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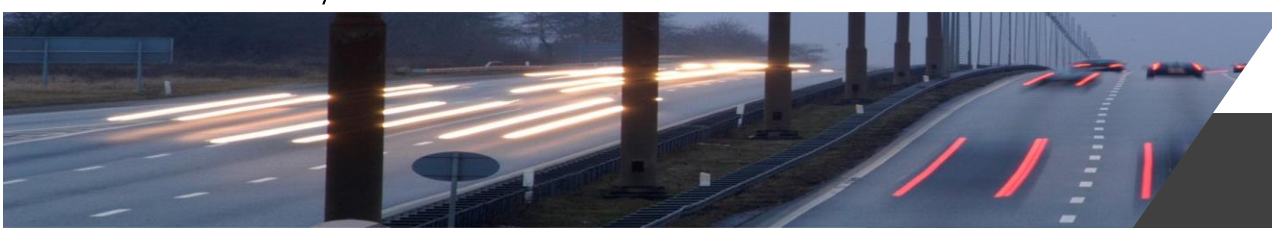
Socioeconomic Impacts of Implementing Low Rolling Resistance SMA

A case study from The Danish Road Directorate



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DANISH ROAD DIRECTORATE (DRD)

1) **3,800 km / 2,400 miles of highways**
2) **SMA-based pavement is predominately used**
3) **Type of SMA is determined by road use and situation**
   - **Various tweaks of SMA is developed**
     - SMA11 is historically used for highways, durable
     - SMA8 is gaining more usage
     - SMA8 SRS used on highways and larger roads around urban areas
     - Now, we have the SMA8 KVS, *Climate Friendly Pavement*

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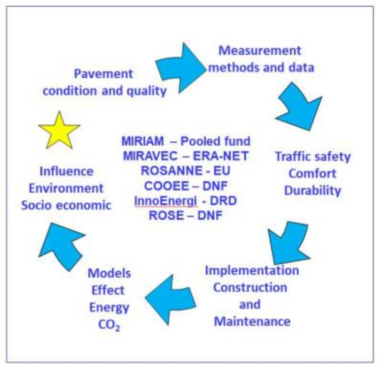
Outline

1) **How socioeconomic analyses benefit**
2) **Conducting socioeconomic analyses on pavement**
   - **Illustration of a new model**
3) **A new form of KPI**
4) **Results and perspectives**
5) **Cliffhanger**

Developing the low rolling resistance SMA, the SM8 KVS

R&D, International collaboration on rolling resistance over a decade



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Adding socio economy

How do we show the ‘actual’ effects and perspectives
of implementation, e.g. to the tax payers and road neighbors?

1) A tangible output for all
2) Translate technical results into €€$$££
3) What’s the objective of use?
   - As a tool on itself
   - Facilitate the way into asset management and decision making

Adding socio economy

How do we show the 'actual' effects and perspectives of implementation, e.g. to the tax payers and road neighbors?

The SM8 KVS is more expensive than the conventional SMA8 or, indeed, an SMA11 due to the specific mix and paving requirements…

… however, it provides resource-saving properties in various ways

Need to monetize the factors to show the socioeconomic effect

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Monetize parameters

- Lowered fuel consumption,
  - Gain for the individual and commercial
- Lowered particle emissions
  - Gain for another sector (health)
- Lowered noise emission
  - Gain for another sector (health)
- Durability equal to conventional pavement
  - Rutting, ravelling, stone-loss, etc.
    Functional and material properties

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The model for fuel consumption

1) A hybrid between the HDM-4 model of fuel consumption & MIRAVEC*

$$IFC = p_1 v^{-1} + p_2 \frac{\mathrm{SP}}{v} + p_3 \frac{\mathrm{SP}^2}{v} + p_4 \frac{\mathrm{SP}^3}{v} + p_5 \sin(\theta) + p_6 a + p_7 a \tan^{-1}\left(\frac{b_3}{v^3}\right) + p_8 w^2 \cos(\alpha) + p_9 w^2 \cos(\alpha)\sin(\alpha) + p_{10}\left(\cos(\sigma) v^2/R - g \sin(\sigma)\cos(\theta)\right) + p_{11} + p_{12} T + p_{13}\,\mathrm{MPD} + p_{14}\,\mathrm{IRI} + p_{15}\,\mathrm{IRI}(v-20)$$

where

$$\mathrm{SP} = \max(20, v).$$

Name	Description	Unit
v	Vehicle speed	m/s
a	Vehicle acceleration	m/s^2
g	Earths gravity	m/s^2
θ	Longitudinal gradient	degrees
σ	Crossfall	degrees
R	Road curvature	m
w	Experinced air speed	m/s
α	Angle of w	degrees
b_3	HDM-4 Tyre stiffness parameter	#
T	Temperature	Celcius
MPD	Mean Profile Depth	mm
IRI	Internation Roughness Index	m/km
$p_1, \ldots, p_{15}$	Model parameters	-

2) MPD and IRI used to calculate fuel consumption and particle emission on the particular road

3) Available from our own measurements

4) We employ this model since we are able to use our own data (MPD and IRI)

5) We plan to look into supplementing approaches to calulate Fc

** MIRAVEC - Modelling Infrastructure Influence on RoAd Vehicle Energy Consumption*

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The model for fuel consumption

Examples on changing fuel consumption (FC) after implementation

	(L/Km)		(%)
	Current State	**Implementation**	**Reduction**
M10			
Car	0,073	0,071	2,069
Truck	0,174	0,171	1,441
M40			
Car	0,072	0,071	1,389
Truck	0,173	0,171	1,156

- Improvements in FC depends on the current state (age and type)
- Results of the socioeconomic analyses largely depend on the state of the surface layer, ADT, and the number of trucks vs cars

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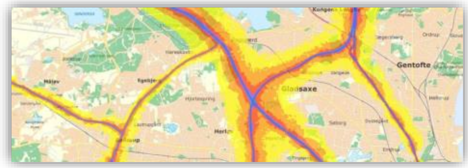

Multi-beneficial, RR and noise

- The pavement with low rolling resistance is based on an SMA8
- The SMA8-based mix for the low rolling resistance pavement has as an added bonus a noise reducing effect relative to an SMA11
  - very important in the socioeconomic analyses

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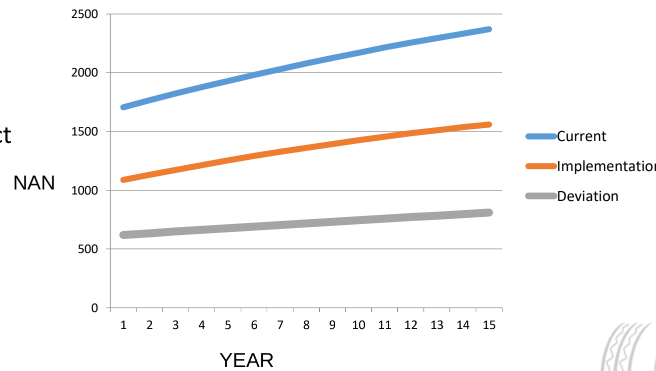
Multi-beneficial, RR and noise

- This enables the calculation of the Danish Noise Annoyance Number (NAN)
  - A function of surface texture, speed limit, and hence noise emission, and density of neighbors in close proximity to the particular road
  - All residential buildings situated within a 58 dB range of road noise is included
  - Currently debated to be set at 53 dB for health purposes – caused by significant increase in traffic intensity
- Using an SMA8 as opposed to an SMA11 can reduce noise by up to 2dB
  - Equate to reducing the traffic by 30 %
- Development of NAN throughout the expected lifespan
- From our own analyses and measurements, we know the development in road noise levels of SMA8-based mixtures, which we apply to the pavement with low rolling resistance

Noise annoyance development

- Example from a major road near Copenhagen with a 5 year old SMA 11
- NAN can be monetized to provide effect in the socioeconomic analyses



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The Socio Economy Model

An extension on an existing accepted model

Factors included

Existing Road or conventionally chosen pavement type

- ADT, including vehicle type and predicted development
- Noise annoyance number, including development
- **Modelled fuel consumption**
- Road area / lanes
- Price of pavement

Pavement with low rolling resistance

- **Modelled fuel consumption**
- Noise annoyance number, including development
- Price of pavement

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Adding socio economy

Analysing the socioeconomic impact

- Results from whole stretches as examples
- 5 different major roads chosen
  - Similar roads, but very different in usage/load
  - Urban areas vs non-urban
  - Great effect on the socioeconomic analyses

ROAD	BREAKEVEN	NPV / Return factor
M10	4 Years	8,53
M14	3 Years	4,67
M40	11 Years	0,53
M50	15 Years	-0,82
M80	15 Years	-0,30

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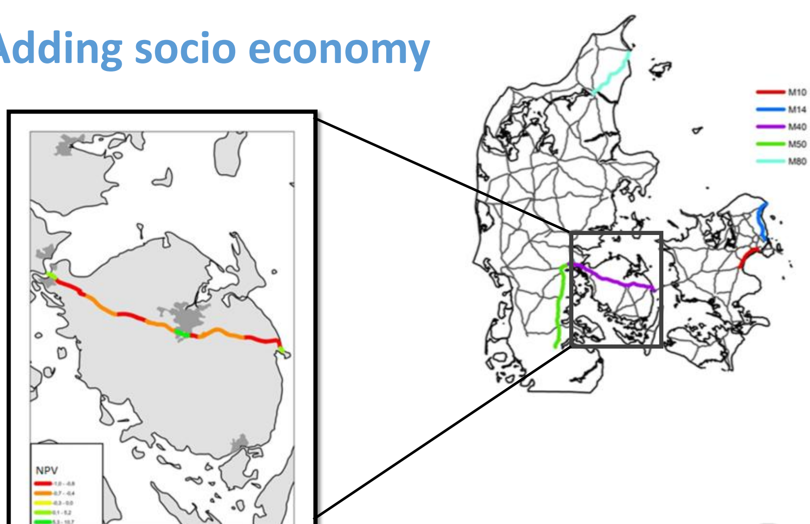
Adding socio economy



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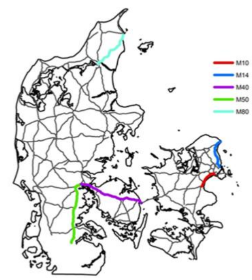
Adding socio economy

How does noise annoyance influence the analyses?

Based on a 15 year life span of the low rolling resistance pavement

M14			M40	
With noise			**With noise**	
Break even	3		Break even	11
Return factor	5,63		Return factor	3,24
Without noise			**Without noise**	
Break even	4		Break even	16
Return factor	2,15		Return factor	-1,03



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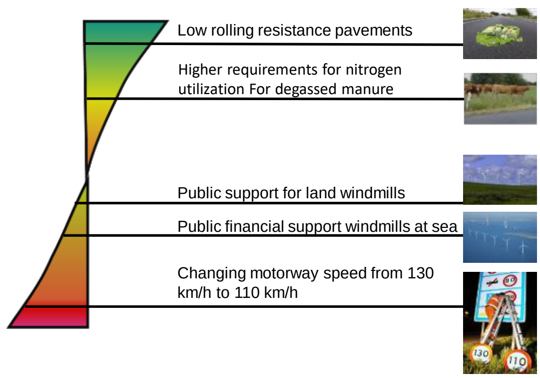
Adding socio economy

- A further outcome is the Price Index (shadow price)
- The cost (price) to reduce 1 metric ton of CO_2
- Enables direct apple-to-apple comparison to other means of CO_2 reduction

Adding socio economy



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Adding socio economy

Initiative	Full scale implementation of the energy efficient pavement	Speed limit decrease from 130 kph to 110 on Danish highways	PSO support by establishing 200 MW near-costal off shore wind farms	PSO-support by establishing new 200 MW land based wind farms
Skyggepris Kr./ton CO_2-eq.	-2,239	13,460	489	55

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Perspective of full-scale implementation

1) Promising outcomes resulted in a state funding for implementation in 2018
2) Four large-scale stretches are paved in 2018
3) Two way objective
   - For us to demonstrate our mix design in terms of material and functional properties
   - For us to evaluate that the industry is capable of mixing and paving, through an open dialogue and collaborations
     - Assessed and measured on price, homogeneity, friction, among more

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Perspective of full-scale implementation

Preliminary results on socioeconomic analysis

		MPD		IRI								
Location	Name	Mean	Deviation	Mean	Deviation	Area m2	SBT	Added price in kr	Added price in %	Break even (years)	Net present valie	Shadow price
Distrikt Østdanmark	Helsingørmotorvejen	1,18	0,22	1,69	0,93	47300	81	236153	20	9	3,62	-176882
Distrikt Østdanmark	Helsingørmotorvejen	0,82	0,16	1,64	0,90	34200	81	236153				
Distrikt Østdanmark	Sydmotorvejen	1,05	0,21	0,80	0,38	83300	4,9	1349460	18	18	-0,65	17351
Distrikt Østdanmark	Sydmotorvejen	1,28	0,18	0,91	0,38	-	4,9					
Distrikt Syddanmar k	Østjyske Motorvej	0,78	0,13	1,32	0,47	12736	0,23	236154	17	18	-0,55	16329
Distrikt Østdanmark	Skovvejen	0,69	0,12	1,16	0,98	14100	0,20	209850	16	18	-0,64	29510

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Perspective of full-scale implementation

… if we jointly succeed with the industry, then a nation-wide implementation is politically present to allocate the necessary resource(s)

Success measured in

- Rolling resistance
- Durability
- Price

- The Danish Government has recently published a 38-point CO_2-reduction plan, in which the developed SMA-based low rolling resistance pavement constitutes one of these

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Perspective of full-scale implementation

Action from now on

- Validate the model used to determine fuel consumption and analyze alternatives and/or supplementing approaches
- Improve rolling resistance measuring and analyze alternatives and/or supplementing approaches
- Include LCA for a more holistic CO2 reducing picture
  - Construction vs. Operation = Operation wins, however construction is significant

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Perspective of full-scale implementation

Action from now on

- Integrate rolling resistance (and noise) into asset management systems
  - As a KPI
  - Decision making on where to focus implementation for smarter allocation of resources
  - Lane differentiation

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