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MIRAVEC - Modelling Infrastructure influence on RoAd Vehicle Energy Consumption

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ENR Energy Final Conference, Stockholm

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY | vti | TRL | ZAG | CDV CENTRUM DOPRAVNÍHO VÝZKUMU | FEHRL

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SEVENTH FRAMEWORK PROGRAMME

ENR Energy Project MIRAVEC

- **Overview & Background**
- **Presentation of Work Packages**
- **Results**

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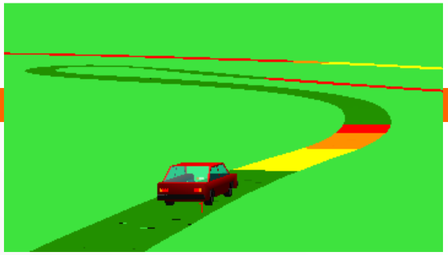
ENR Energy Project MIRAVEC

- Title: Modelling Infrastructure influence on RoAd Vehicle Energy Consumption
- Project duration: Nov 2011 - Dec 2013
- Partners:

Partner	Name	Country	Roles
Coordinator	AIT	Austria	WP1, WP5 leader
1	TRL	UK	WP3 leader
2	VTI	Sweden	WP2 leader
3	ZAG	Slovenia	WP4 leader
4	CDV	Czech Republic	WP4 contribution
5	FEHRL	Belgium	Task T5.2 & T5.3 leader

ENR Energy Project MIRAVEC

- **Background:**
  - CO_2 emissions from road transport contribute to overall GHG emissions
  - Reduction efforts are essential – how can National Road Authorities (NRAs) contribute?
  - Improvement of road infrastructure can contribute to emission reduction
- **Requirements:**
  - Understanding and modelling of vehicle-road interaction
  - Implementation of results in asset management



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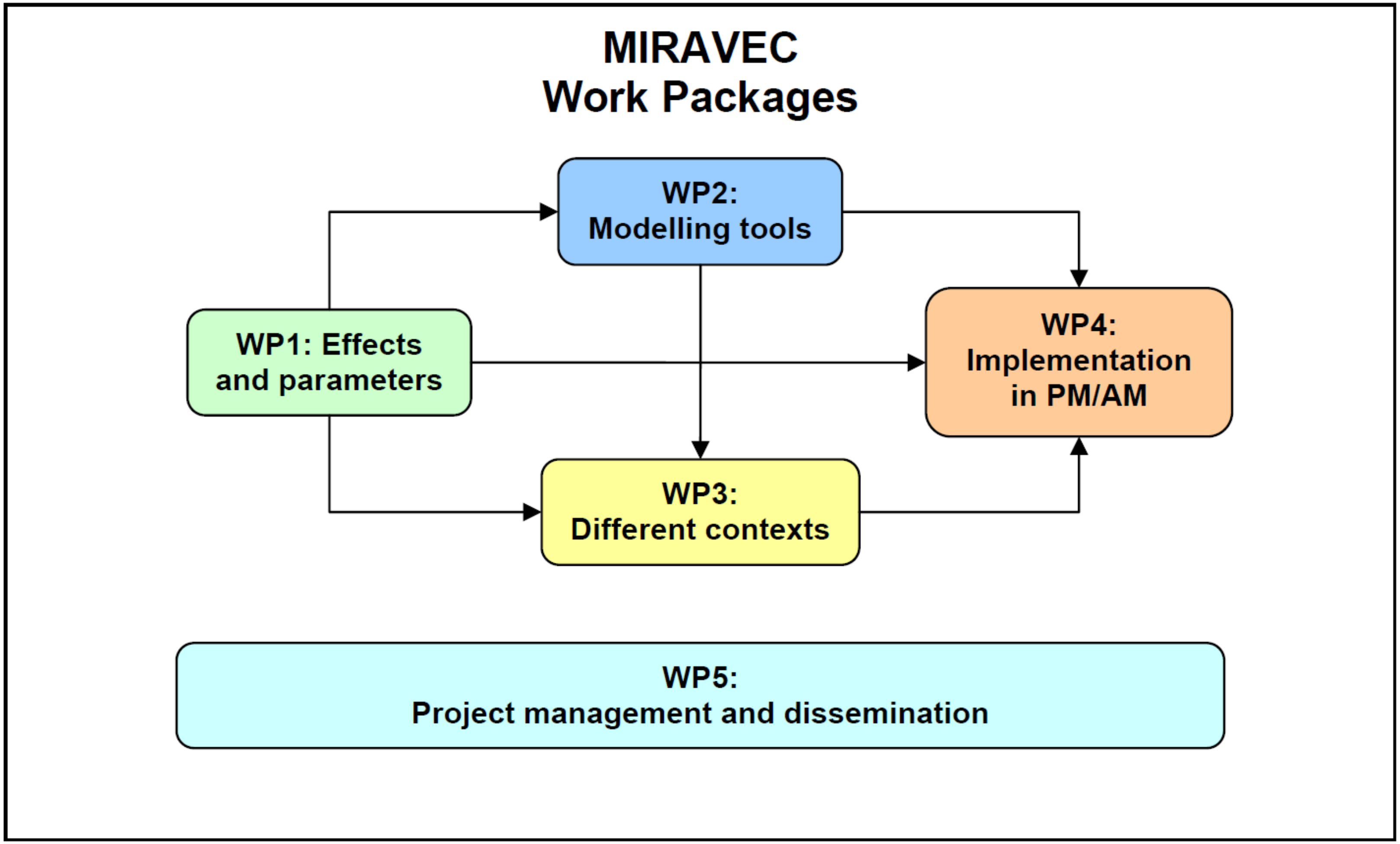

WP1: Effects and Parameters

- Analysis of road infrastructure influence effects on vehicle energy consumption and associated parameters
- Output: Identified the most important effects contributing to road vehicle energy consumption which are governed by interaction with the infrastructure and associated parameters.

WP1: Effects and Parameters

Parameters describing road infrastructure effects

No.	Name of effect or property	Group	NRA influence level (H,M,L)	Parameters
1	Rolling resistance (pavement)	A	H	C_R
2	Texture	A	H	MPD, texture spectrum
3	Longitudinal unevenness	A	H	IRI
4	Transversal unevenness	A	H	Rut depth
5	Surface defects	A	H	Defect area density
6	Road strength	A	H	deflection, C_R contribution
7	Vertical alignment (Gradient)	B	H	Angle β or %, RF
8	Crossfall	B	H	Angle γ
9	Horizontal alignment (Curvature)	B	H	R_{Curv}, ADC
10	Road width and lane and carriageway layout	B	H	w_{Road}
11	Intersections and roundabouts	B	H	Level of service
12	Tunnels	B	H	Level of service, $v_{average}$, v_{85}
13	Traffic volume and composition	C	L	AADT, %
14	Traffic flow	C	M	Level of service
15	Traffic speed	C	M	$v_{average}$, v_{85}
16	Traffic lights, road signs, road markings and ITS measures	C	M	Level of service, $v_{average}$, v_{85}
17	Driver behaviour	C	M	driving pattern
18	Vehicle type	D	L	vehicle type
19	Tyre type	D	L	tyre type
20	Air resistance	D	M	F_{air}
21	Temperature	E	L	T
22	Wind	E	L	v_{Wind}, α_{Wind}
23	Water	E	M	d_{water}
24	Snow and ice	E	L	d_{snow}, d_{ice}

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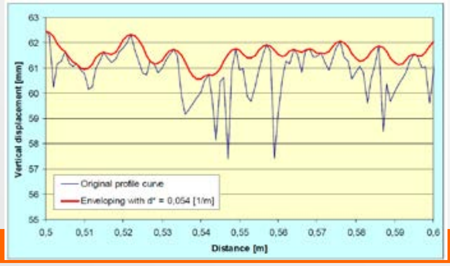
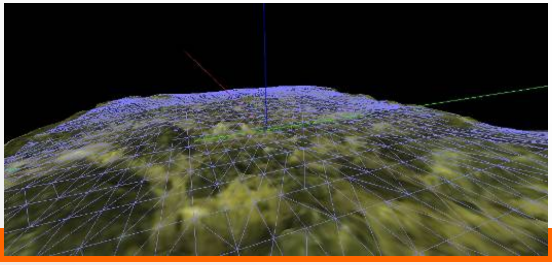
WP1: Effects and Parameters

Compilation of input parameters for WP2+3+4

No.	**Name of effect or property**	**Group**	**NRA influence level (H,M,L)**	**Parameters**
2	Texture	A	H	MPD, texture spectrum
3	Longitudinal unevenness	A	H	IRI
4	Transversal unevenness	A	H	Rut depth
7	Vertical alignment (Gradient)	B	H	Angle β or %, RF
8	Crossfall	B	H	Angle γ
9	Horizontal alignment (Curvature)	B	H	R_{Curv}, ADC
10	Road width and lane and carriageway layout	B	H	w_{Road}
13	Traffic volume and composition	C	L	AADT, %
15	Traffic speed	C	M	$v_{average}$, v_{85}





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WP2: Modelling tools

- Evaluation of modelling tools for the effects defined in WP1
- Output: Evaluation of currently available tools and their capabilities, including further developments to improve their performance and scope, the possibilities for integration of different tools and the remaining gaps

WP2: Modelling tools

- Evaluation of projects and models in order to identify deficiencies and strengths
- Road infrastructure variables in the models used in IERD, ECRPD and MIRIAM

	Variable									
Project / Model	MPD	IRI	Rut depth	Grad-ient	Cross-fall	Curve radius	Width	AADT	Traffic com-position	Traffic Speed
IERD – VETO	X	X		X	X	X	X	x	(x)	X
ECRPD – VETO	X	X		X	X	X	X	x	(x)	X
MIRIAM										
- VETO	X	X	(x)	X	X	X	X	X	(x)	X
- FTire/Dym./Mod.	X	X	X	X	X	X	X			
- MOVES	(x)	(x)		X			(x)	X	X	X

- Proposal for the inclusion of additional parameters: Rolling resistance effect of RUT, Speed effect of MPD, presence of water, moisture, snow or ice, surface defects and road strength (road deterioration model)

WP2: Modelling tools

The MIRAVEC model:

Fuel consumption function developed in MIRIAM SP2 :

$$F_{cs} = c_1 \times (1 + k_5 \times (F_r + F_{air} + d_1 \times ADC \times v^2 + d_2 \times RF + d_3 \times RF^2))^{e1} \times v^{e2}$$

where F_{cs} is fuel consumption, F_r is rolling resistance, F_{air} is air resistance, *ADC* is average degree of curvature, *RF* is rise and fall (gradient), v is velocity, and c_1, k_5, d_1, d_2, d_3, e_1 and e_2 are empirical parameters.

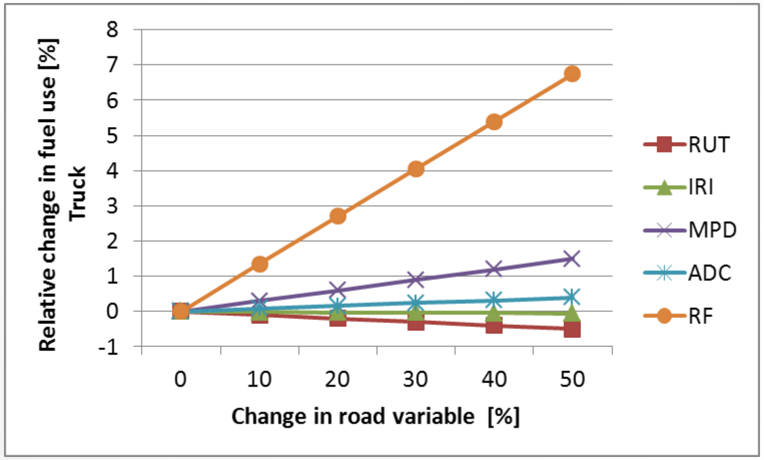
$$F_r = (Cr_{00} + Cr_{Temp} \times (T_0 - T) + Cr_1 \times IRI \times v + Cr_2 \times MPD) \times m \times g$$

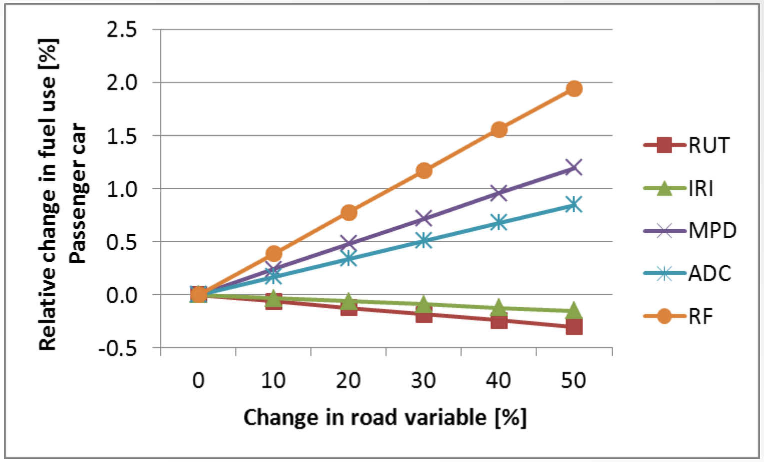
where T is the ambient temperature, *IRI* (International Roughness Index) is an unevenness measure and *MPD* (Mean Profile Depth) is a measure of macrotexture.

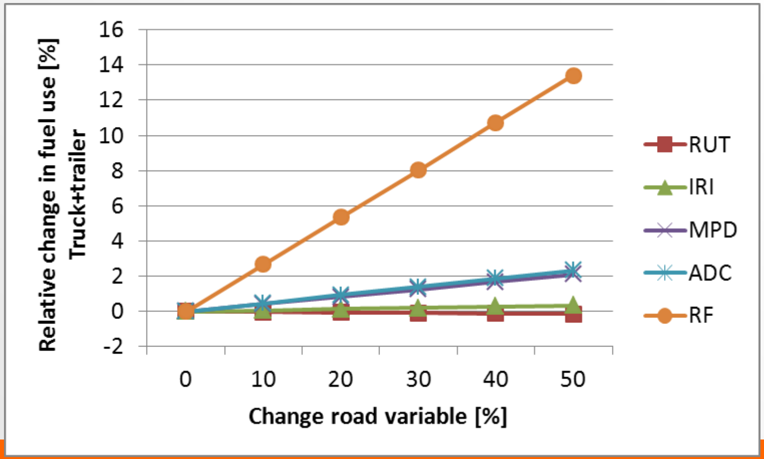
Overall fuel consumption is calculated by **aggregation** (based on traffic volume, vehicle type distribution), also taking speed effects of the level of traffic and some infrastructure features into account.

WP2: Modelling tools

Analysis of the parameters included in these models and uncertainty analysis







Results:

- A change in RF leads to the largest changes in fuel use, followed by MPD and ADC
- Relative changes in fuel use are dependent on vehicle size and road type
- A speed effect for IRI and RUT offsets fuel use savings to some extent

WP3: MIRAVEC tool

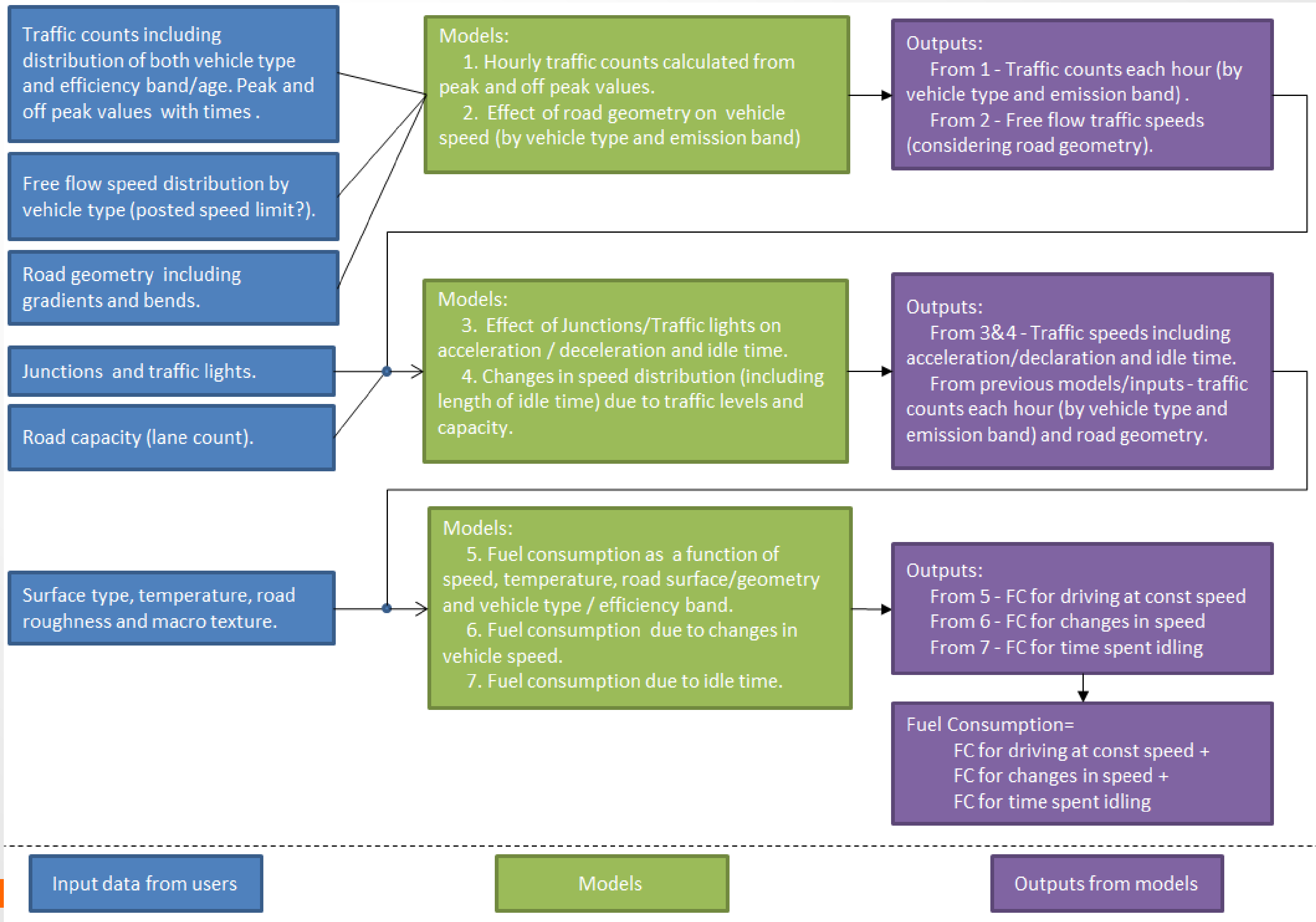
Objectives:

- Assess the relative importance of the effects from WP1 in different contexts and settings
- Evaluation of the potential savings in vehicle energy use achievable by NRAs actions

Output:

- Spread sheet calculation tool based on simplified models
- Case studies and scenario comparisons

WP3: MIRAVEC tool



WP3: MIRAVEC tool

Features:

- Spreadsheet tool for estimating vehicle energy use
- User enters traffic counts and distribution, surface condition, geometry and road layout
- The spreadsheet outputs the fuel consumption as an overall value for the route and also in graph format over the length of the route
- The spreadsheet tool allows the user to compare two scenarios to investigate the affects of changes to the route on fuel consumption

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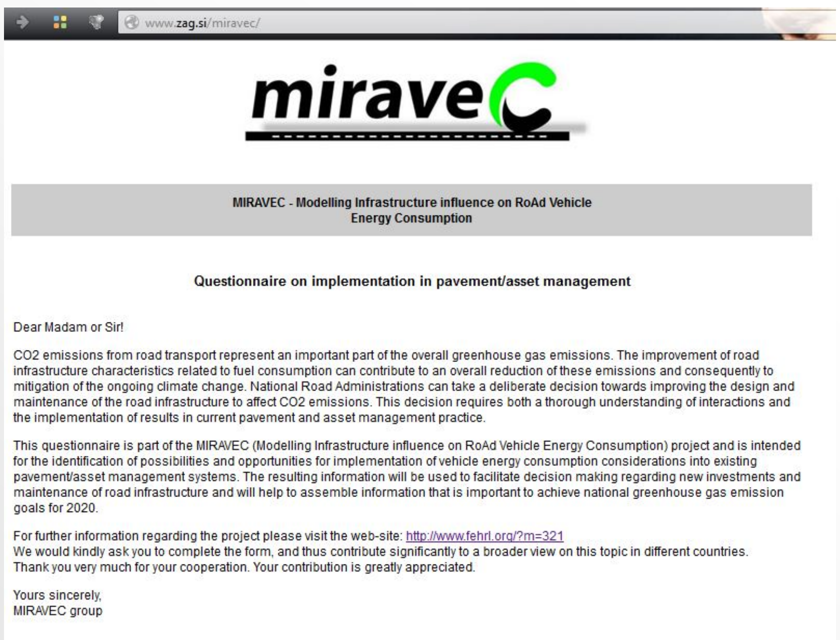
WP4: Implementation

Objectives:

- Investigation of the current role of road vehicle energy consumption in road asset management
- Recommendations how to implement the available knowledge and/or models
- Support energy efficiency considerations in the decision making processes of NRAs

WP4: Implementation

- Identification of the current role of road vehicle energy consumption and CO2 emissions in existing systems and of opportunities for improvement (surveys)
- Derivation of recommendations



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MIRAVEC - Modelling Infrastructure influence on RoAd Vehicle Energy Consumption

Questionnaire on implementation in pavement/asset management

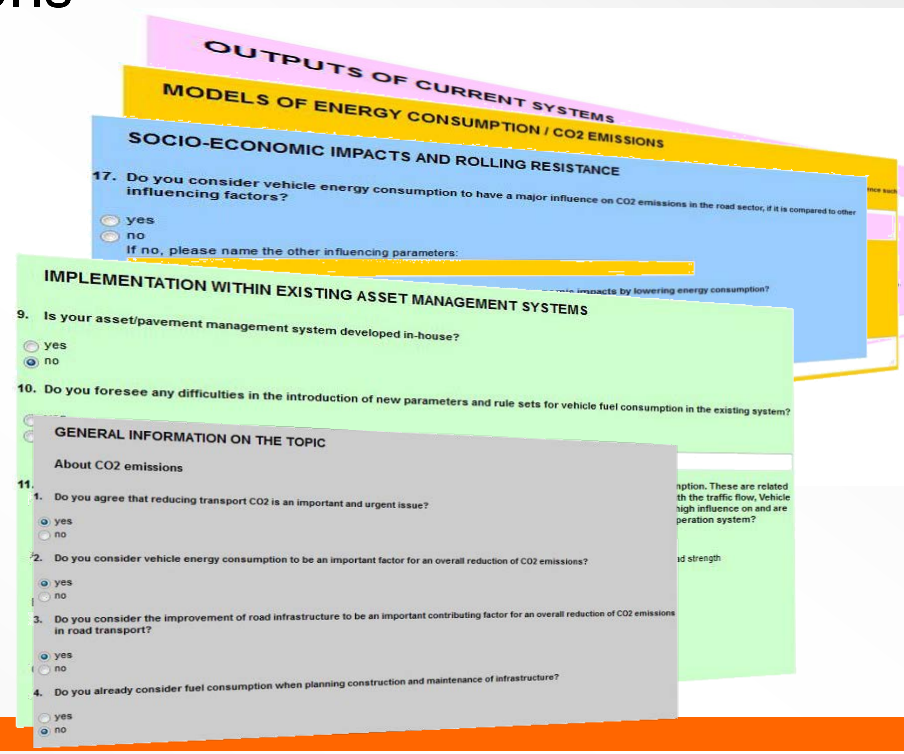
Dear Madam or Sir!

CO2 emissions from road transport represent an important part of the overall greenhouse gas emissions. The improvement of road infrastructure characteristics related to fuel consumption can contribute to an overall reduction of these emissions and consequently to mitigation of the ongoing climate change. National Road Administrations can take a deliberate decision towards improving the design and maintenance of the road infrastructure to affect CO2 emissions. This decision requires both a thorough understanding of interactions and the implementation of results in current pavement and asset management practice.

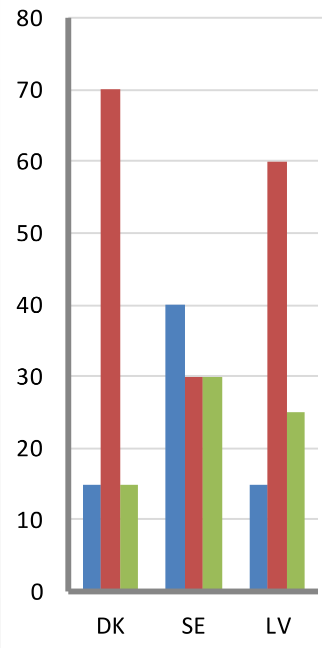
This questionnaire is part of the MIRAVEC (Modelling Infrastructure influence on RoAd Vehicle Energy Consumption) project and is intended for the identification of possibilities and opportunities for implementation of vehicle energy consumption considerations into existing pavement/asset management systems. The resulting information will be used to facilitate decision making regarding new investments and maintenance of road infrastructure and will help to assemble information that is important to achieve national greenhouse gas emission goals for 2020.

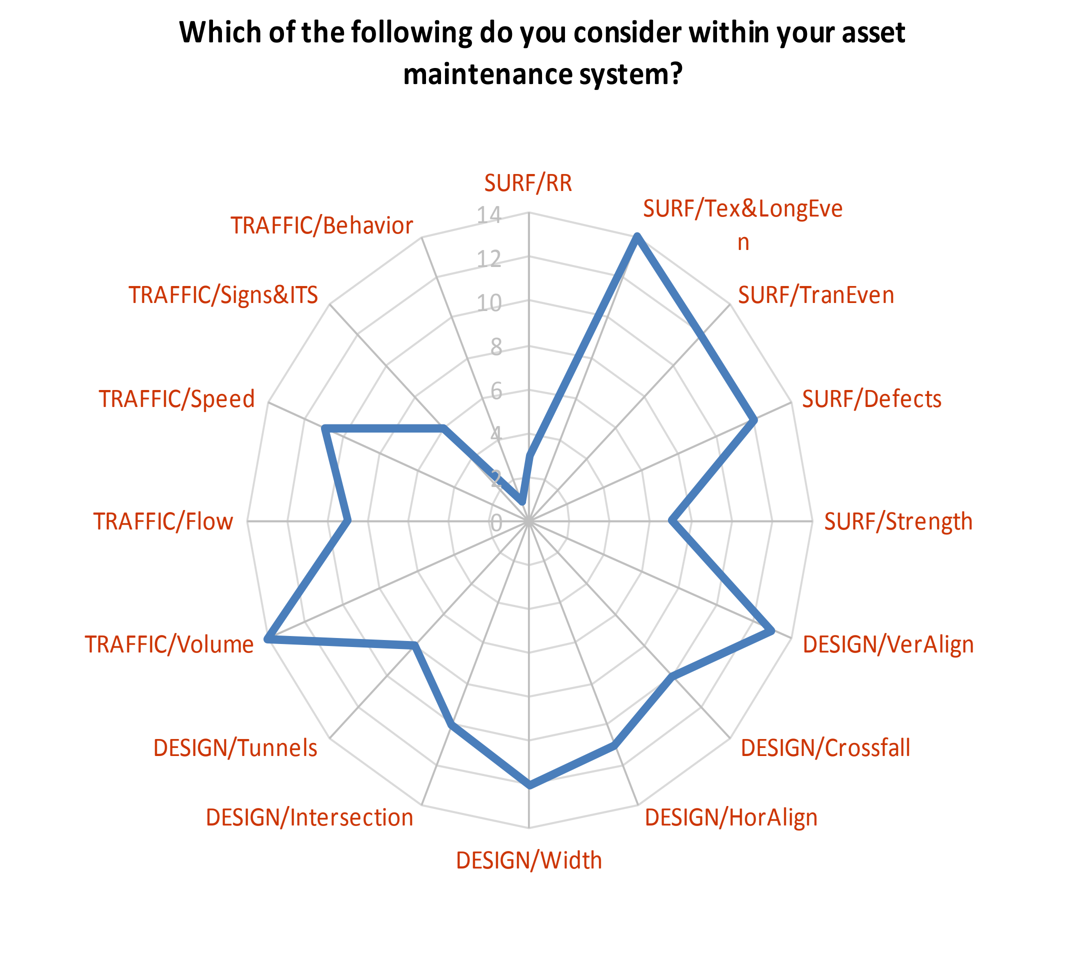
For further information regarding the project please visit the web-site: http://www.fehrl.org/?m=321
We would kindly ask you to complete the form, and thus contribute significantly to a broader view on this topic in different countries.
Thank you very much for your cooperation. Your contribution is greatly appreciated.

Yours sincerely,
MIRAVEC group



WP4: Implementation





The MIRAVEC tool

- A spreadsheet tool was developed to describe the influence on vehicle energy use of
  - Traffic
  - Vehicle characteristics
  - **Infrastructure design**

- The tool enables vehicle energy use to be estimated for different situations, given appropriate input data, and displays the uncertainty associated with the estimates

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The MIRAVEC tool

Models included in the tool

- Fuel consumption model for free flow traffic:
  - Vehicle characteristics (type, fuel used, Euro class)
  - Rolling resistance, Air resistance, Average degree of curvature, Rise and fall/gradient, Velocity
- Rolling resistance dependent on
  - Ambient temperature, IRI, MPD
- Vehicle velocity
  - Based on posted speed, vehicle type, traffic volume, gradient, IRI and rutting present
- Idle time

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The MIRAVEC tool

Tool capabilities

- Estimate vehicle fuel consumption associated with a specific route
- Explore the effects of various changes to the road infrastructure on the fuel consumption
- Implemented using a spreadsheet package
- Split into three main (colour coded) sections, further divided into separate worksheets:
  - First section (red) allows the user to enter global variables
  - Second section (blue) is used to enter the details of the road route being assessed.
  - Third section (green) provides the output data from the tool

The MIRAVEC tool

Input data needed

The global data is entered on the sheets with red tabs and consists of:

- Traffic breakdown
- Traffic flow distribution
- Default values

Local data is provided for each length on the route (e.g. each 100m):

- Properties of road: type, number of lanes, AADT, Posted speed
- Pavement characteristics: Gradient, Curvature IRI, Rutting, MPD

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Input: Traffic breakdown

Fuel consumption for user defined vehicle class equals 50 % of Euro 3 for same vehicle type.

Total of percentage distribution	100.0%
Percentage heavy vehicles	19.0%

	Percentage distirbution								Vehicle type typically u		
	Pre-Euro 1	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	User	Pre-Euro 1	Euro 1	Euro 2
Cars											
Petrol <1400cc		5.0%							No	No	No
Petrol 1400-2000cc			5.0%	5.0%	5.0%	5.0%	5.0%		No	No	No
Petrol >2000cc				5.0%	5.0%				No	No	No
Diesel <1400cc		2.0%	2.0%	2.0%	2.0%	1.0%	1.0%		No	No	No
Diesel 1400-2000cc			2.0%	2.0%	2.0%	2.0%	2.0%		No	No	No
Diesel >2000cc									No	No	No
LPG	N/A		1.0%	2.0%	1.0%				N/A	No	No

	Petrol	Diesel	Total
Total Car percentage	40.0%	24.0%	64.0%

Light Goods Vehicles	Pre-Euro 1	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	User	Pre-Euro 1	Euro 1	Euro 2
LGV N1(I) Petrol			1.0%						No	No	Yes
LGV N1(I) Diesel			1.0%	1.5%					No	No	Yes
LGV N1(II) Petrol			1.0%						No	No	Yes
LGV N1(II) Diesel			1.0%	1.5%					No	No	Yes
LGV N1(III) Petrol			1.0%						No	No	Yes
LGV N1(III) Diesel			1.0%	1.5%					No	No	Yes

	Petrol	Diesel	Total
Total LGV percentage	3.0%	7.5%	10.5%

Rigid Heavy Goods Vehicles

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Input: Traffic flow distribution

	Hourly Flow group (HFG)	Description	Percentage increase in traffic per hour releative to flow group 2	
Weekdays	1	Low weekday traffic periods	-50	%
	2	Typical weekday traffic levels	0	%
	3	higher weekday traffic periods	200	%
	4	Peak weekday traffic periods	500	%
Weekends	5	Low weekend traffic periods	-80	%
	6	Typical weekend traffic levels	-50	%
	7	higher weekend traffic periods	100	%
	8	Peak weekend traffic periods	150	%

		Flow group asignment			
From	To	Mon-Thurs	Frid	Sat	Sun
00:00	01:00	1	1	5	5
01:00	02:00	1	1	5	5
02:00	03:00	1	1	5	5
03:00	04:00	1	1	5	5
04:00	05:00	1	1	5	5
05:00	06:00	1	1	5	5
06:00	07:00	1	1	5	5
07:00	08:00	2	2	5	5
08:00	09:00	2	2	6	5
09:00	10:00	2	2	6	6
10:00	11:00	2	2	7	6
11:00	12:00	2	2	8	6
12:00	13:00	2	3	8	6
13:00	14:00	2	3	8	6
14:00	15:00	2	3	7	6
15:00	16:00	2	3	6	6
16:00	17:00	3	3	6	7
17:00	18:00	4	4	6	8
18:00	19:00	2	3	6	7
19:00	20:00	1	1	6	6
20:00	21:00	1	1	5	6
21:00	22:00	1	1	5	5
22:00	23:00	1	1	5	5
23:00	00:00	1	1	5	5

Input: Default values

Typical Air Temperature	8	°C
Typical Air Pressure	1013	mbar

Motorway: Rural

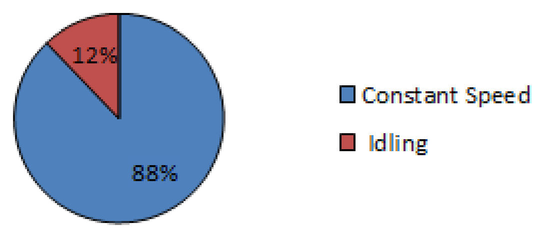
Parameter	User Override	Default value	Typical values AUT	Typical values UK	User Override (±%)	Default Uncertainty (±%)	Typical Uncertainty (±%) AUT	Typical Uncertainty (±%) UK
Number of lanes open to traffic		2.5	2	3	*not applicable*			
Posted speed limit: Car (Km/h)		121	130	112	*not applicable*			
Posted speed limit: LGV (Km/h)		96	80	112				
Posted speed limit: HGV (Km/h)		88	80	96				
Posted speed limit: Truck and Trailer (Km/h)		88	80	96				
Posted speed limit: Bus / Coach (Km/h)		96	80	112				
Posted speed limit: Motorbike (Km/h)		121	130	112				
Gradient (m/km)		0.47	1.4	0		10	10	10
Horizontal curvature (rad/km)		0.00	0.0001	0		20	20	20
Road roughness (iri)		1.65	1.6	1.7		10	10	10
Macro Texture (mpd)		1.03	0.55	1.5		6.7	6.7	6.7
Rut Depth (mm)		4.10	3.4	4.8		7.5	7.5	7.5
AADT		52900	30000	75800	*not applicable*			

Motorway: Urban

Parameter	User Override	Default value	Typical values AUT	Typical values UK	User Override (±%)	Default Uncertainty (±%)	Typical Uncertainty (±%) AUT	Typical Uncertainty (±%) UK
Number of lanes open to traffic		3	3	3	*not applicable*			
Posted speed limit: Car (Km/h)		96	80	112	*not applicable*			
Posted speed limit: LGV (Km/h)		96	80	112				
Posted speed limit: HGV (Km/h)		88	80	96				
Posted speed limit: Truck and Trailer (Km/h)		88	80	96				
Posted speed limit: Bus / Coach (Km/h)		96	80	112				
Posted speed limit: Motorbike (Km/h)		96	80	112				
Gradient (m/km)		0.47	1.4	0		10	10	10

Input: Local data

Length of route:	31.000	km
Average daily CO2 for route:	1377.617	Tonnes
Route CO2 due to idling:	166.821	Tonnes
Average daily CO2 per km:	44.439	Tonnes/km

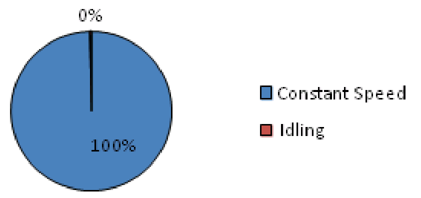


Location inforamtion

Section Reference	Start Chainage (m)	End chainage (m)	Motorway, Single or Dual carriageway	Urban or Rural
3700M42/142	0	100	Motorway	Urban-non central
3700M42/142	100	200	Motorway	Urban-non central
3700M42/142	200	300	Motorway	Urban-non central
3700M42/142	300	400	Motorway	Urban-non central
3700M42/142	400	500	Motorway	Urban-non central
3700M42/146	0	100	Motorway	Urban-non central
3700M42/146	100	200	Motorway	Urban-non central
3700M42/146	200	300	Motorway	Urban-non central
3700M42/146	300	400	Motorway	Urban-non central
3700M42/148	0	100	Motorway	Urban-non central

Infrastructure characteristics

Length of route:	124,000 km
Average daily CO2 for route:	1481,807 Tonnes
Route CO2 due to idling:	5,327 Tonnes
Average daily CO2 per km:	11,950 Tonnes/km



	Location inforamtion				Speed Limits (km/h)						Pavement Chacteristics					Traffic
19	Section Reference	Start Chainage (m)	End chainage (m)	Junction and/or traffic lights?	Car	LGV	HGV	Truck and Trailer	Bus / Coach	Motor-bike	Gradient (m/km)	Horizontal curvature (rad/km)	Road roughness (iri)	Macro Texture (mpd)	Rut Depth (mm)	AADT
20	MW = motorway in Austria	0	1000	No event	130	80	80	80	80	130	-8,28	0,036876	1,475	0,495	2,13	50803
21	MW	1000	2000	No event	130	80	80	80	80	130	-11,1	0,008463	1,64	0,51	2,53	50803
22	MW	2000	3000	No event	130	80	80	80	80	130	2,81	0,027753	2,025	0,545	2,63	50803
23	MW	3000	4000	No event	130	80	80	80	80	130	20,6	0,034907	1,37	0,545	2,12	50803
24	MW	4000	5000	No event	130	80	80	80	80	130	-11,28	-0,06342	1,515	0,58	2,455	50803
25	MW	5000	6000	No event	130	80	80	80	80	130	3	-0,03347	1,37	0,625	2,24	51581
26	MW	6000	7000	No event	130	80	80	80	80	130	6,19	-0,00047	1,445	0,655	2,64	52000
27	MW	7000	8000	No event	130	80	80	80	80	130	-21,19	-0,05457	1,565	0,51	2,855	52000
28	MW	8000	9000	No event	130	80	80	80	80	130	-23,18	0,084561	1,845	0,59	2,78	52000
29	MW	9000	10000	No event	130	80	80	80	80	130	11,41	-0,06008	1,75	0,54	2,745	52000
30	MW	10000	11000	No event	130	80	80	80	80	130	14,57	-0,03256	1,835	0,52	3,39	52000
31	MW	11000	12000	No event	130	80	80	80	80	130	9,38	-0,00713	1,8	0,635	3,285	52000
32	MW	12000	13000	No event	130	80	80	80	80	130	-1,96	0,008881	1,61	0,61	3,235	52000
33	MW	13000	14000	No event	130	80	80	80	80	130	-8,46	0,077344	1,9	0,665	2,6	52000
34	MW	14000	15000	No event	130	80	80	80	80	130	3,15	-0,03423	2,28	0,445	2,99	52000
35	MW	15000	16000	No event	130	80	80	80	80	130	1,52	-0,01218	2,015	0,58	3,285	52488
36	MW	16000	17000	No event	130	80	80	80	80	130	-1,55	-0,00245	1,455	0,5	1,795	53625
37	MW	17000	18000	No event	130	80	80	80	80	130	0,6	-0,04684	1,135	0,55	1,645	53625
38	MW	18000	19000	No event	130	80	80	80	80	130	7,19	-0,04966	1,06	0,49	1,77	53625
39	MW	19000	20000	No event	130	80	80	80	80	130	-3,36	0,07078	1,29	0,48	2,21	53625

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Output data

All Flow groups

Selection acounts for 100.00% of the year
Selection acounts for 100.00% of the AADT

Average Fuel Consumption for route in litres for 1 year of traffic, for All Flow groups									
	All	Car (Petrol)	Car (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV	Truck and Trailer	Bus / Coach	Motorbike
Route 1 Constant speed	107,180,100	30,429,400	12,649,956	2,966,414	6,681,638	######	-	7,621,612	######
Route 1 expected error	1.05%	0.82%	0.82%	1.63%	1.63%	1.63%	3.95%	1.63%	0.82%
Route 2 Constant speed	112,398,026	32,000,619	13,303,136	3,191,100	7,187,727	######	-	7,934,119	######
Route 2 expected error	0.42%	0.32%	0.32%	0.65%	0.65%	0.65%	1.57%	0.65%	0.32%
Route 1 Idling	23,962,858	8,703,353	2,209,773	888,152	2,000,499	######	-	2,628,563	808,167
Route 2 Idling	-	-	-	-	-	-	-	-	-
Route 1 Total	131,142,958	39,132,754	14,859,729	3,854,566	8,682,137	######	-	######	######
Route 2 Total	112,398,026	32,000,619	13,303,136	3,191,100	7,187,727	######	-	7,934,119	######

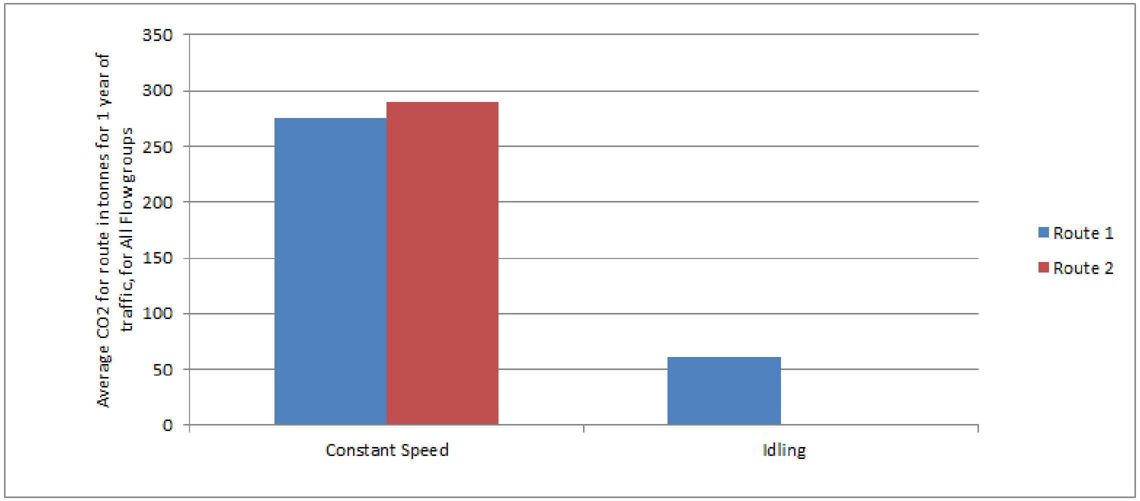
Fuel Consumption for route in litres (single pass), average of All Flow groups								
	Car (Petrol)	Car (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV	Truck and Trailer	Bus / Coach	Motorbike
Route 1 Constant speed	2.01	1.40	2.62	2.36	7.28	0.00	6.73	1.15
Route 2 Constant speed	2.12	1.47	2.82	2.54	7.58	0.00	7.00	1.21
Route 1 Idling	0.58	0.24	0.78	0.71	1.11	0.00	2.32	0.33
Route 2 Idling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Route 1 Total	2.59	1.64	3.40	3.07	8.40	0.00	9.05	1.48
Route 2 Total	2.12	1.47	2.82	2.54	7.58	0.00	7.00	1.21

road ERA net

Output data

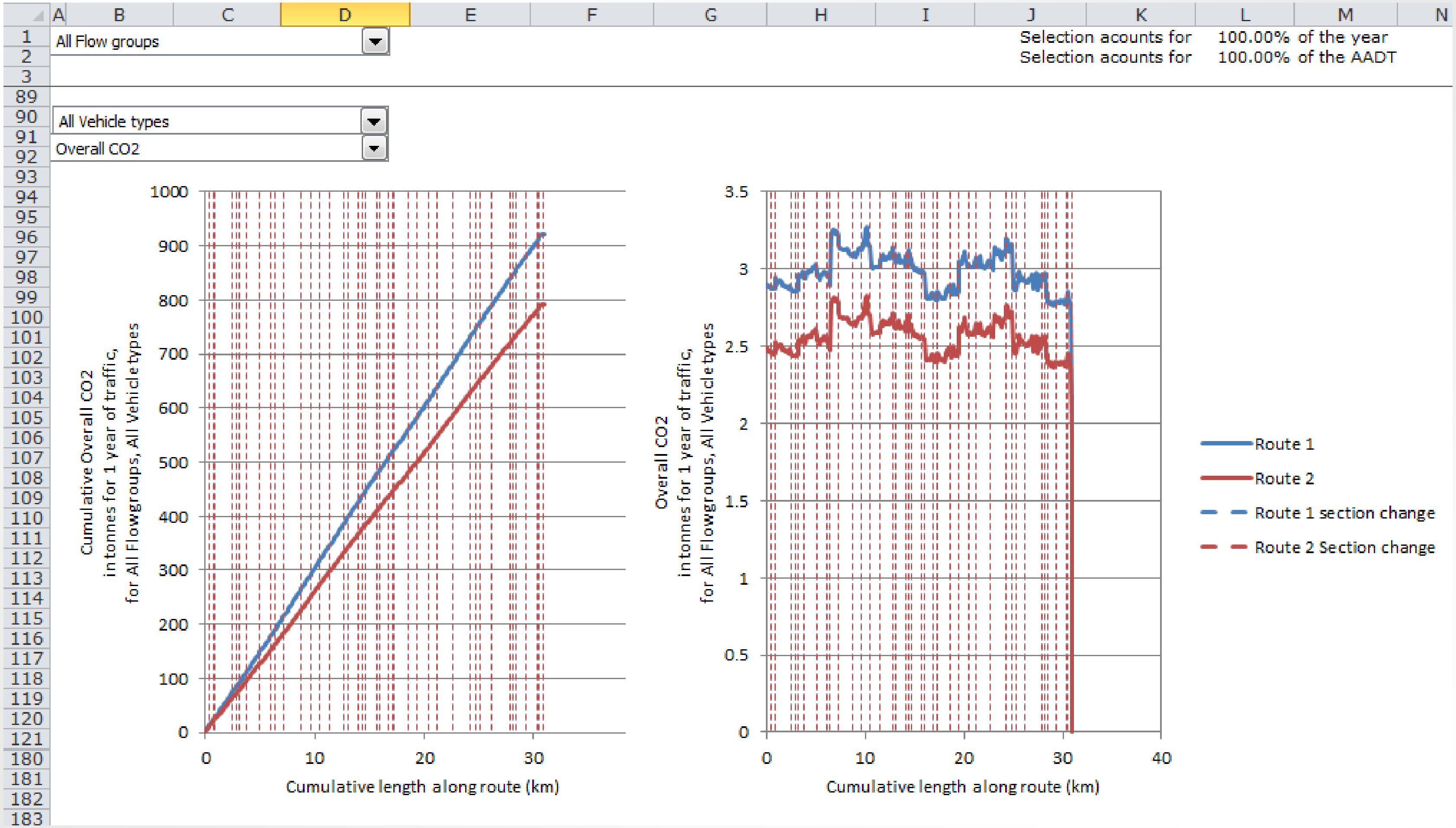
All Flow groups

Selection acounts for 100.00% of the
Selection acounts for 100.00% of the



	Average CO2 for route in tonnes for 1 year of traffic, for All Flow groups								
	All	Car (Petrol)	Car (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV	Truck and Trailer	Bus / Coach	Motorbike
Route 1 Constant speed	275,855.79	71,448.23	34,015.73	6,965.14	17,966.92	######	-	20,494.52	6,634.47
Route 2 Constant speed	289,224.64	75,137.45	35,772.13	7,492.70	19,327.80	######	-	21,334.85	6,977.04
Route 1 Idling	60,889.84	20,435.47	5,942.08	2,085.38	5,379.34	######	-	7,068.21	1,897.58
Route 2 Idling	-	-	-	-	-	-	-	-	-
Route 1 Total	336,745.63	91,883.71	39,957.81	9,050.52	23,346.27	######	-	27,562.72	8,532.04
Route 2 Total	289,224.64	75,137.45	35,772.13	7,492.70	19,327.80	######	-	21,334.85	6,977.04

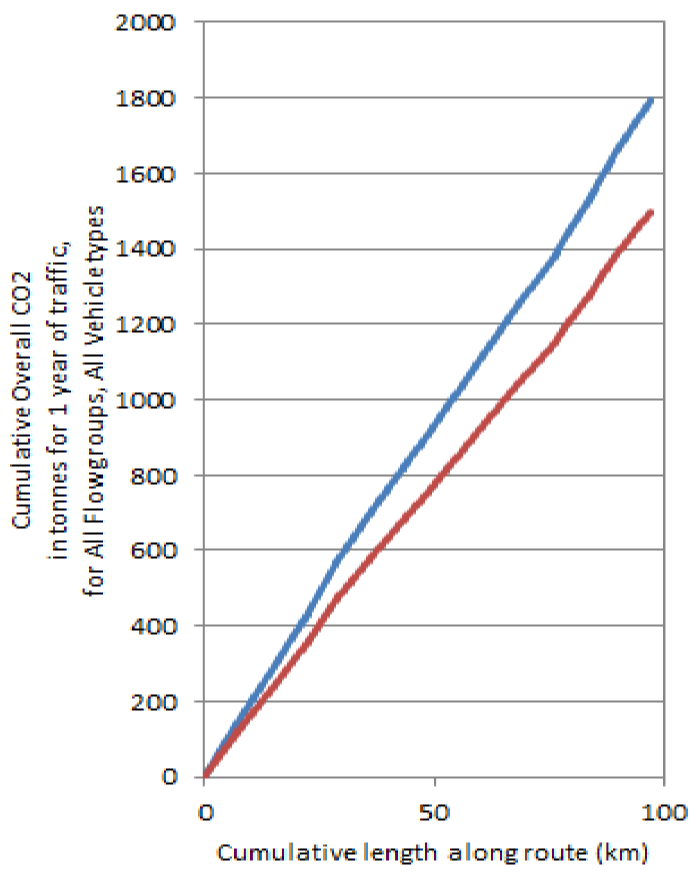
Output data

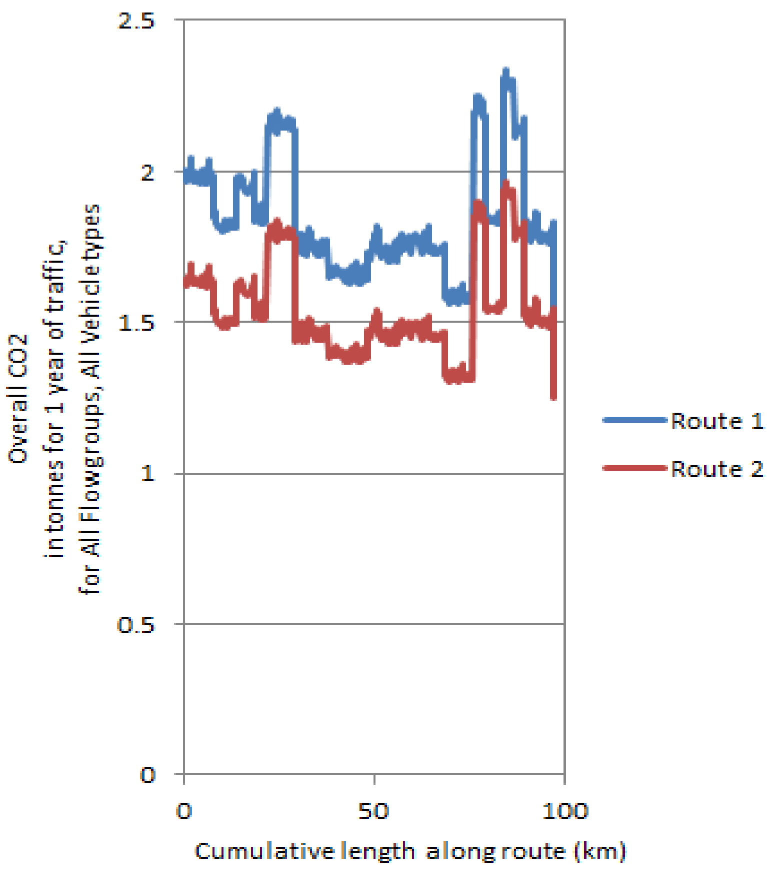

All Flow groups
Selection acounts for 100.00% of the year
Selection acounts for 100.00% of the AADT
All Vehicle types
Overall CO2
Cumulative Overall CO2 in tonnes for 1 year of traffic, for All Flowgroups, All Vehicle types
Cumulative length along route (km)
Overall CO2 in tonnes for 1 year of traffic, for All Flowgroups, All Vehicle types
Cumulative length along route (km)
Route 1
Route 2
Route 1 section change
Route 2 Section change

Scenario comparison

Example: part of the M25 motorway (London orbital)

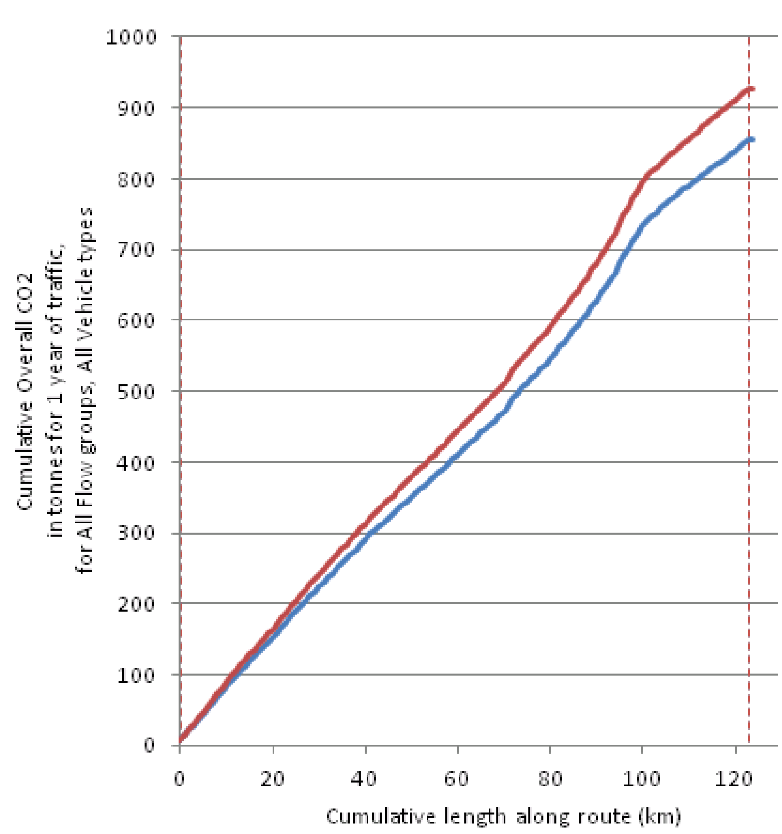
- Route 1: current speed limit
- Route 2: limited to 80km/h for all vehicles

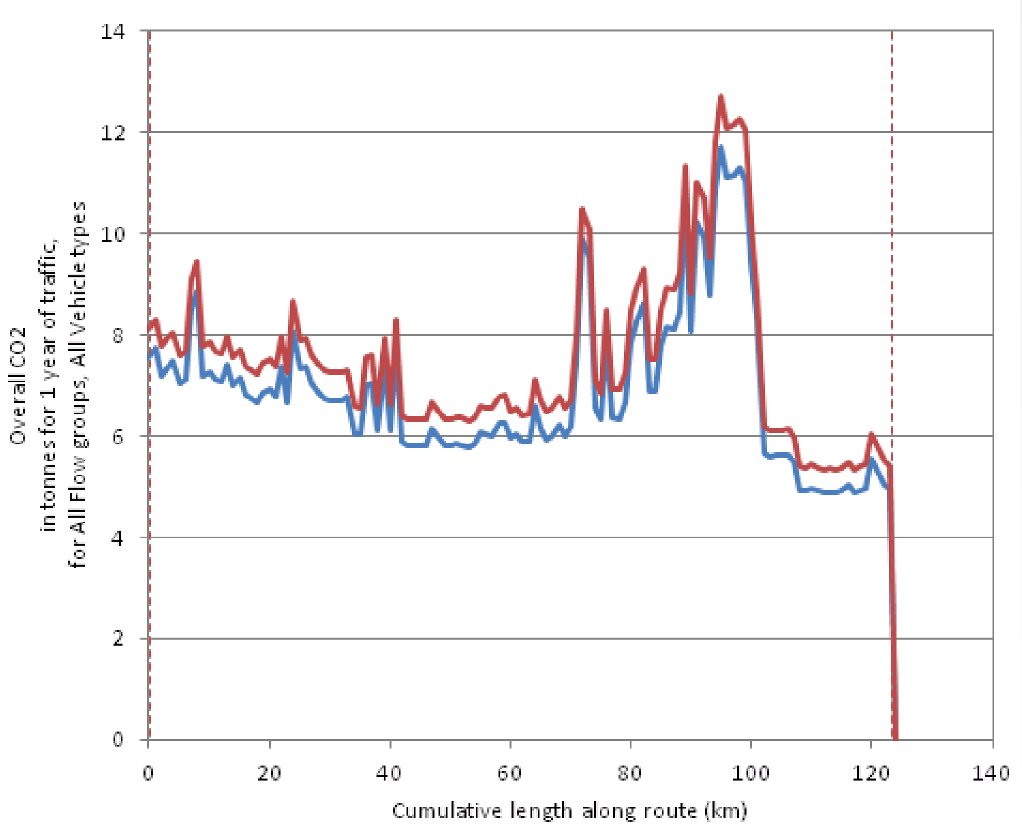




Effect of infrastructure

red: normal RR-coefficient
blue: half RR-coefficient





Results

Example results from selected scenarios

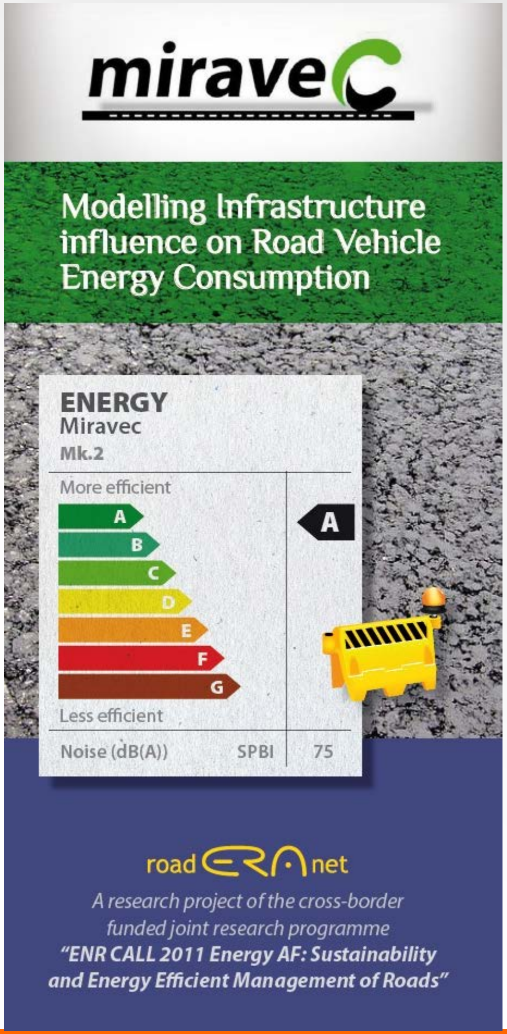
- Change in road layout:
  - Opening a 4th lane on a highly trafficked 3-lane motorway
  - CO_2 reduction between 14% and 17% due to decrease in the amount of idle time experienced
- Change in road alignment
  - Bypass to avoid going over a hill
  - Effect of greater length by far surpasses the effect of the reduction in gradients
- Change in MPD (network view)
  - Changes in MPD will only affect part of the network
  - However, emission reductions in the range of 2% are possible
- Changes in traffic volume and composition
  - Large effects possible
  - Combined analyses (e.g. introducing electric cars)
- Context is important for assessing the effectiveness of infrastructure measures, especially national fleet composition

road ERA net

Conclusion

Output of MIRAVEC

- the relevant effects and parameters for the infrastructure influence on road vehicle energy consumption
- their importance in different contexts
- the available modelling capabilities and
- their implementation in pavement and asset management



Thank you for your attention

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miraveC