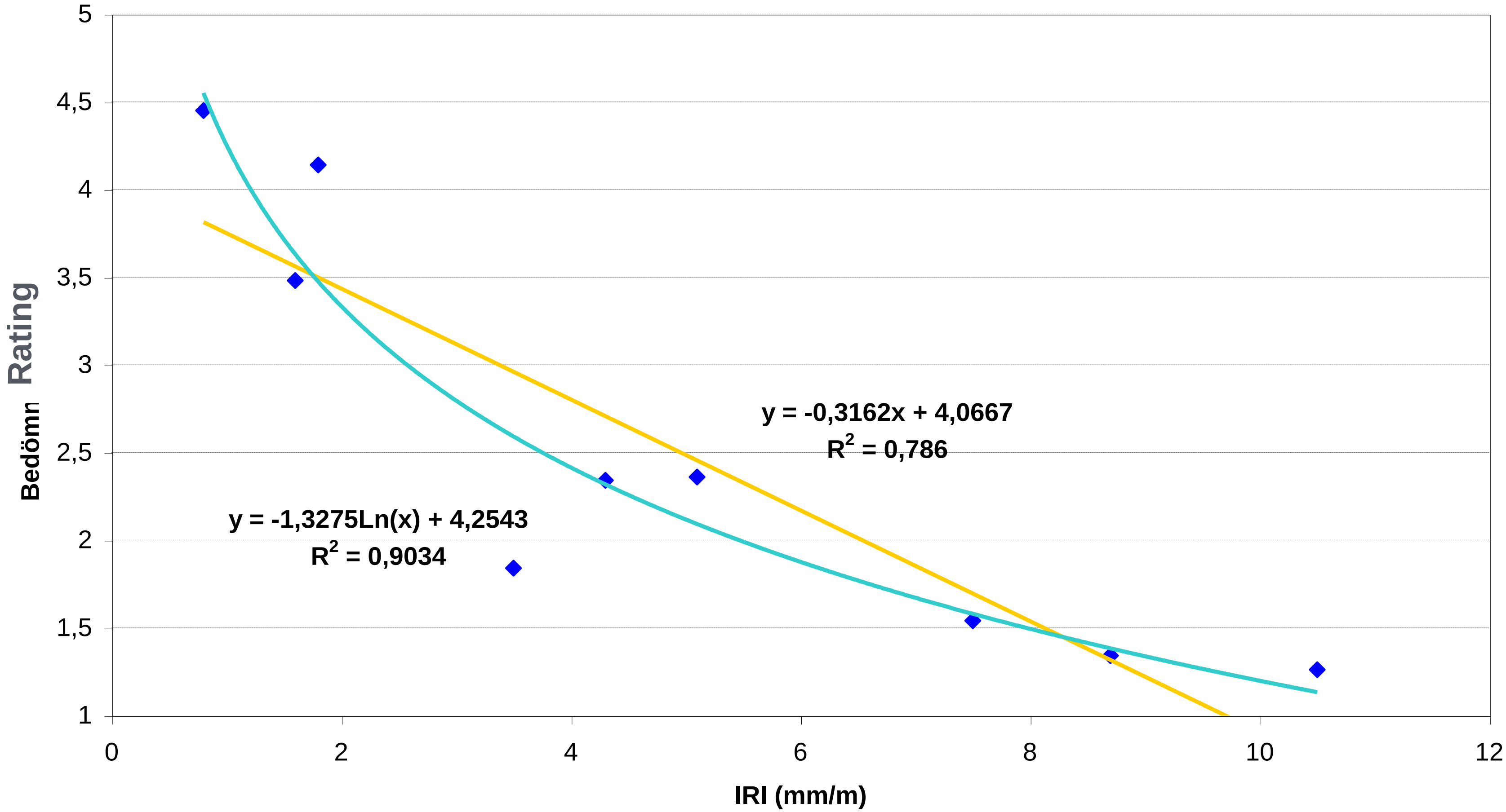


→ Vibration

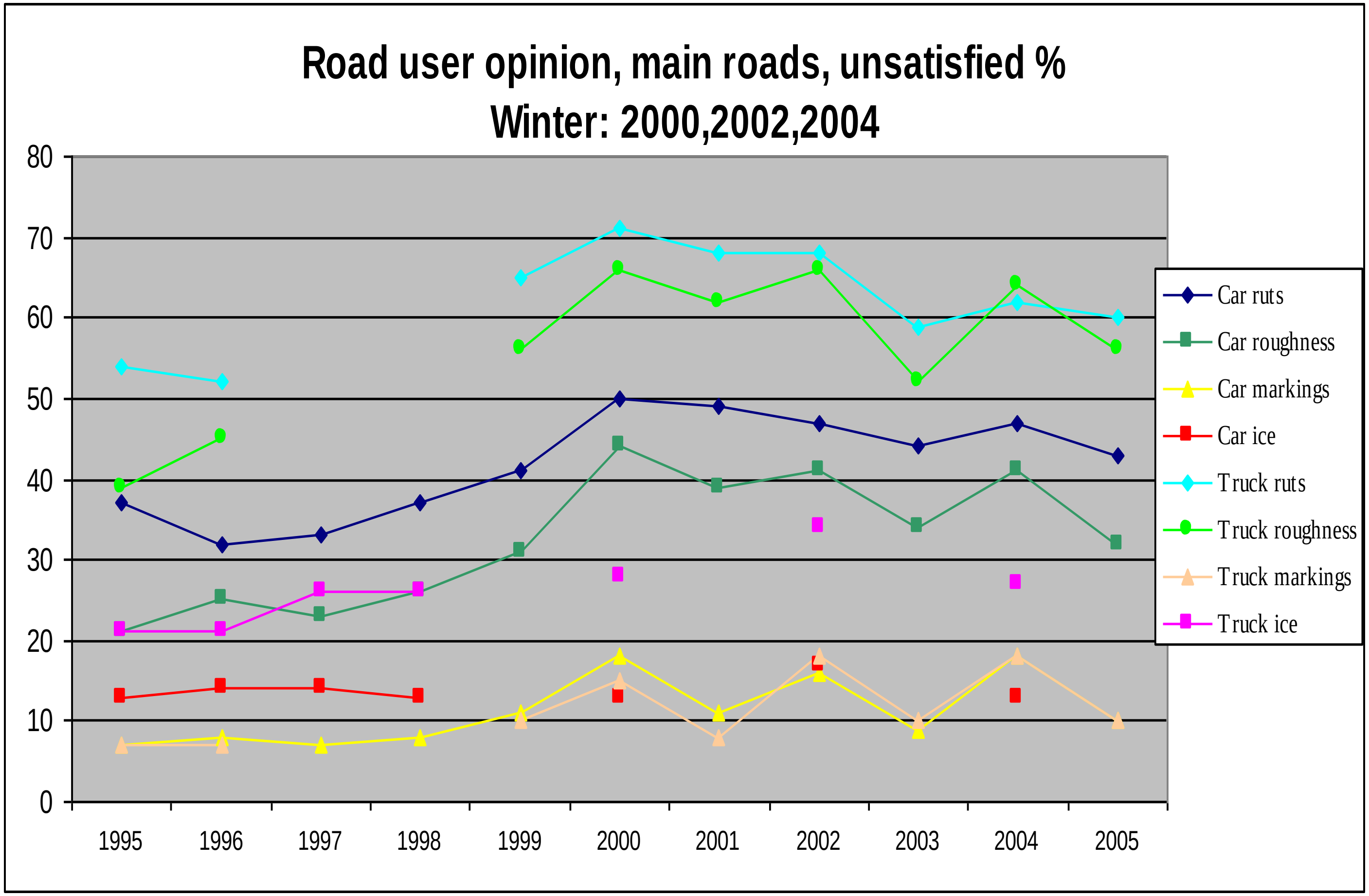
Panel rating ↔ Vibration

Comfort

IRI vs. Panel rating



Summary road user opinion survey



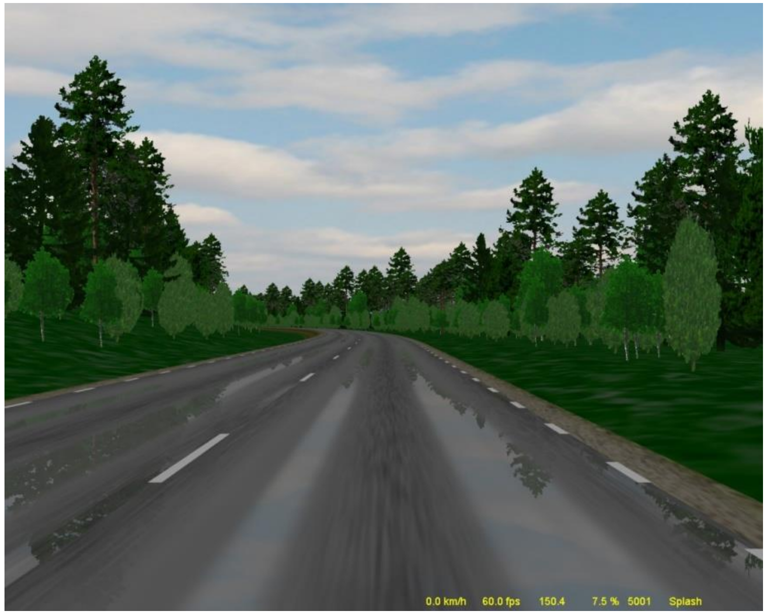
Road user requirements on road condition

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

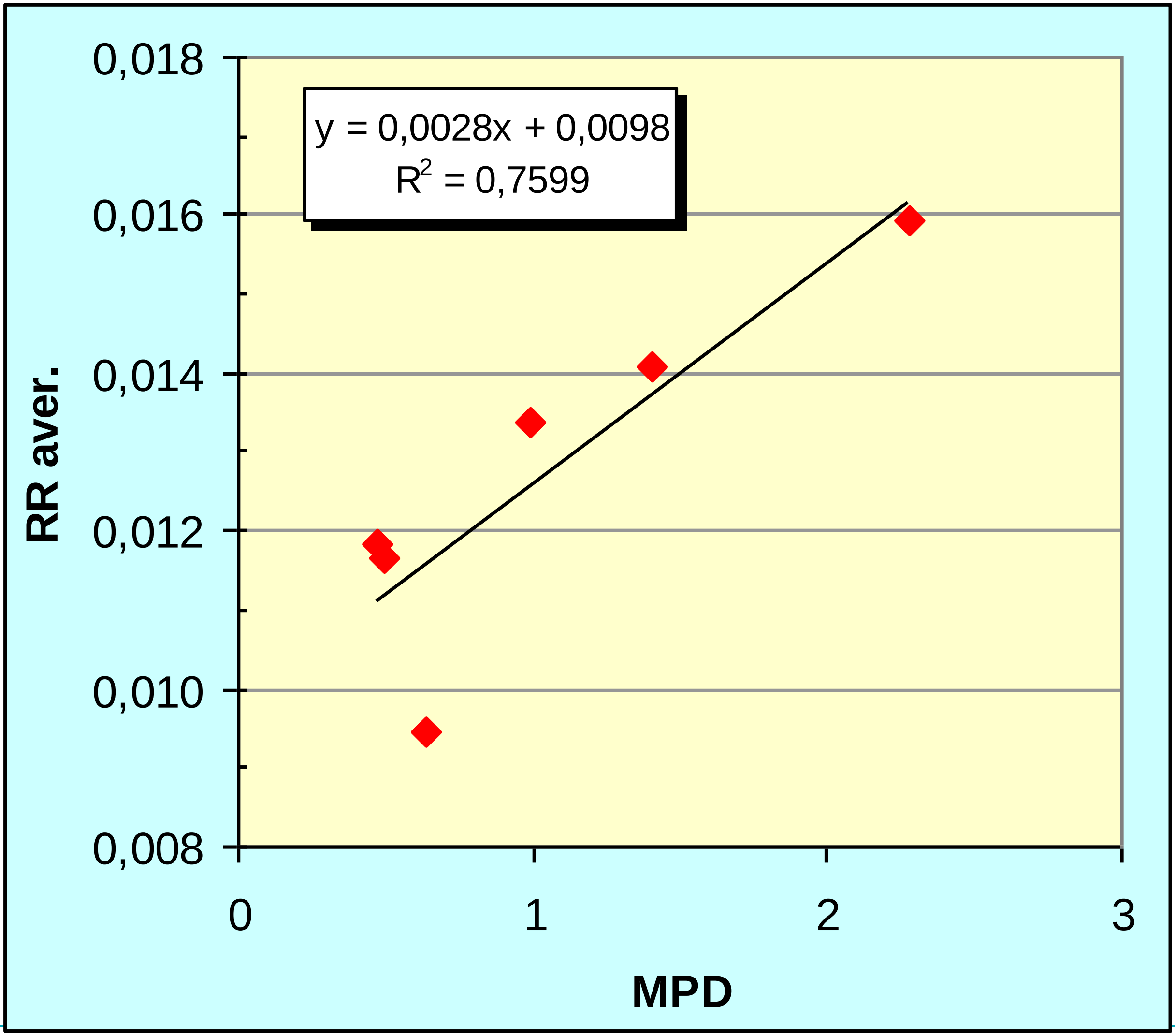
Driving simulator study

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 restistance vs. texture

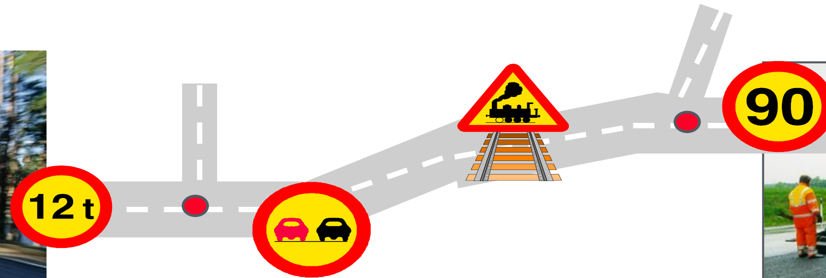


Old road after maintenance

Old road in need of maintenance

PMS - Overview

PMS Components



Road condition

Longitudinal unevenness

Transversal unevenness

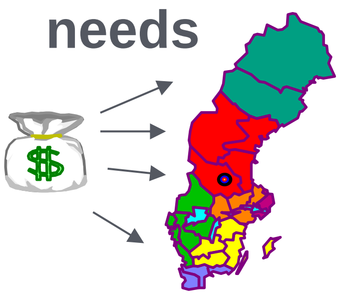
Road Inventory

Pavement information

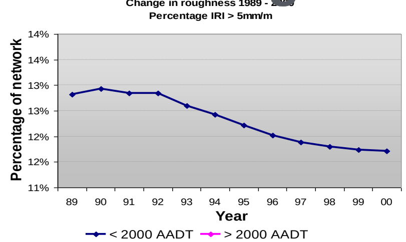
Database

Evaluation models

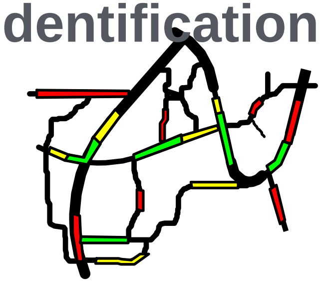
Budget needs



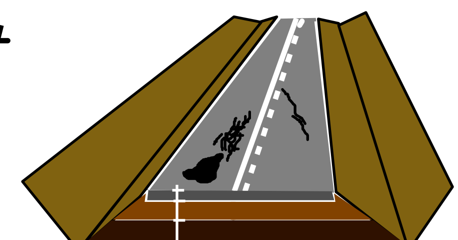
Condition monitoring

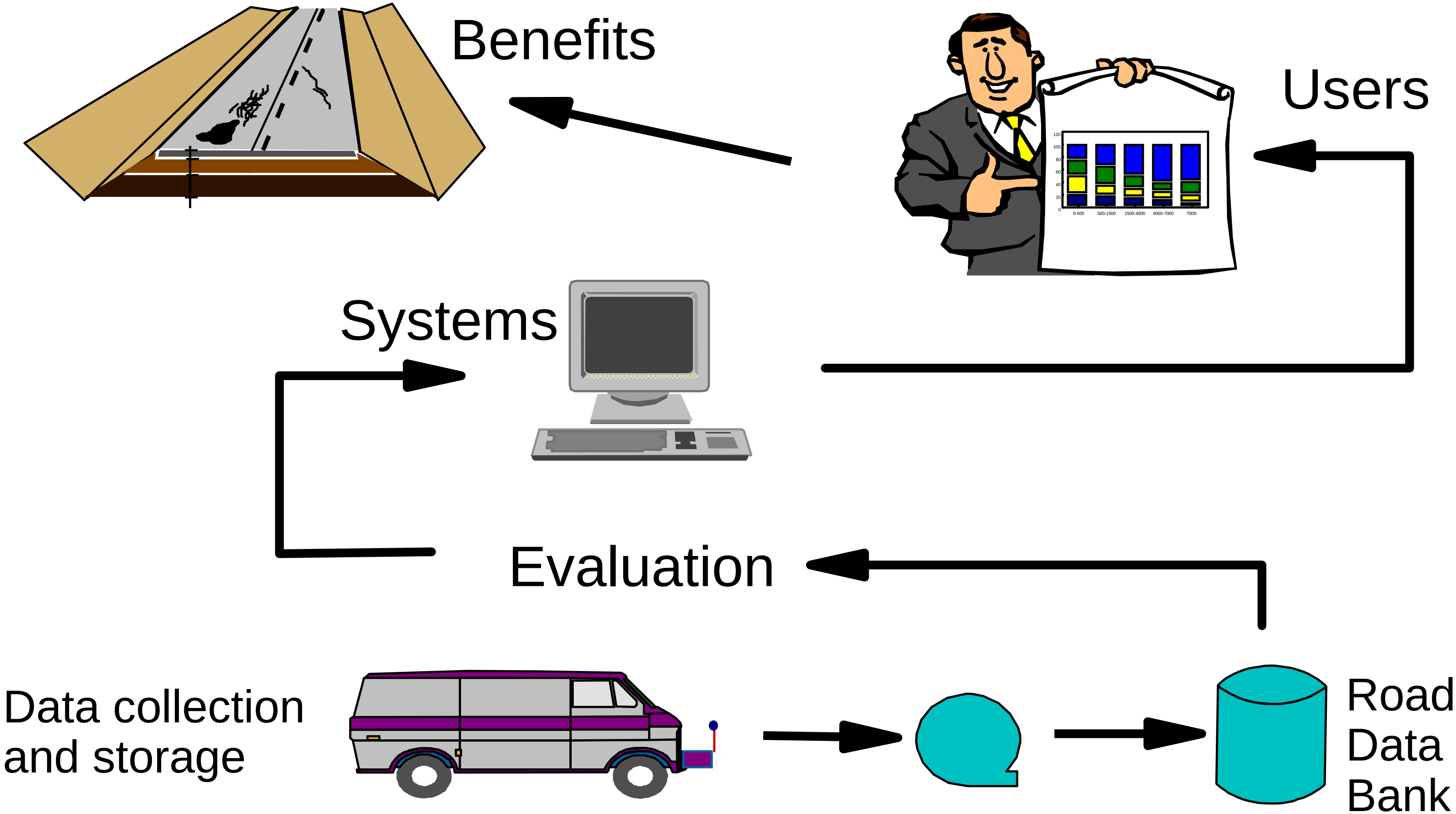


Project identification



Follow-up contracts




Benefits
Users
Systems
Evaluation
Data collection
and storage
Road
Data
Bank

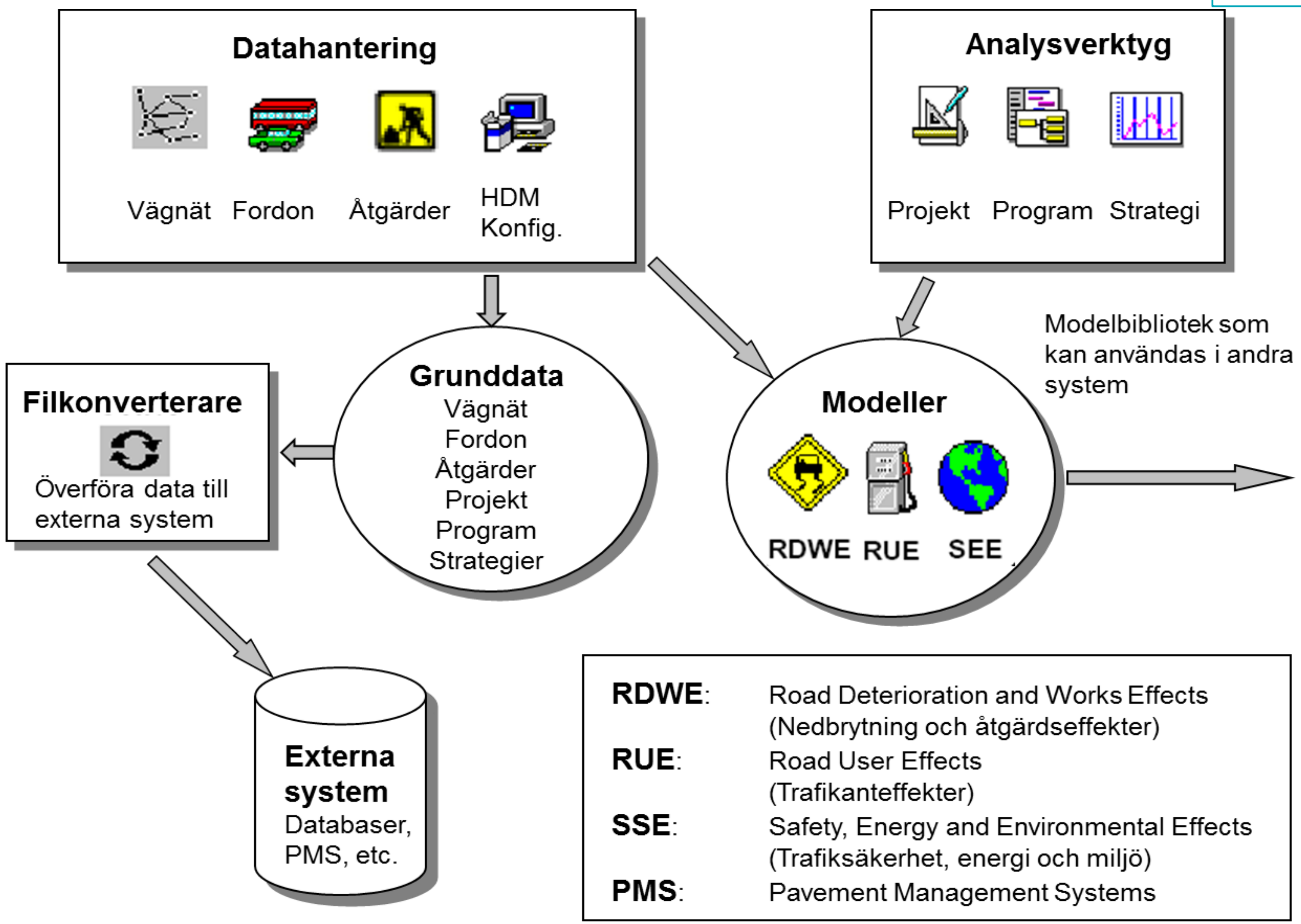
HDM-4 Highway Development and Management

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



Resultat

H D M - 4

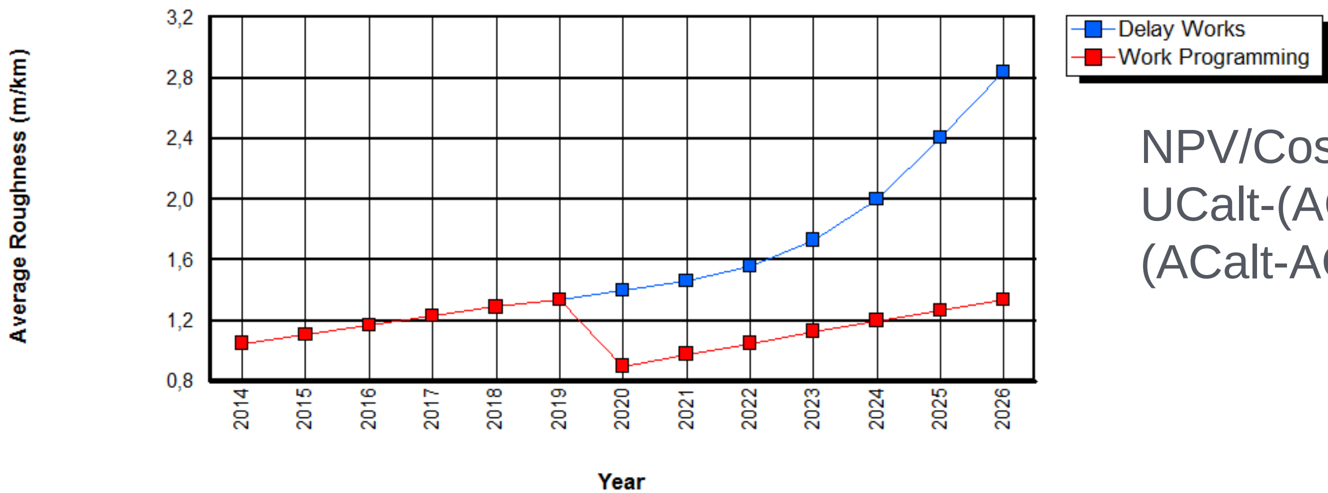
HIGHWAY DEVELOPMENT & MANAGEMENT

Average Roughness by Section (Graph)

Study Name: **MY3 Hdm_2012_300_10**
Run Date: **10-04-2013**

Section: 8210024
Sensitivity: No Sensitivity Analysis Conducted

ID: 8210024 Road Class: Övriga nationella vägar Length: 2,10km
Rise + Fall: 0,77m/km Width: 7,00m Curvature: 2,60deg/km



NPV/Cost= (UCbase-UCalt-(ACalt-ACbase)/(ACalt-ACbase)

HDM-4 Version 2,1

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Resultat

H D M - 4

HIGHWAY DEVELOPMENT & MANAGEMENT

Roughness: Average for Road Network by Budget Scenario (Graph)

Study Name: **MY3 Hdm_2012_300_10**

Run Date: **10-04-2013**

Surface Class: **Bituminous**