dTIMS: The NRA Pavement Management System

NRA National Roads Conference 2013, Galway

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- Alain Hueppi, Managing Director
  - dTIMS around the World
- Alfred Weninger-Vycudil, Technical Director
  - dTIMS and the NRA-PMS Idea
  - dTIMS NRA in Practice

History

1983

1990

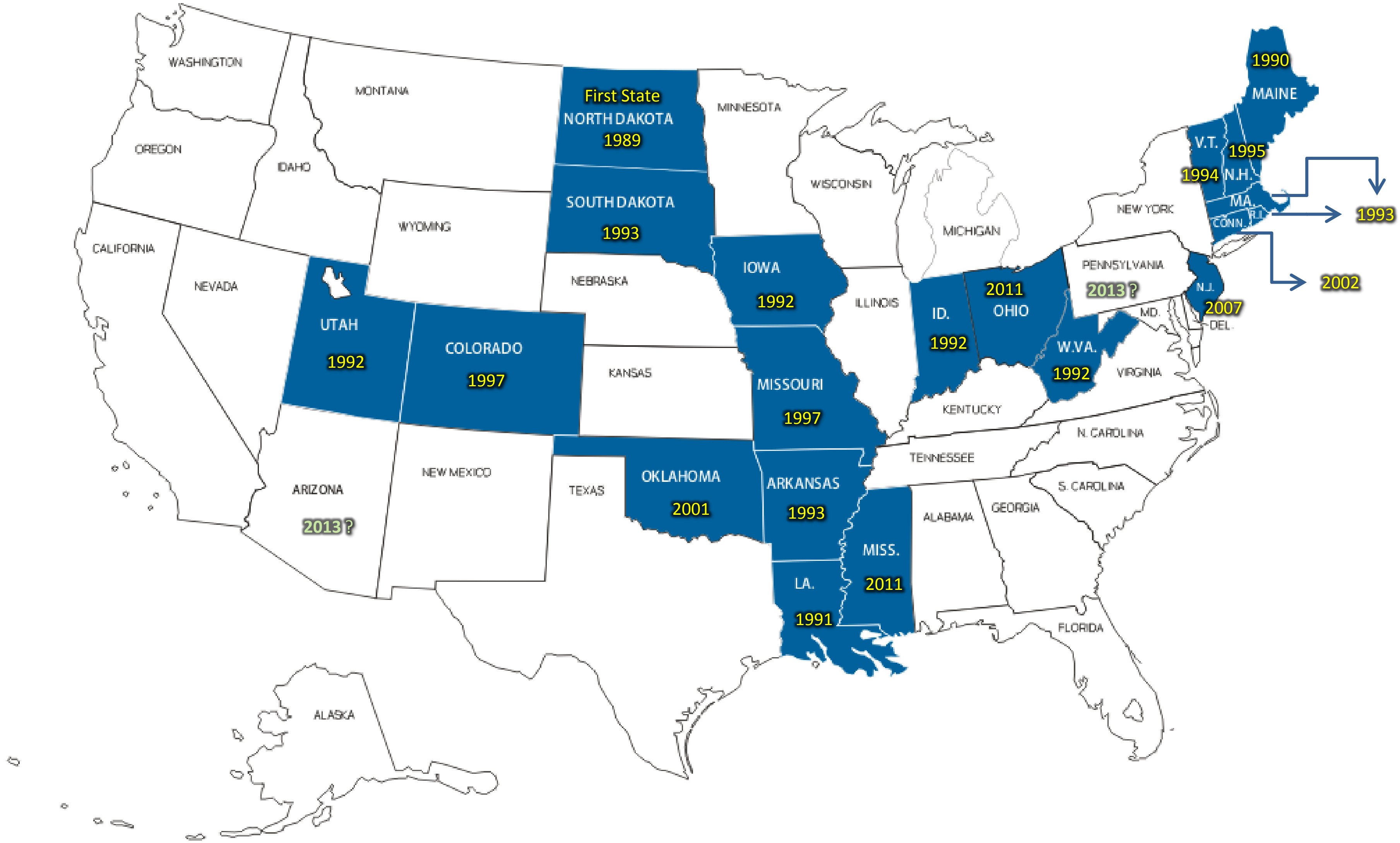
1989

deighton Total Infrastructure Management System

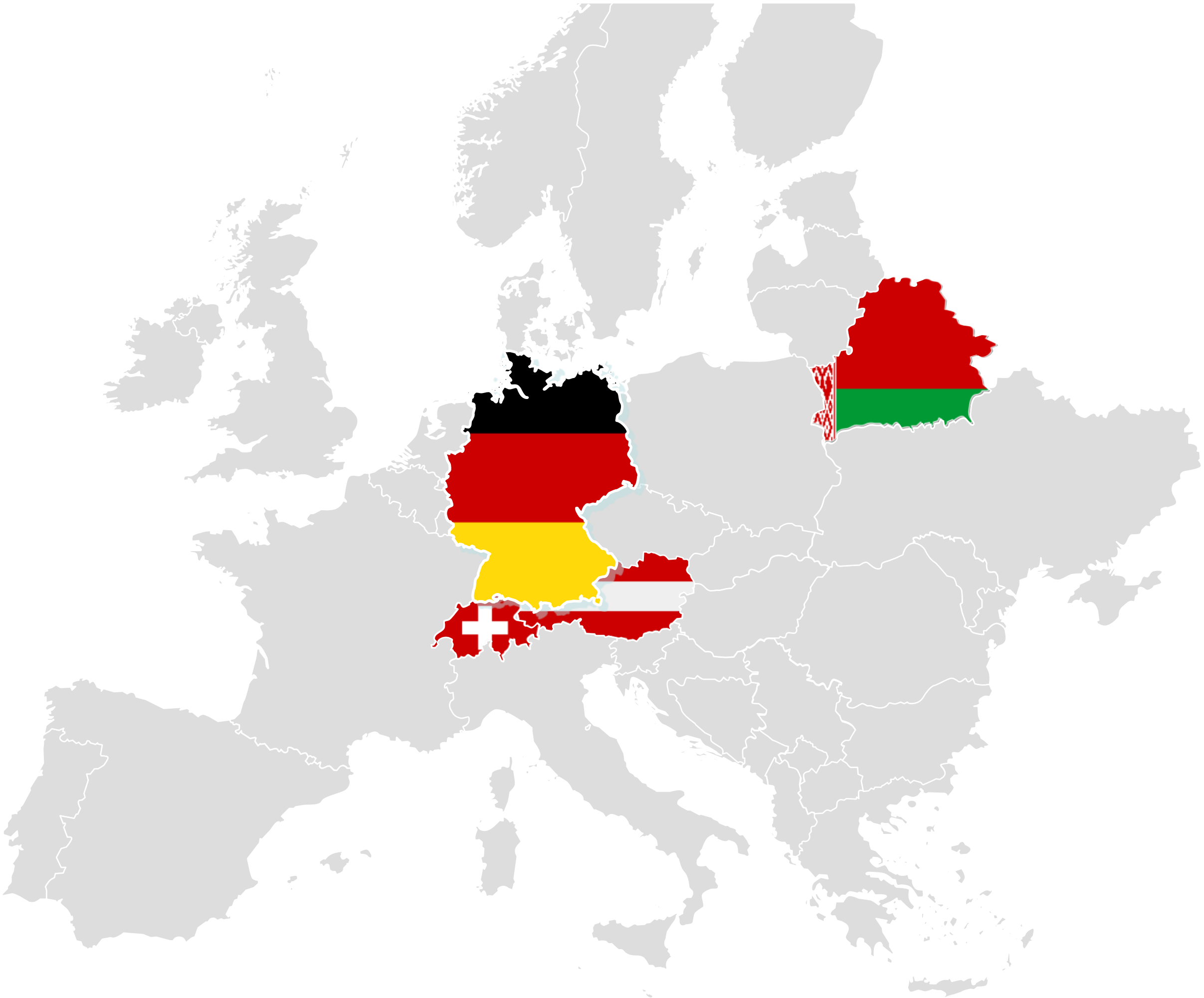
dTIMS around the world

Worldwide Presence

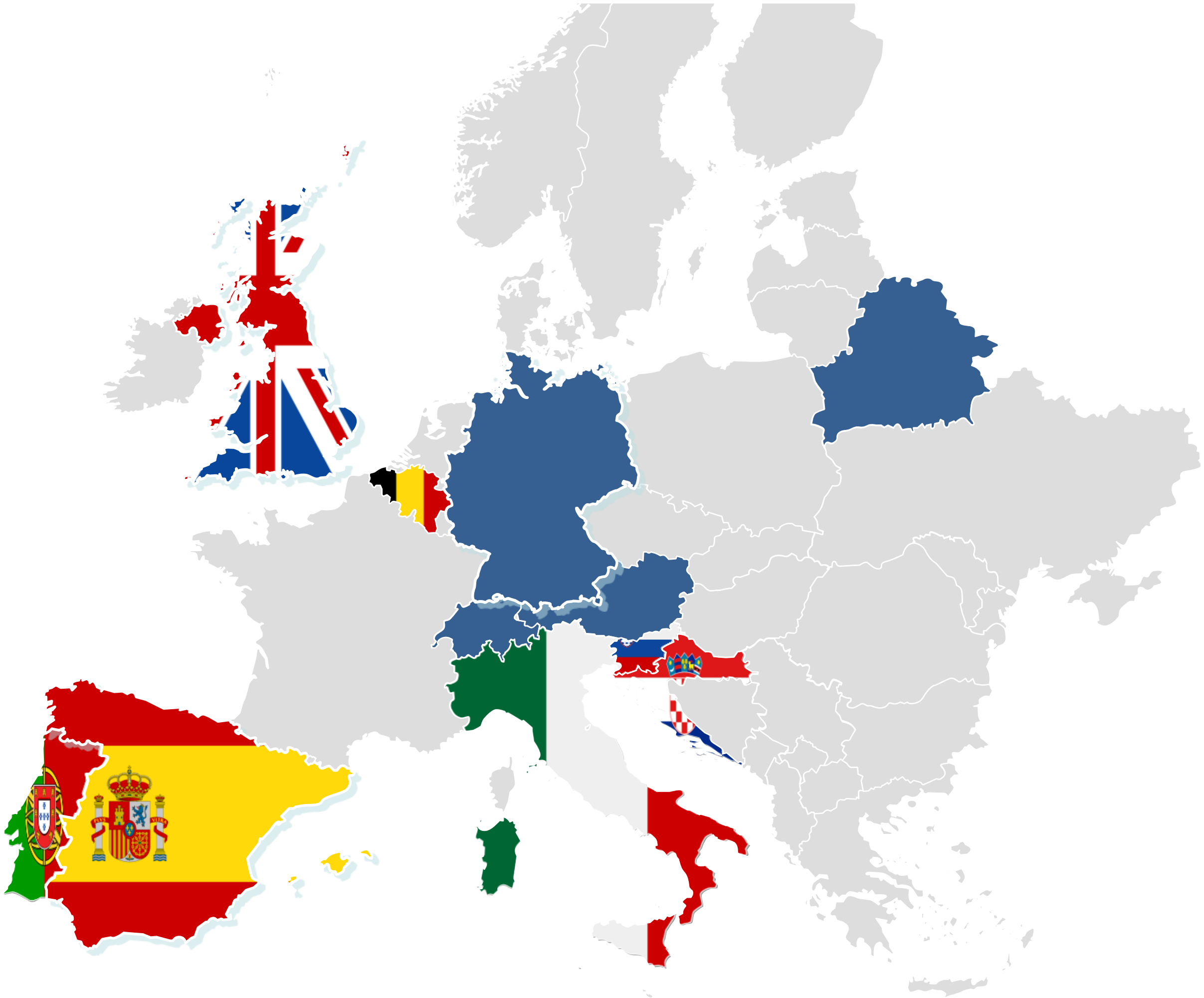
US State DOT's



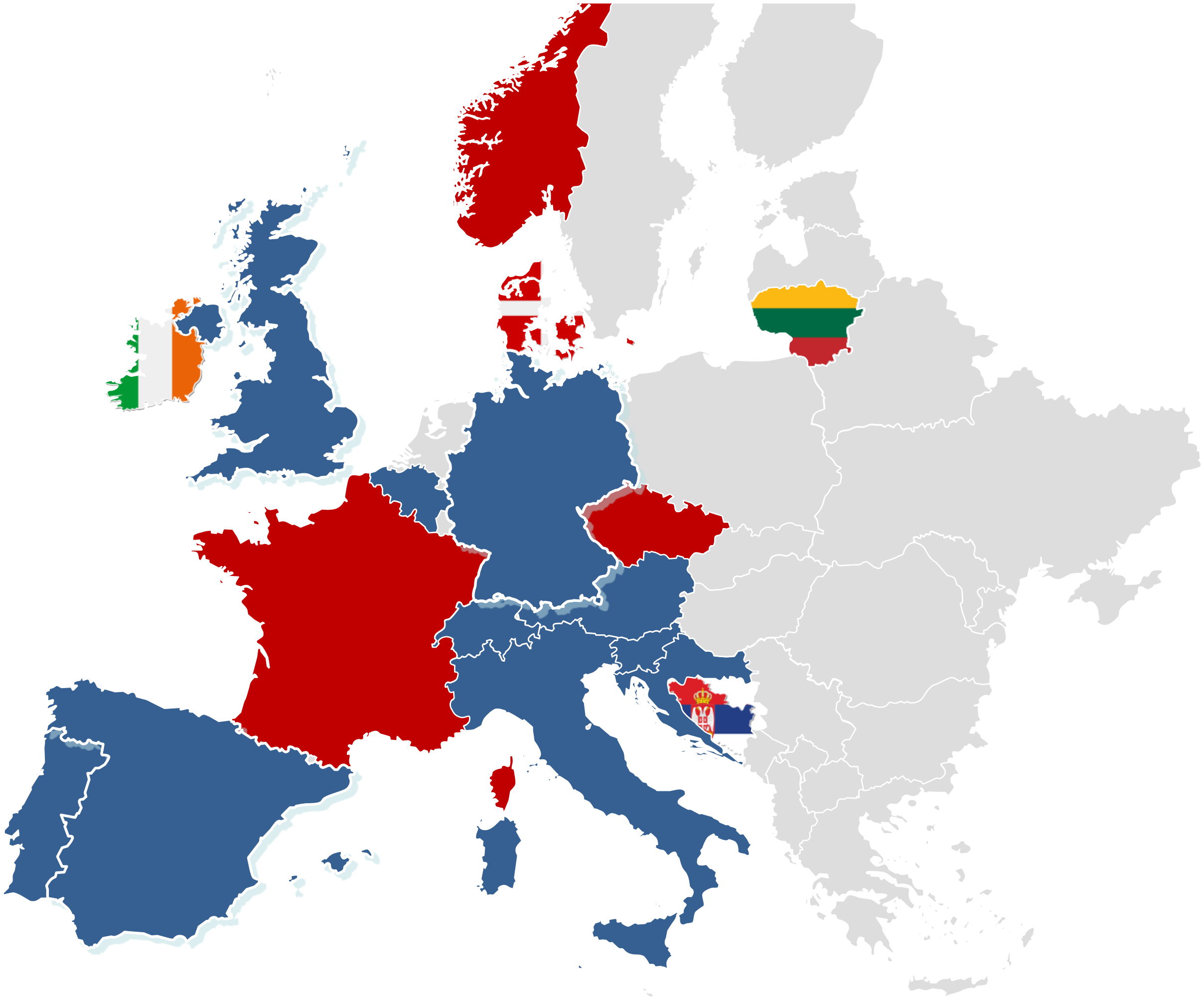
Europe 1990 - 2000



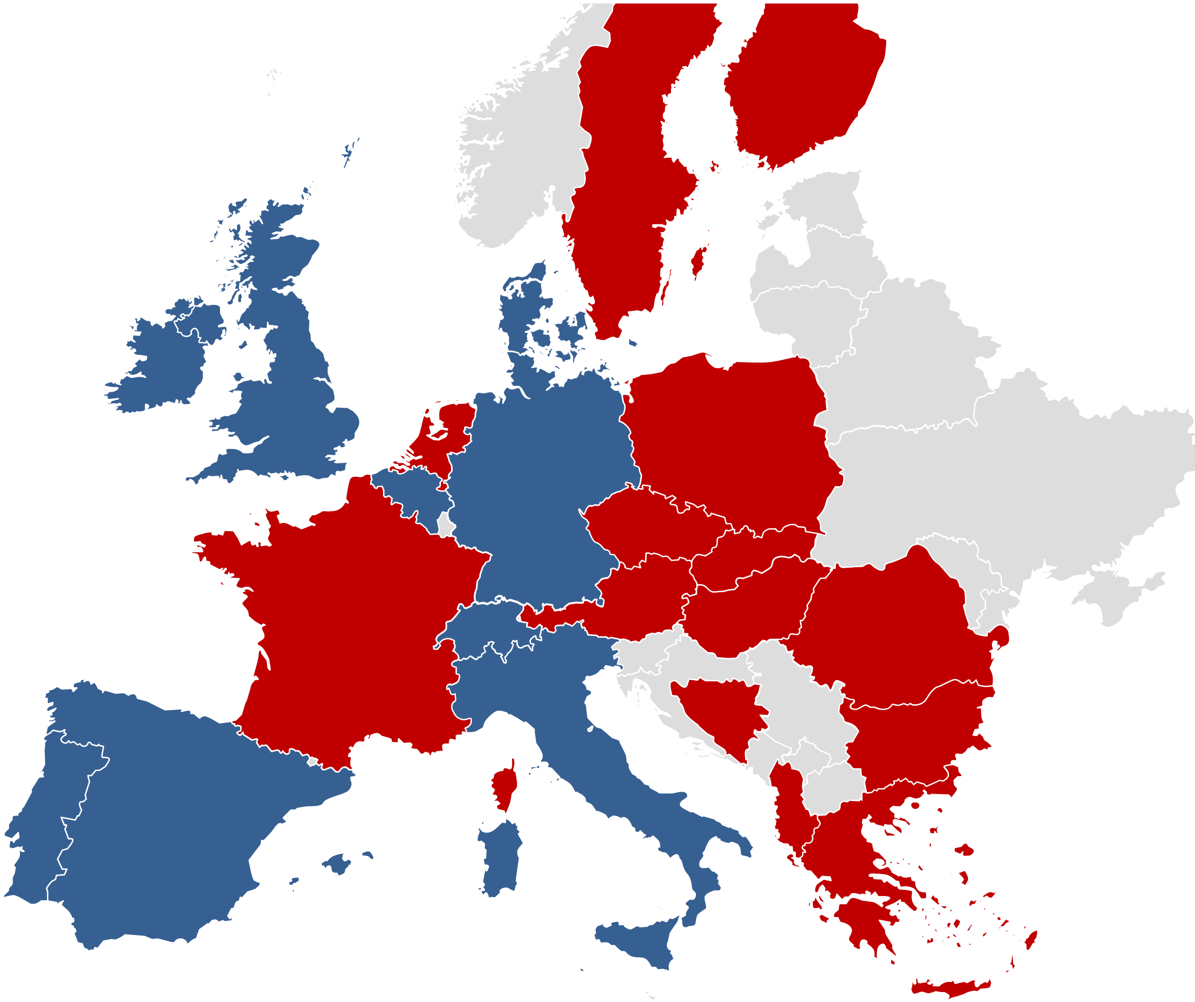
Europe 2000 - 2010



Europe 2011 – 2012 – 2013 .....



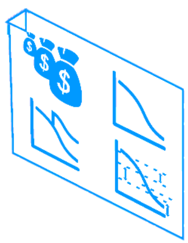
Viagroup Licenses and Projects



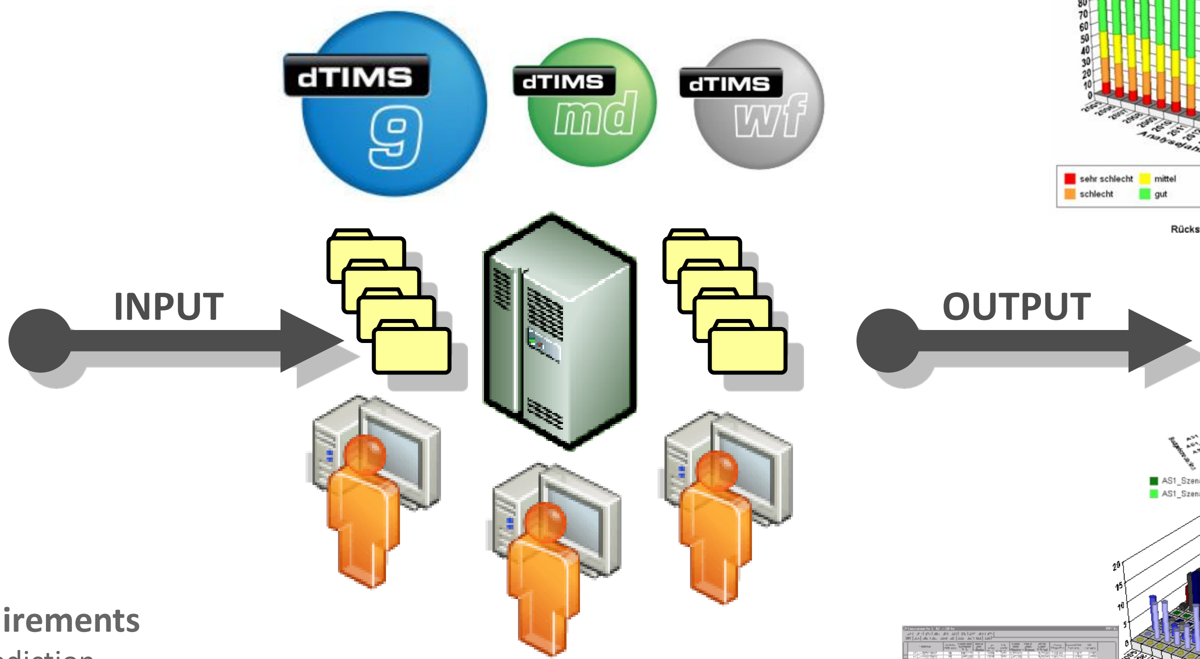
dTIMS and the NRA-PMS Idea

What is the NRA-PMS idea?

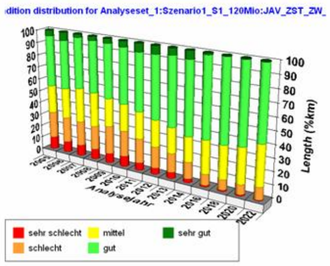
Inventory
- Netdata
- Pavement
- Traffic
- Condition
- Others

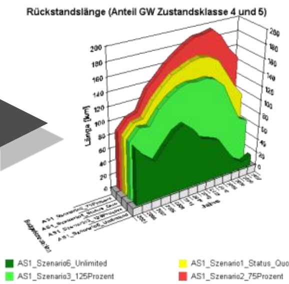


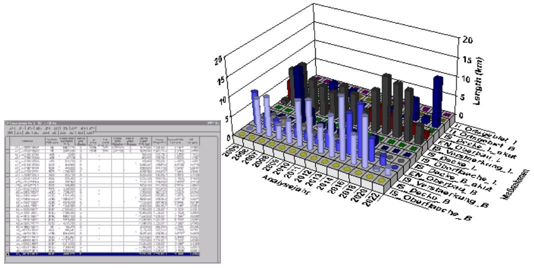
Models and requirements
- Performance prediction
- Treatments
- Requirements (framework conditions)
- Time frame and intervals



Basics for strategic decisions



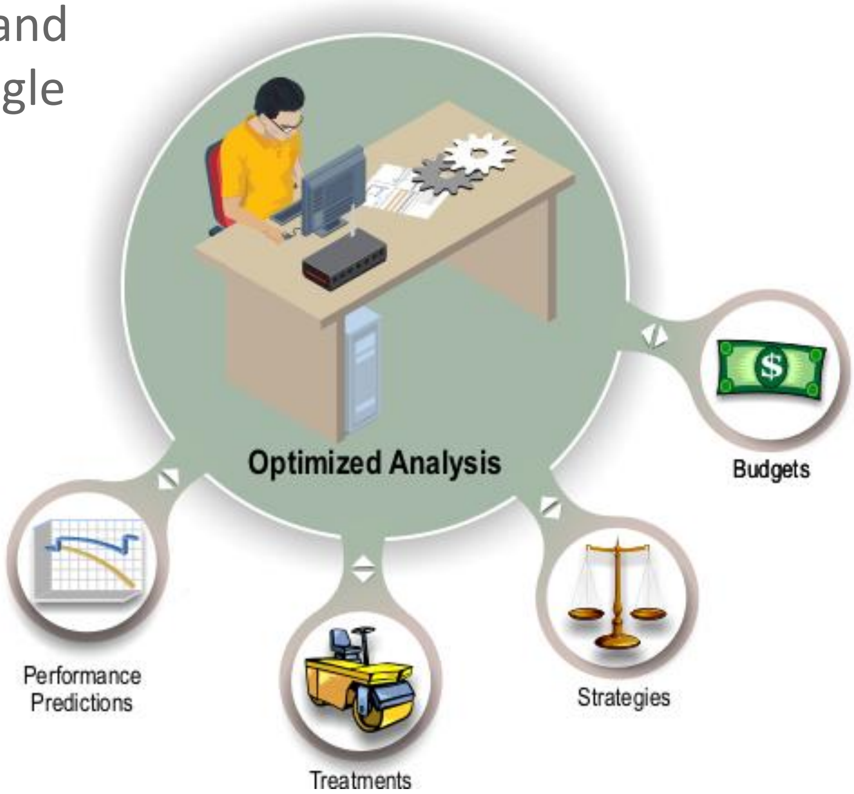




Basics for recommended construction program

What is the NRA-PMS idea?

- **Technical requirements**
  - Ability to forecast future condition and apply LCA/LCCA process on each single road section
  - Define custom deterioration curves
  - Propose maintenance treatment strategies
- **Economic requirements**
  - Define multiple budget scenarios
  - Optimize recommendations
- **Organisational requirements**
  - Supports existing decision process
  - Supports existing asset management



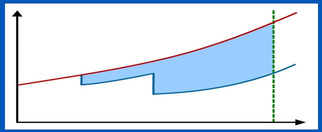
Basic assessment concept

Pavement Condition
Rutting, IRI & LPV3 and CSC
Pavement Construction
Traffic and Others

Single condition classes and Total condition class

Maintenance Treatments
based on technical related triggers and reset values

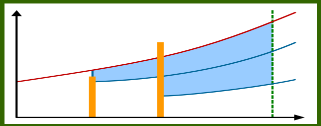
Benefit Technical



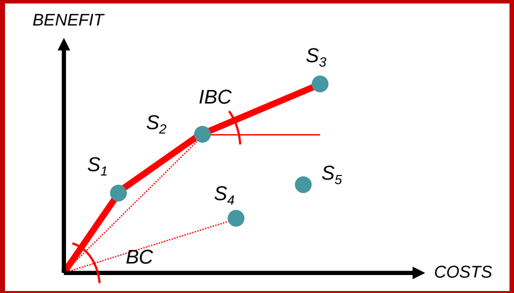
User costs
Condition related user costs
Treatment related user costs

Construction costs
Costs for each single maintenance treatment

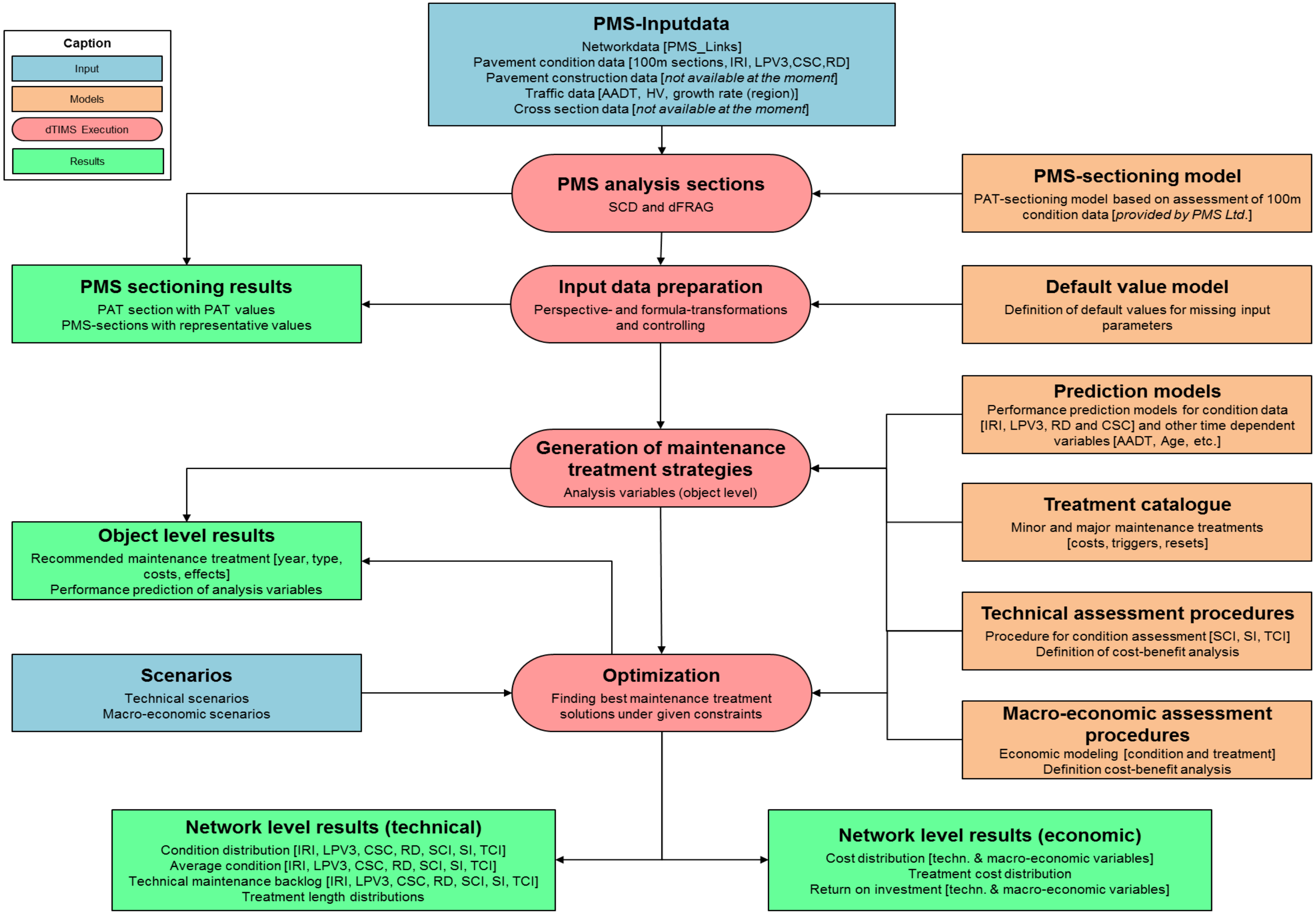
Benefit User costs



Selection optimum solution
By using benefit-cost ratio

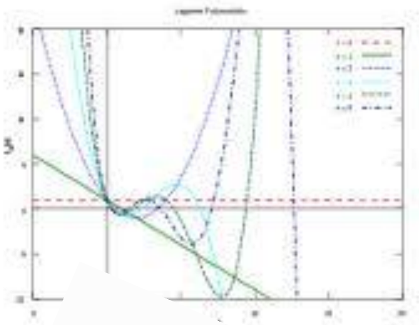


The dTIMS NRA system architecture



How to model this?

$$
\begin{aligned}
0 \;=\; & \tilde{u}_{\xi\xi}\left(\tilde{a}(\xi,\eta)\xi_x^2 + 2\tilde{b}(\xi,\eta)\xi_x\xi_y + \tilde{c}(\xi,\eta)\xi_y^2\right) \\
+\; & 2\tilde{u}_{\xi\eta}\left(\tilde{a}(\xi,\eta)\xi_x\eta_x + \tilde{b}(\xi,\eta)(\xi_x\eta_y + \xi_y\eta_x) + \tilde{c}(\xi,\eta)\xi_y\eta_y\right) \\
+\; & \tilde{u}_{\eta\eta}\left(\tilde{a}(\xi,\eta)\eta_x^2 + 2\tilde{b}(\xi,\eta)\eta_x\eta_y + \tilde{c}(\xi,\eta)\eta_y^2\right) \\
+\; & \tilde{u}_{\xi}\left(\tilde{a}(\xi,\eta)\xi_{xx} + 2\tilde{b}(\xi,\eta)\xi_{xy} + \tilde{c}(\xi,\eta)\xi_{yy} + \tilde{d}(\xi,\eta)\xi_x + \right. \\
+\; & \tilde{u}_{\eta}\left(\tilde{a}(\xi,\eta)\eta_{xx} + 2\tilde{b}(\xi,\eta)\eta_{xy} + \tilde{c}(\xi,\eta)\eta_{yy} + \tilde{d}(\xi,\eta)\eta_x + \right. \\
+\; & \tilde{u}\cdot\tilde{f}(\xi,\eta) \\
+\; & \tilde{g}(\xi,\eta)\;,
\end{aligned}
$$



$$d^3q = q^2 dq \sin\vartheta\, d\vartheta\, d\phi$$

$$\vec{q}\vec{s} = qs\cos\vartheta$$

$$G(\vec{s},\tau) = \frac{c}{(2\pi)^3}\int_0^\infty dq\, q\left(\frac{e^{-icq\tau} - e^{icq\tau}}{-2i}\right)\int_{-1}^{1} d\cos\vartheta\, e^{iqs\cos\vartheta}\int_0^{2\pi} d\phi$$

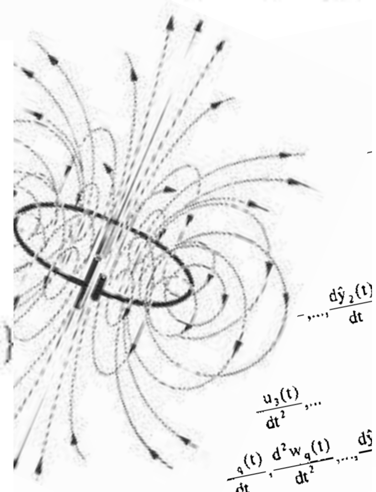
$$\int_{-1}^{1} d\cos\vartheta\, e^{iqs\cos\vartheta} = \frac{e^{iqs} - e^{-iqs}}{iqs}$$

$$\xi := cq$$

$$\Rightarrow G(\vec{s},\tau) = \frac{c}{2(2\pi)^2 s}\int_0^\infty d\xi\left\{e^{i(\tau-\frac{s}{c})\xi} + e^{-i(\tau-\frac{s}{c})\xi} - e^{i(\tau+\frac{s}{c})\xi} - e^{-i(\tau+\frac{s}{c})\xi}\right\}$$

$$\Rightarrow G(\vec{s},\tau) = \frac{c}{4\pi s}\int_0^\infty d\xi\left\{\delta\left(\tau-\frac{s}{c}\right) - \delta\left(\tau+\frac{s}{c}\right)\right\}$$

$$\delta\left(\tau+\frac{s}{c}\right) = 0 \quad \text{für } \tau > 0$$

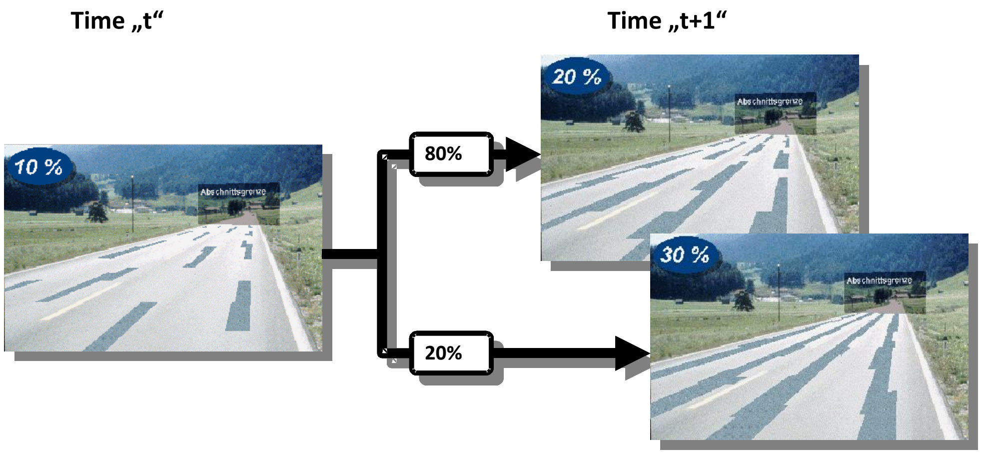


Performance prediction is core element of any modern PMS using LCA/LCCA!

(Empirical) Performance prediction model

Probabilistic models

Description of pavement condition in the future by using a probability distribution

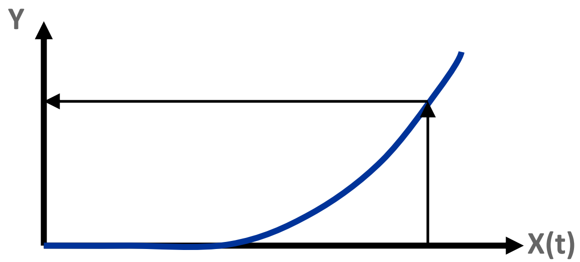


Deterministic models

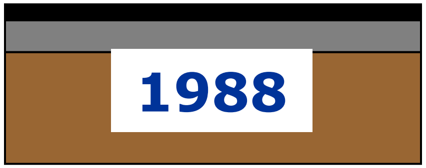
Description of pavement condition in the future by using a mathematical correlation between condition and parameters

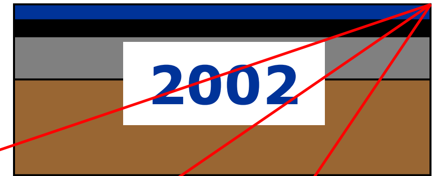
Mathematical model:

$$Y(t) = f(X_1(t), X_2, \dots, X_i)$$



Performance prediction (2)





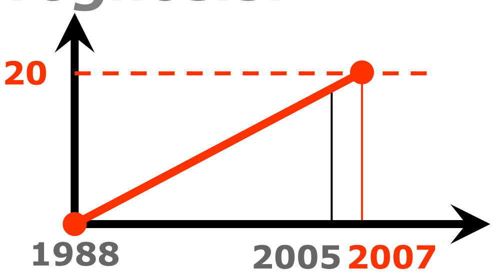
Rutting:

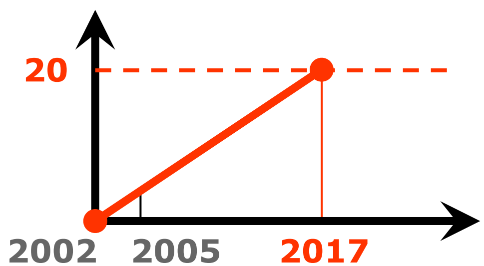
1988	2002	1995
18 mm	4 mm	8 mm

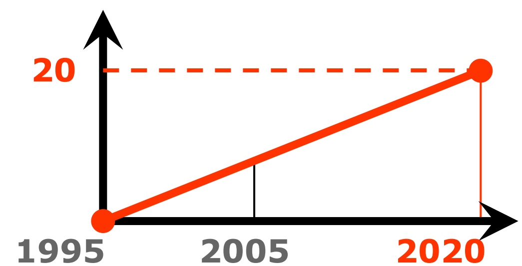
Ranking:

1988	2002	1995
I	III	II

Prognosis:





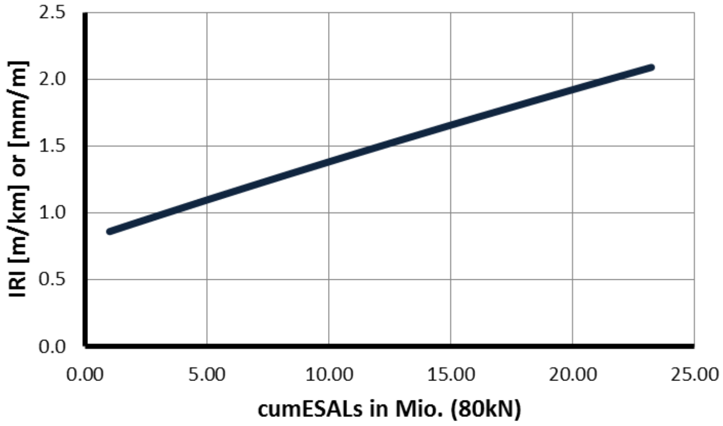


Final ranking:

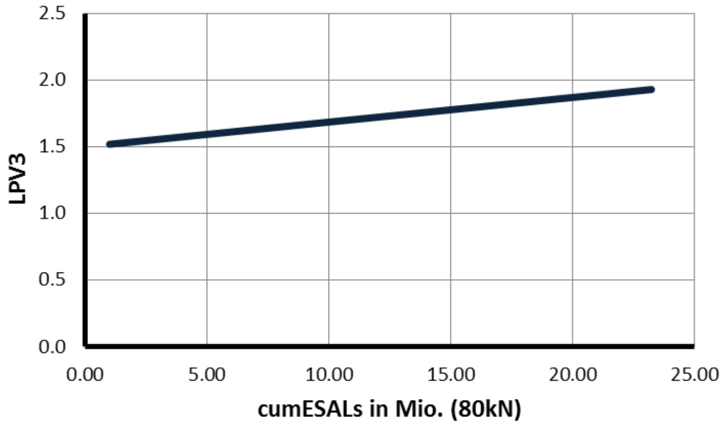
1988	2002	1995
I	II	III

Performance prediction (3)

- **Longitudinal evenness**
  - Expressed by IRI (International Roughness Index) and LPV3 (3m variance)
  - Source IRI-model: Austrian IRI-model and adjusted to NRA requirements
  - Source LPV3-model: Belgium 2.5m-wavelength model, transformed and adjusted to NRA requirements
  - Both models are relative empirical performance functions
  - Main parameter is traffic (expressed by ESALs), model parameters according to level of sub-network



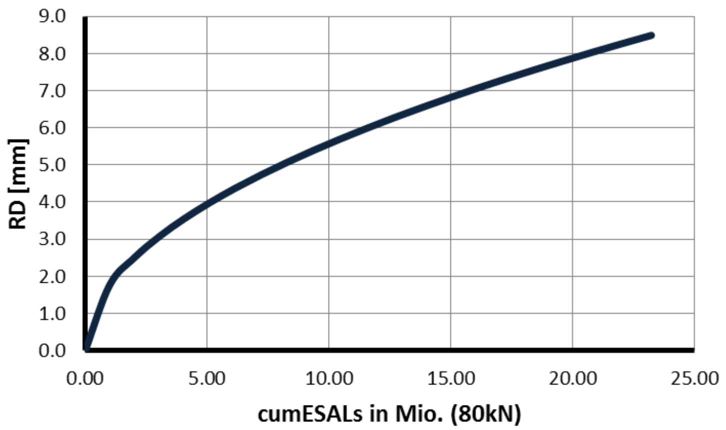
$$IRI_t = IRI_{t-1} + (a + b \cdot ESAL_t \cdot 0.41 \cdot 10)$$



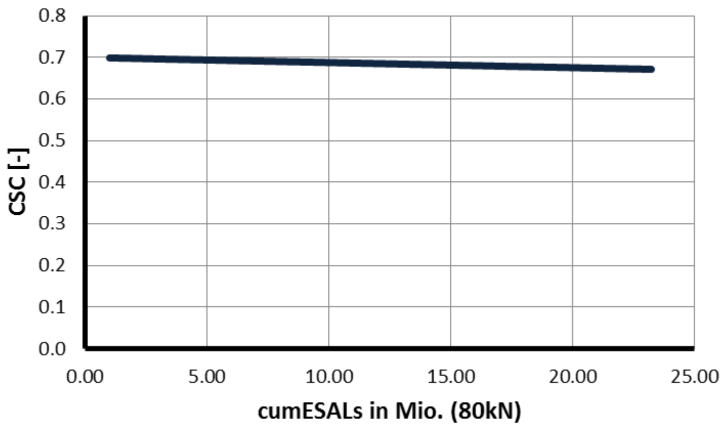
$$LPV3_t = LPV3_{t-1} + a \cdot ESAL_t \cdot 0.41$$

Performance prediction (3)

- **Transverse evenness**
  - Expressed by rut depth
  - Source: Belgium rutting model and adjusted to NRA requirements
  - Absolute model based on traffic (cumulative ESALs) and model parameter calculated from the measured rut depth
- **Skid resistance**
  - Friction coefficient
  - Source: Belgium skid resistance model
  - Relative model based on traffic (ESALs), model parameters according to level of sub-network



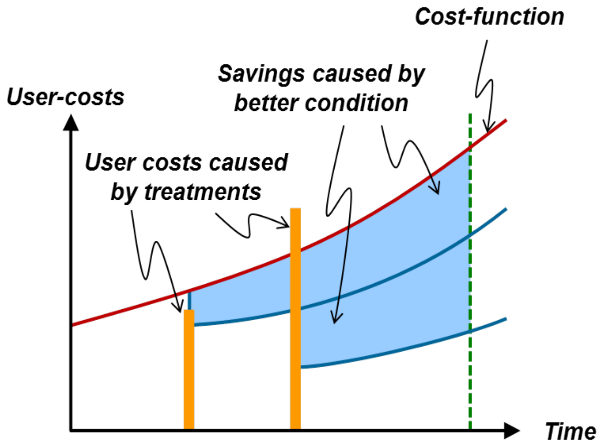
$$RD_t = A \cdot (0.41 \cdot cumESAL_t)^b$$



$$CSC_t = CSC_{t-1} + a \cdot ESAL_t \cdot 0.41$$

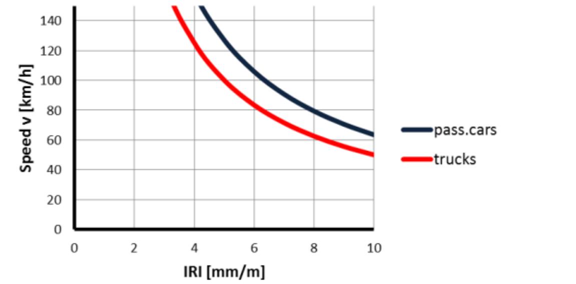
Implementation of User-Cost model (1)

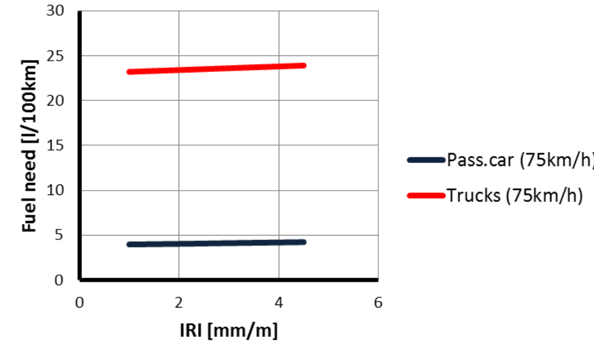
- Implementation of a simplified user costs model based on available NRA information and data.
- Indicators to describe user costs and other macro-economic effects:

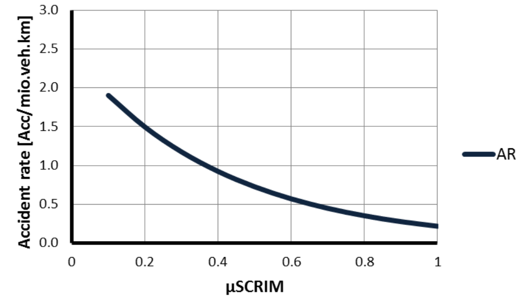


- **User costs due to pavement condition**
  - Time costs
  - Vehicle operating costs
  - Accident costs
  - CO_2 equivalents (environmental effects)
- **Treatment related user costs and other effects**
  - Time loss due to construction site
  - Additional accidents due to construction site
  - CO_2 equivalents (environmental effects)

- User-Cost module is a general approach based on simplified (understandable) models
- Time costs
  - Reduction of speed due to poor condition or maintenance treatments [HDM4]
- Vehicle operating costs (VOC)
  - Increase of fuel consumption [HDM4]
- Accident costs
  - Accident rate as a function of rutting and skid resistance [German model]
- CO_2 equivalents
  - CO_2 emissions due to fuel need [HDM4]
  - Calculation together with (VOC)

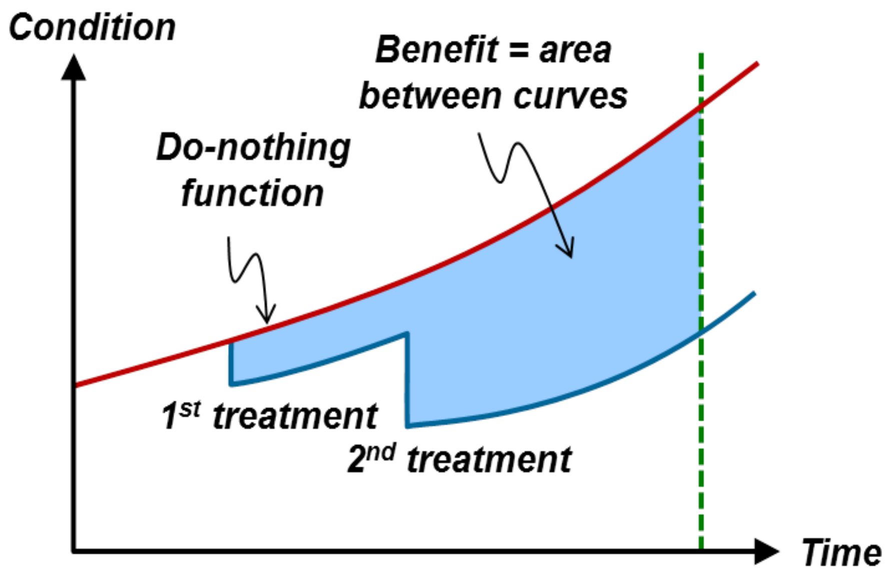






Cost-benefit analysis (1)

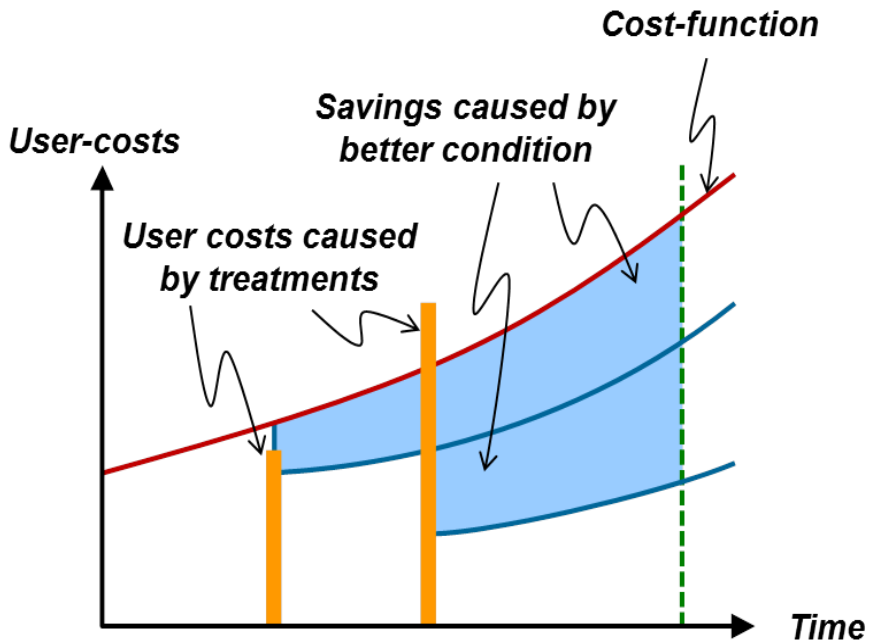
- Calculation of technical benefit (implemented)



- Effects of treatments (treatment strategies) can be quantified for each single condition parameter
- Total condition class represents all effects and is the basis for the technical benefit
- Area between the curves has to be weighted according to traffic load (effect of a maintenance treatment on a high volume road should be quantified higher in comparison to a low-level road)

Cost-benefit analysis (2)

- Calculation of macro-economic benefit (draft version)



\+ Savings in time costs due to better pavement condition

\+ Savings in vehicle operating costs due to better pavement condition

\+ Savings in accident costs due to better pavement condition

\+ Savings in CO_2 cost-equivalents due to better pavement condition

\- Costs due to time loss within construction site

\- Costs due to increased accident rate within construction site

\- Costs due to increased CO_2-emission within construction site

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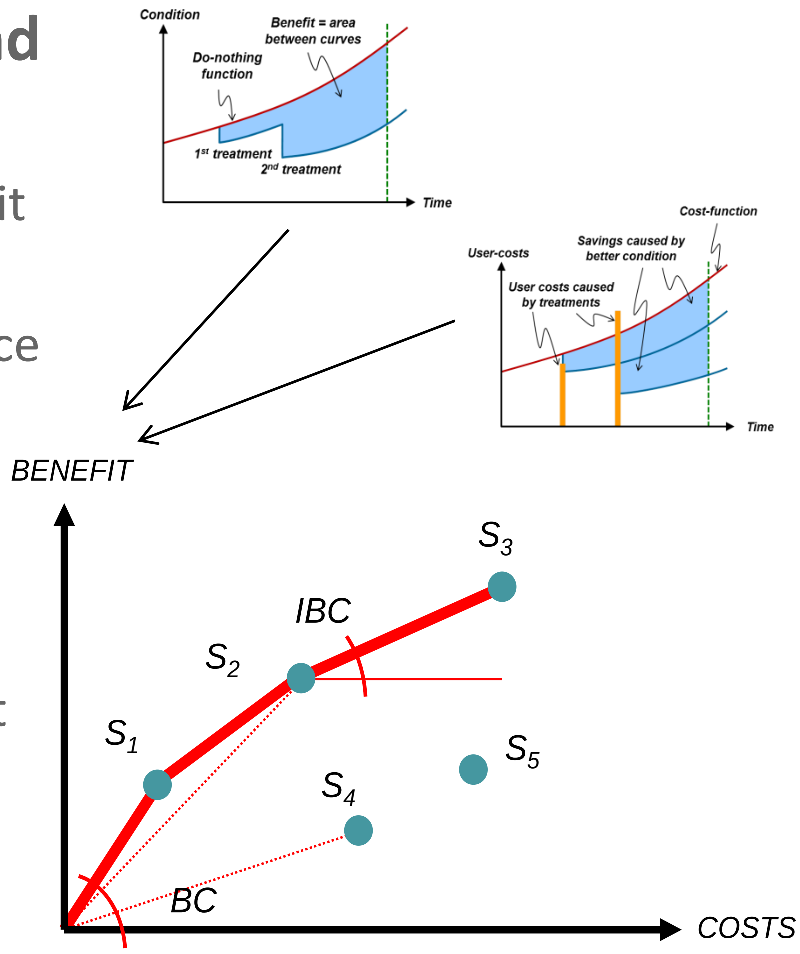
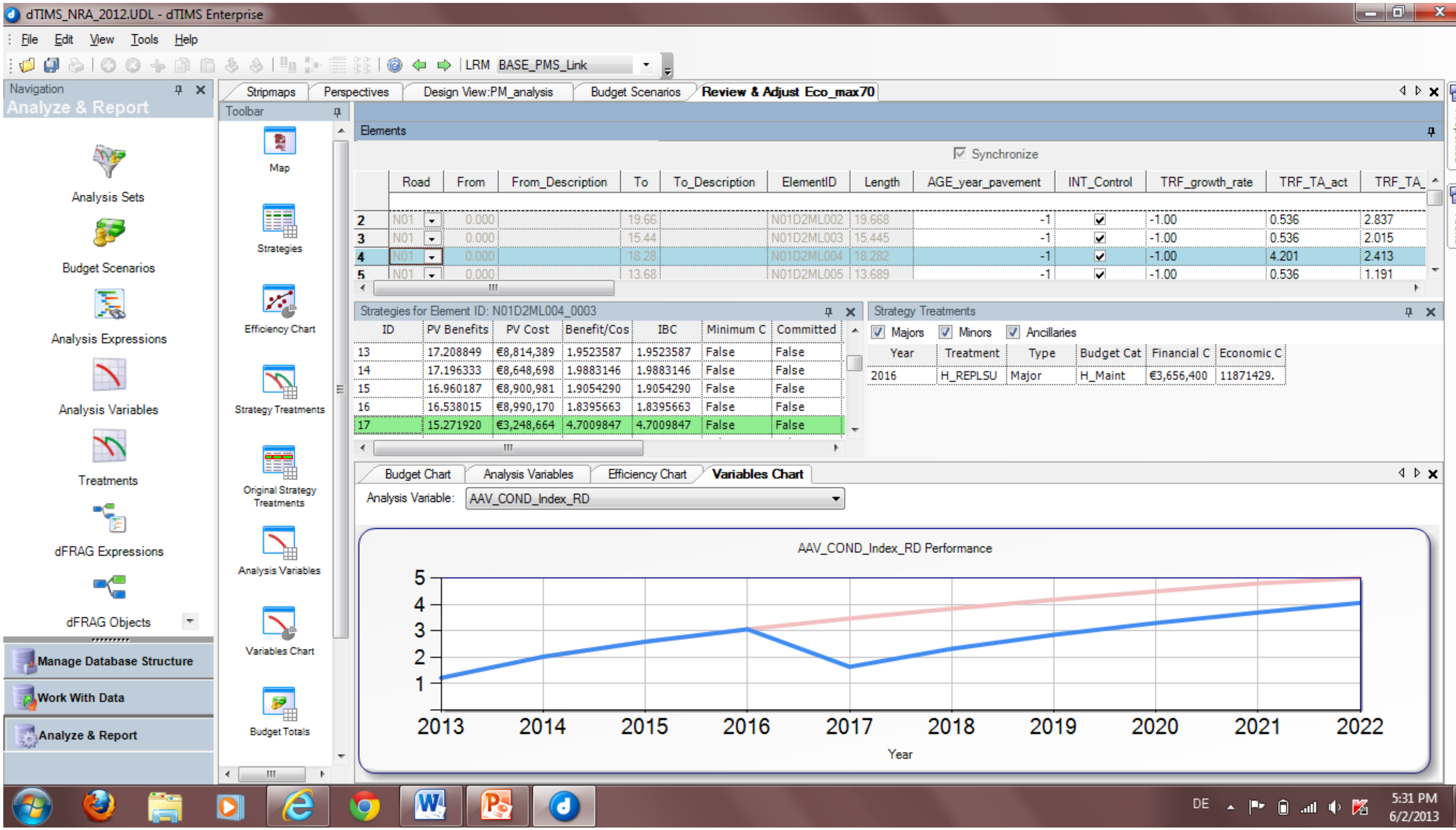
Sum of all costs = benefit

- **Comparison of treatment costs and benefit**
  - Calculation of (incremental) cost-benefit ratio (IBC-technique)
  - Selection of most adequate maintenance treatment strategies over the whole network within the optimisation (budget scenarios)
- **Output of analysis**
  - Recommended maintenance treatment strategy for each single road section
  - Network level results as a sum of the section level results

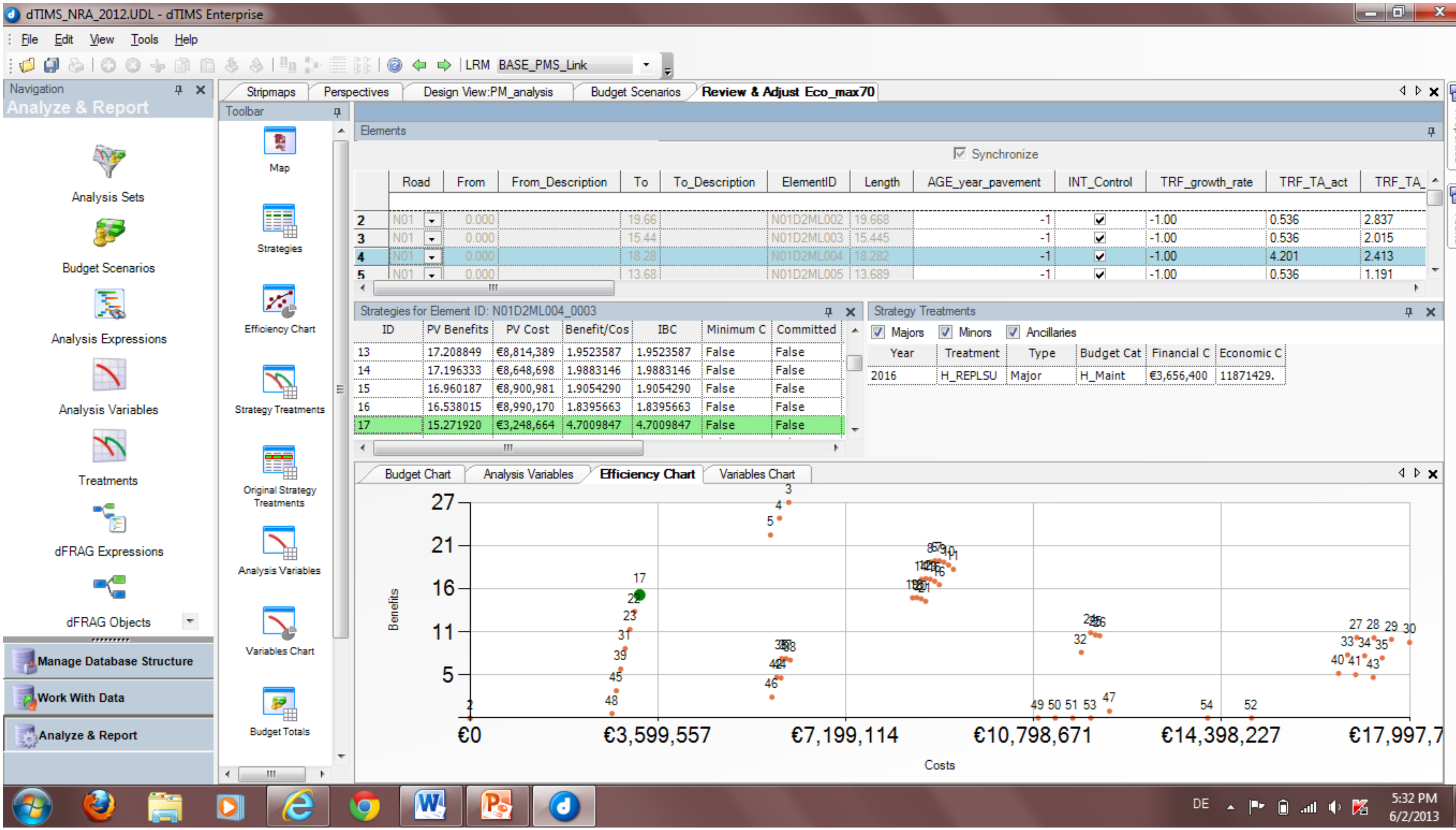


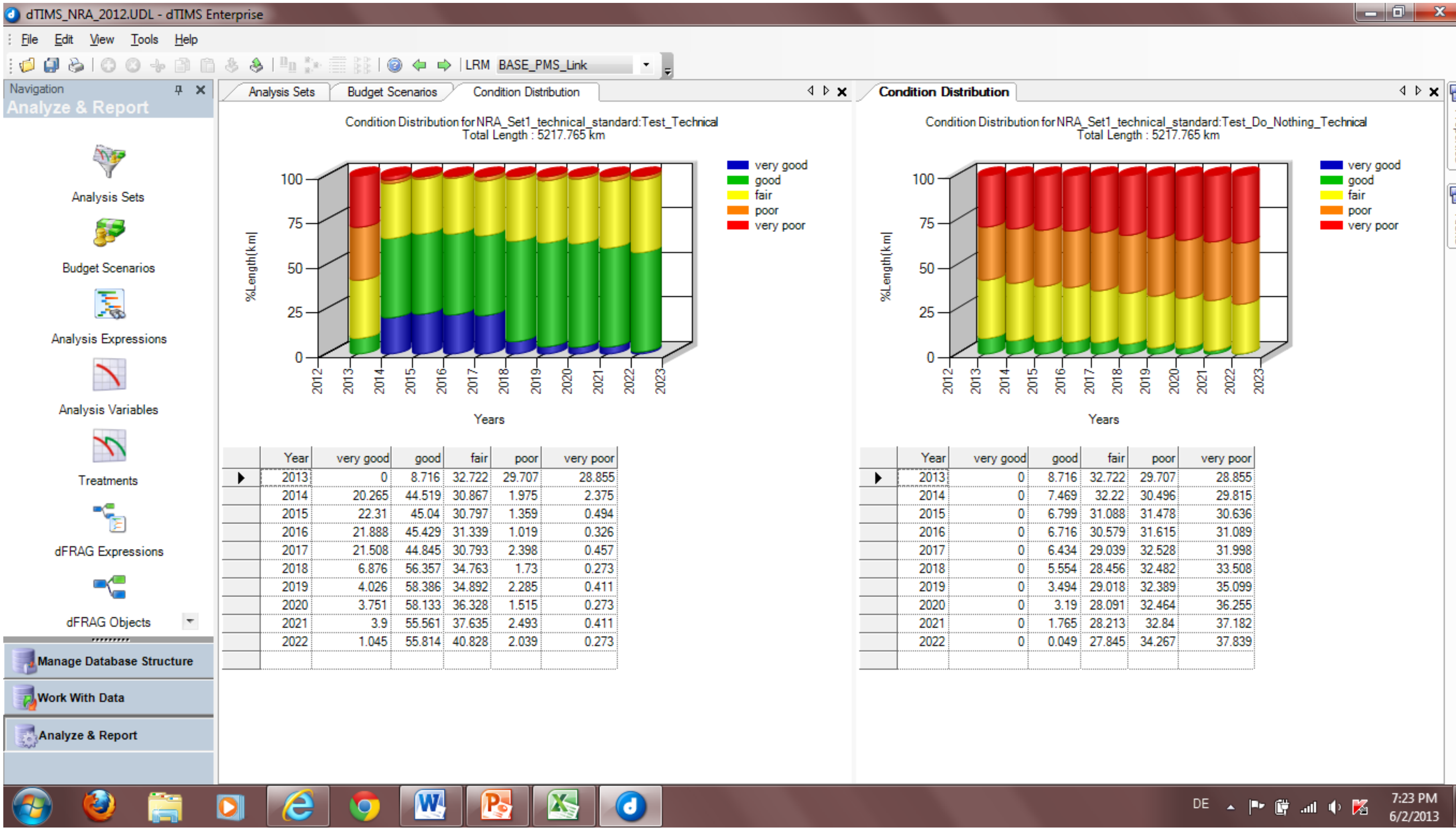
dTIMS NRA in Practice

dTIMS NRA in practice



dTIMS NRA in practice





Year	very good	good	fair	poor	very poor
2013	0	8.716	32.722	29.707	28.855
2014	20.265	44.519	30.867	1.975	2.375
2015	22.31	45.04	30.797	1.359	0.494
2016	21.888	45.429	31.339	1.019	0.326
2017	21.508	44.845	30.793	2.398	0.457
2018	6.876	56.357	34.763	1.73	0.273
2019	4.026	58.386	34.892	2.285	0.411
2020	3.751	58.133	36.328	1.515	0.273
2021	3.9	55.561	37.635	2.493	0.411
2022	1.045	55.814	40.828	2.039	0.273

Year	very good	good	fair	poor	very poor
2013	0	8.716	32.722	29.707	28.855
2014	0	7.469	32.22	30.496	29.815
2015	0	6.799	31.088	31.478	30.636
2016	0	6.716	30.579	31.615	31.089
2017	0	6.434	29.039	32.528	31.998
2018	0	5.554	28.456	32.482	33.508
2019	0	3.494	29.018	32.389	35.099
2020	0	3.19	28.091	32.464	36.255
2021	0	1.765	28.213	32.84	37.182
2022	0	0.049	27.845	34.267	37.839

dTIMS NRA in practice