KARAYOLLARI GENEL MÜDÜRLÜĞÜ

European Commission

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LCE4ROADS

LCE4ROADS Cases Studies

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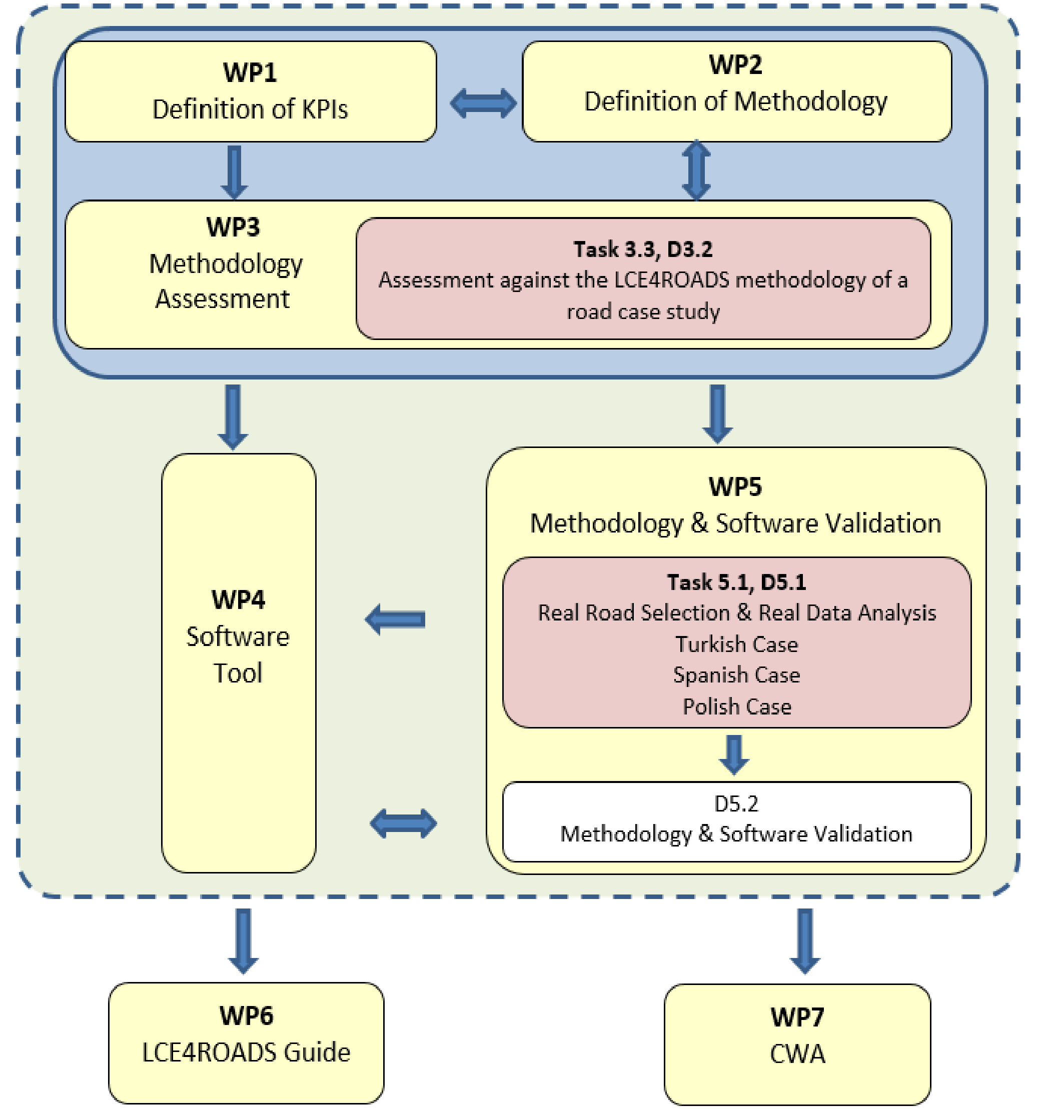

Real road cases studies have been carried out in both **WP3&WP5**

Life Cycle Engineering approach to develop
a novel EU-harmonized sustainability certification system
for cost-effective, safer and greener road infrastructures

TASK 3.3: Analysis and evaluation of road infrastructures.

Objective

The aim of this task is to analyse and evaluate the construction, maintenance, rehabilitation of road pavements against the LCE4ROARDS methodology. «**Deliverable D3.2 Assessment against the LCE4ROADS methodology of a road case study**» has been prepared.

The approach consists of two phases:

- first, a small case study is investigated in order to develop a first approach for any case study assessment.
- Second, a larger case study, has been

performed by KGM

TASK 3.3: Analysis and evaluation of road infrastructures

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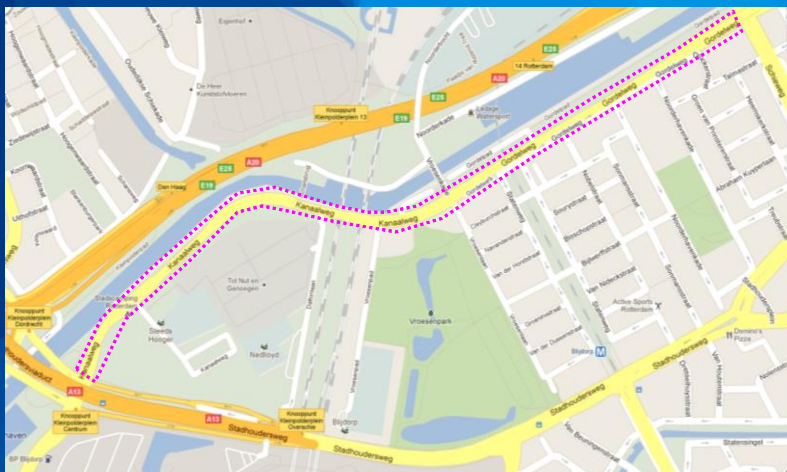
Small Case study – Asphalt Road – Project Rotterdam



Location of the Rotterdam project.

Project road profile			
Layer	Material	Thickness (m)	Mass (kg)
Top layer	Asphalt type W	0.025	727000
Adhesive layer	Bituminous layer	n/a	4838
Sub layer	AC Base	0.06	1818629
Adhesive layer	Bituminous layer	n/a	4838
Base layer	AC Bind	0.07	2121734
Scattering	Sand	n/a	15000

Project dimensions	
Length (m):	1728
Number of lanes:	2
Width of lanes (m):	3.5
Emergency lane (m):	0
Total width (m)	7
Total surface (m^2 – calculated from information above):	12096

Summary of KPIs results for Rotterdam project case

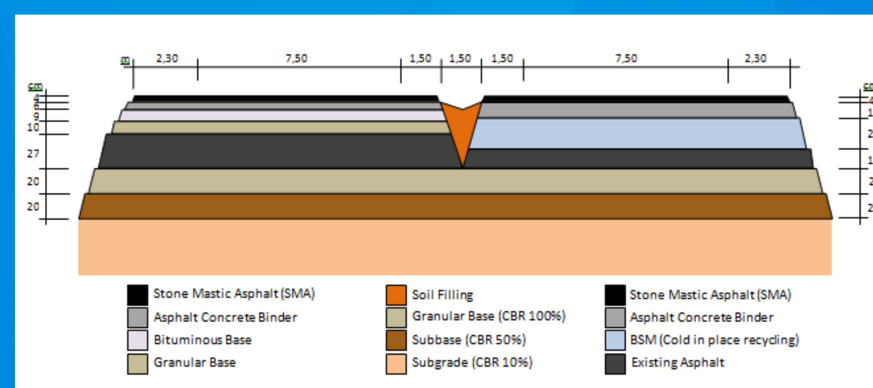
Sustainability pillar	Topic	Indicator	Data needed (examples: see next sheet)	#	Score	Unit
Technical	Durability	Period of service	Project life time	1	36	years
	Durability	Structural index #1	IRI	2	5	mm/m
	Durability	Structural index #2	Rut depth	3	2	mm
	Skid resistance	Skid resistance	Skid resistance can be measured in several ways and is expressed in deceleration (m/s^2)	4	5	m/s2
Environmental	Environmental impacts	LCA-indicators:	All amounts of materials used and processes needed to produce, apply and dispose materials over the project life time; LCA database needed			
		Abiotic depletion, excl energy carriers		5	3,08E+00	kg Sb eq
		Abiotic depletion, energy carriers		6	1,33E+04	kg Sb eq
		Acidification		7	6,11E+03	kg SO_2 eq
		Eutrophication		8	9,65E+02	kg PO_4^{3-} eq
		Global warming (GWP100)		9	9,78E+05	kg CO_2 eq
		Ozone layer depletion (ODP)		10	3,56E-01	kg CFC-11 eq
		Human toxicity		11	3,89E+05	kg 1,4-DB eq
		Fresh water aquatic ecotox.		12	1,22E+04	kg 1,4-DB eq
		Fresh water sediment ecotoxicity		13	2,87E+04	kg 1,4-DB eq
		Marine aquatic ecotoxicity		14	1,17E+08	kg 1,4-DB eq
		Marine sediment ecotoxicity		15	9,98E+07	kg 1,4-DB eq
		Terrestrial ecotoxicity		16	2,85E+03	kg 1,4-DB eq
		Photochemical oxidation		17	1,33E+03	kg C_2H_4
	Embodied Energy	MJ	Same as for LCA	18	unknown	MJ
	Resource efficiency	% recycled materials	% recycled of raw materials	19	50%	
	Resource efficiency	% recyclability of waste	% recyclability of waste streams	20	0%	
	Biodiversity	Biodiversity index	Number of organisms present at the project location	21	unknown	
			Number of species present at the project location	22	unknown	
Economic	Total costs	Life cycle costs	All amounts of materials used and processes needed to produce, apply and dispose materials over the project life time; also use & maintenance costs; cost database needed; discount factor + inflation rate needed.	23	673.700	€€
Social	Noise	Noise exposure to number of people	People that are exposed to a physical level of 55 dB(A) during den-period (day-evening-night)	24	unknown	
			People that are exposed to a physical level superior to 50 dB(A) during night-period	25	unknown	
	Comfort	IRI/macrotexture	IRI of top layer	26	5	mm/m
	Safety	Risk of accidents	Amount of accidents (during projetc life time)	27	unknown	
	Hindrance	Lost travel hours	Traffic intensity, speed limit, maintance planning (week or weekend, duration in days and hours/day), type of road block, etc; hindrance model needed	28	240300	euros
Climate resilience	Vulnerability	Probability (%)	Vulnerability to sea level increase	29	unknown	%
			Vulnerability to sea extreme temperatures	30	unknown	%
			Vulnerability to extreme floods	31	unknown	%
	Measures	Measures taken (yes/no & description)	Project information: has there been measures taken to protect against sea level increase?	32	no	
			Project information: has there been measures taken to protect against sea extreme temperatures?	33	no	
			Project information: has there been measures taken to protect against extreme floods?	34	no	
	Expenditures	% of project budget	% of budget allocated/reserved/spent on climate resilience	35	0%	

Big Case study - Asphalt Road
Ankara – İstanbul State Road

General information

Project dimensions	
Length (m):	3500
Number of lanes:	2
Width of lanes (m):	3,75
Emergency lane (m):	2,3
Total width (m):	11,3
Total surface area (m²):	39550

SMA Wearing Course	4 cm
AC Binder course	6 cm
Regulating Binder	avg. 6 cm
Base course stabilized with bitumen/Cold-recycling in place	25 cm



Summary of KPIs results for Turkish road case

Domain	Topic	Indicator	Type of data needed	Value	Unit
Technical	Durability	Period of service	Project life time	36	years
	Durability	Structural index #1	IRI, ASTM E950	2,5	mm/m
	Durability	Structural index #2	Rut depth, EN ISO 13036-8/7	30	mm
	Safety	Skid resistance	Skid resistance, ASTM E274/E274M	30	SN
Environmental	Environmental impacts	LCA-indicators:	All amounts of materials used and processes needed to produce, apply and dispose materials over the project life time; LCA database needed		
		Abiotic depletion, excluding energy carriers		3,08E+00	kg Sb eq
		Abiotic depletion, energy carriers		1,33E+04	kg Sb eq
		Acidification		6,11E+03	kg SO_2 eq
		Eutrophication		9,65E+02	kg PO_4^{3-} eq
		Global warming (GWP100)		9,78E+05	kg CO_2 eq
		Ozone layer depletion (ODP)		3,56E-01	kg CFC-11 eq
		Human toxicity		3,89E+05	kg 1,4-DB eq
		Fresh water aquatic ecotox.		1,22E+04	kg 1,4-DB eq
		Fresh water sediment ecotoxicity		2,87E+04	kg 1,4-DB eq
		Marine aquatic ecotoxicity		1,17E+08	kg 1,4-DB eq
		Marine sediment ecotoxicity		9,98E+07	kg 1,4-DB eq
		Terrestrial ecotoxicity		2,85E+03	kg 1,4-DB eq
		Photochemical oxidation		1,33E+03	kg C_2H_4
	Embodied Energy	MJ	Same as for LCA	4,09E+07	MJ
	Resource efficiency	% recycled materials	% recycled of raw materials	50%	
	Resource efficiency	% recyclability of waste	% recyclability of waste streams	0%	
	Biodiversity	Biodiversity index	Number of organisms present at the project location	unknown	
			Number of species present at the project location	unknown	

Domain	Topic	Indicator	Type of data needed	Value	Unit
Economic	Total costs	Life cycle costs	All amounts of materials used and processes needed to produce, apply and dispose materials over the project life time; also use & maintenance costs; cost database needed; discount factor + inflation rate needed.	1.507.439,69	€
Social	Noise	Noise exposure to number of people	People that are exposed to a physical level of 55 dB(A) during den-period (day-evening-night)	unknown	
			People that are exposed to a physical level superior to 50 dB(A) during night-period	unknown	
	Comfort	IRI/macrotexture	IRI of top layer	2,5	mm/m
	Safety	Risk of accidents	Amount of accidents (during project life time)	unknown	
	Hindrance	Lost travel hours	Traffic intensity, speed limit, maintenance planning (week or weekend, duration in days and hours/day), type of road block, etc.; hindrance model needed	0	€
Climate resilience	Vulnerability	Probability (%)	Vulnerability to sea level increase	unknown	%
			Vulnerability to sea extreme temperatures	unknown	%
			Vulnerability to extreme floods	unknown	%
	Measures	Measures taken (yes/no & description)	Project information: has there been a measure taken to protect against sea level increase?	no	
			Project information: has there been a measure taken to protect against sea extreme temperatures?	no	
			Project information: has there been a measure taken to protect against extreme floods?	no	
	Expenditures	% of project budget	% of budget allocated/reserved/spent on climate resilience	0%	

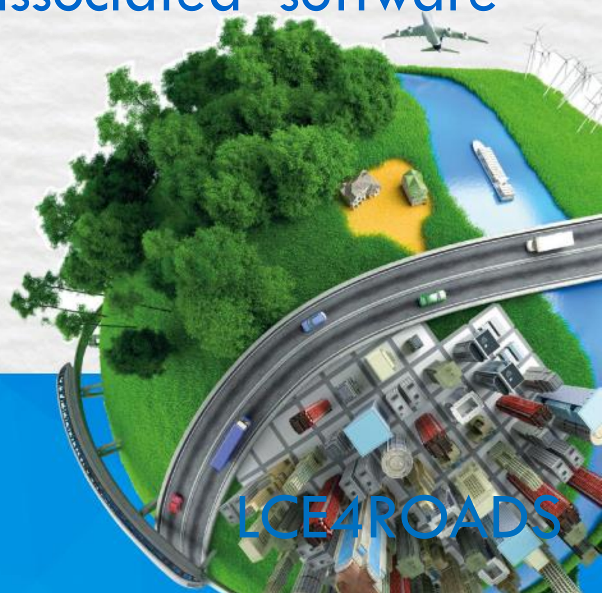
TASK 5.1:Selection of the real road cases for construction and maintenance so as to validate the software tool.

Deliverable 5.1

Real Road Cases Selection and Real Data Analysis for the Validation of the LCE4ROADS Methodology and Software Tool

Objective

The main objective is to select real road project cases to obtain reliable results for the necessary evaluation and comparison while covering the widest European area as possible and properly validate the LCE4ROADS methodology and associated software tool.



TASK 5.1:Selection of the real road cases for construction and maintenance so as to validate the software tool.

- **KGM**
  Asphalt road TEN-T → -traditional - WMA → Data collecting → analysis & assessments
- **IECA**
  Concrete road → traditional → Data → analysis & assessments
- **INVESTEKO** and **NAPE**
  Asphalt road Expressway → traditional → Data → analysis & assessments

Deliverable 5.1

TASK 5.1:Selection of the real road cases for construction and maintenance so as to validate the software tool.

European area

Aiming at covering the widest European area as possible and the most representatives of the widely implemented road infrastructures, *KGM*, *IECA*, *INVESTEKO* and *NAPE* have selected road cases from their road network: Turkey, Spain and Poland, respectively.

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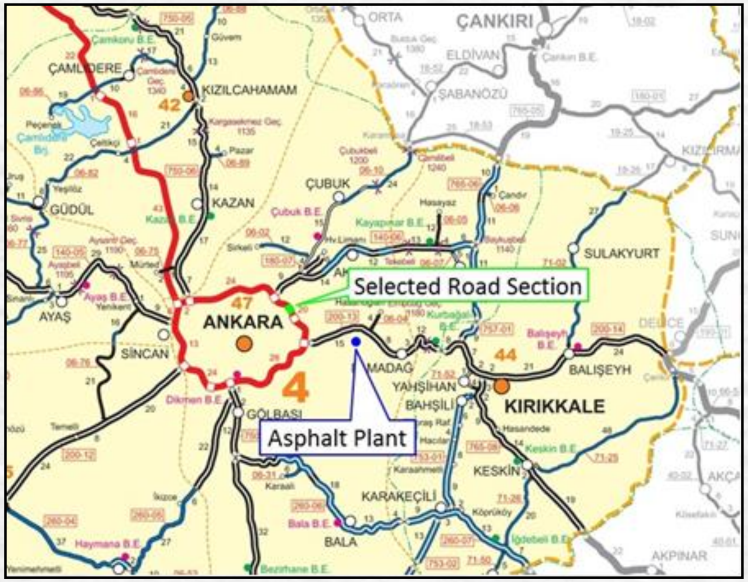
DELIVERABLE 5.1

Information on Selected Road Cases

Partner	Country	Road Type	Road Network	Pavement Type	Length, m	Mixture Type
KGM	Turkey	Motorway, 2x4	TEN-T	Asphalt	800	Traditional
KGM	Turkey	Motorway, 2x4	TEN-T	Asphalt	800	WMA
IECA	Spain	Highway, 2x4	National road	Concrete	912	Traditional
INVESTEKO, NAPE	Poland	Expressway	National road	Asphalt	15600	Traditional

D5.1 - Turkish Road Case Study - Asphalt Road

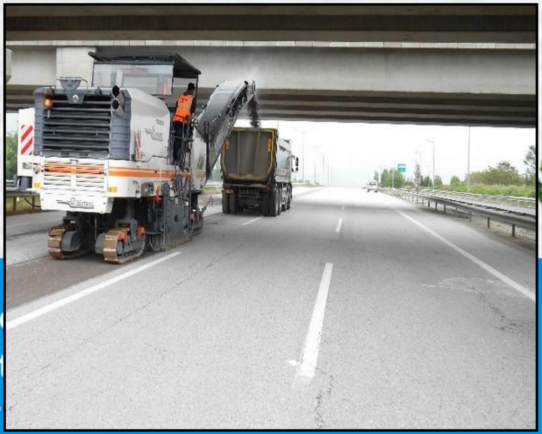


Length of the Ankara ring road	110 km
Construction, year	1997
Rehabilitation, year	June 2015
Length of the selected sections	800+800m

D5.1 - Turkish Road Case Study - Asphalt Road

Summary of the scope of certification

Type of certificate	Complete version
Certification stage	After construction, CS2
LCE stages assessed	Extraction, production, construction, maintenance, end-of-life
LCE stages omitted	Use stage is omitted due to lack of information.
Data collection	All data during the construction has been collected. And after opening to traffic, IRI and skid resistance measurement have been taken
Relevant KPIs	Environmental, economic, social, technical



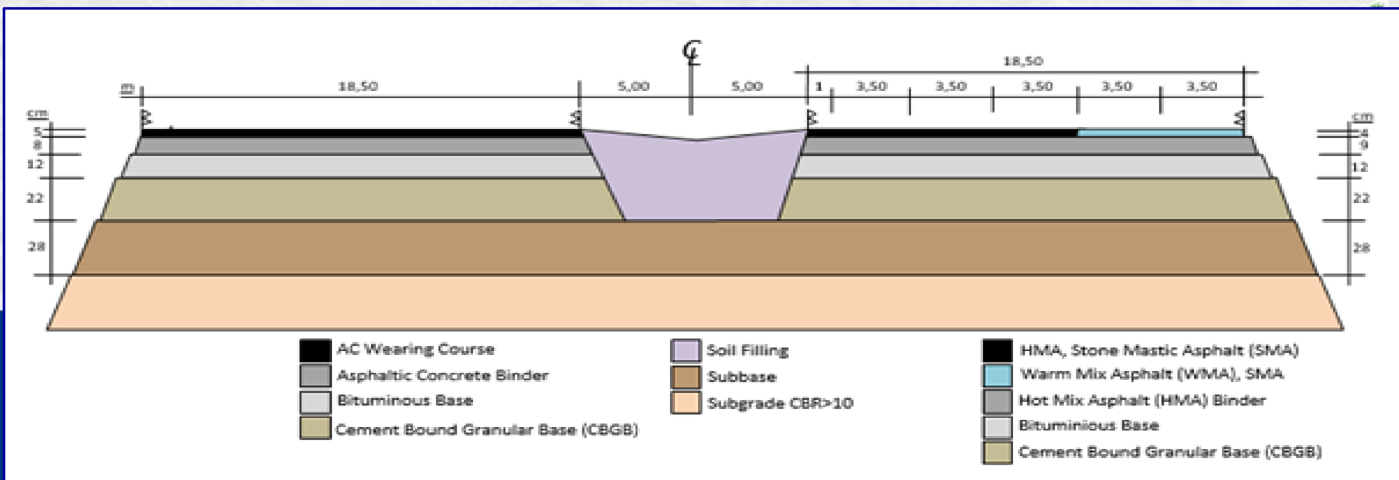
D5.1 - Turkish Road Case Study - Asphalt Road

Data for LCA analysis – WMA road section

1. Road Section Information				
Km	O20/11/200 – O20/11/1000			
Length	800 m			
Paved Cross Section,7m	3,5m emergency lane + 3,5m right lane			
Number of Lane	2			
2. Amount and Cost of Pavement & Pavement Layer Thickness				
Type of Layer	Thickness	Amount of mix. (ton)	Opt. bitumen (%)	Unit Price
WMA, SMA Wearing Course	4 cm	538	7,5	
AC Binder Course	9 cm	1210	3,9	
Milling of old asphalt	13 cm	1747	-	
Total emulsion amount for tack coat (ton)	-	2,80	-	-

Data for LCA analysis – HMA road section

1. Road Section Information				
Km	O20/11/1000 – O20/11/1800			
Length	800 m			
Paved Cross Section,7m	3,5m emergency lane + 3,5m right lane			
Number of Lane	2			
2. Amount and Cost of Pavement & Pavement Layer Thickness				
Type of Layer	Thickness	Amount of mix. (ton)	Opt. bitumen (%)	Unit Price
HMA, SMA Wearing Course	4 cm	538	7,5	
AC Binder Course	9 cm	1210	3,9	
Milling of old asphalt	13 cm	1747	-	
Total emulsion amount for tack coat (ton)	-	2,80	-	-



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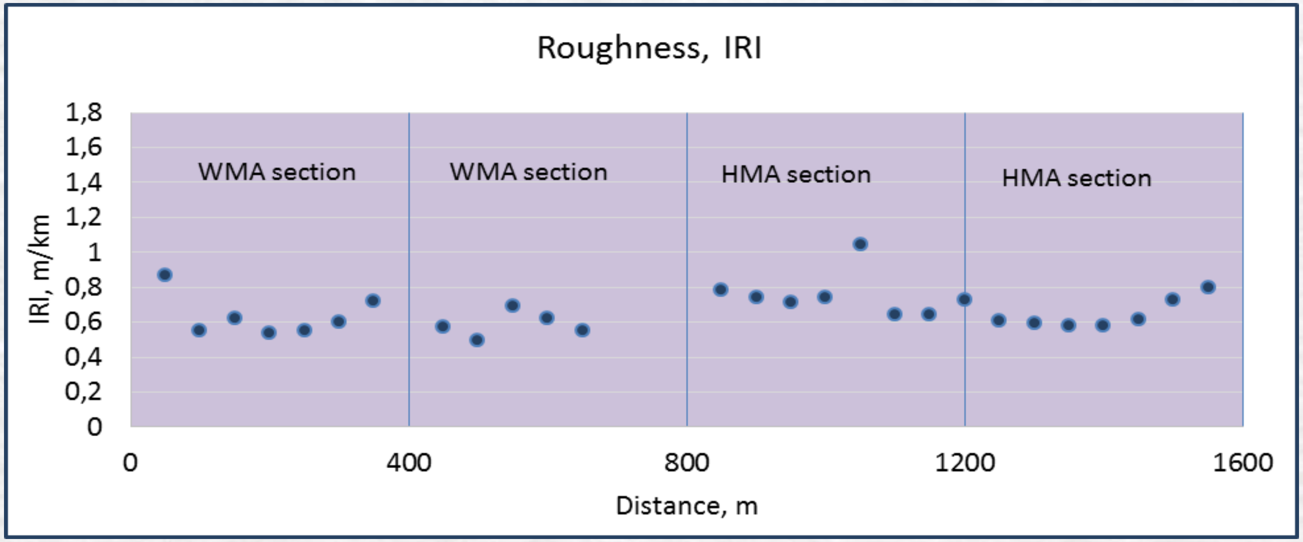
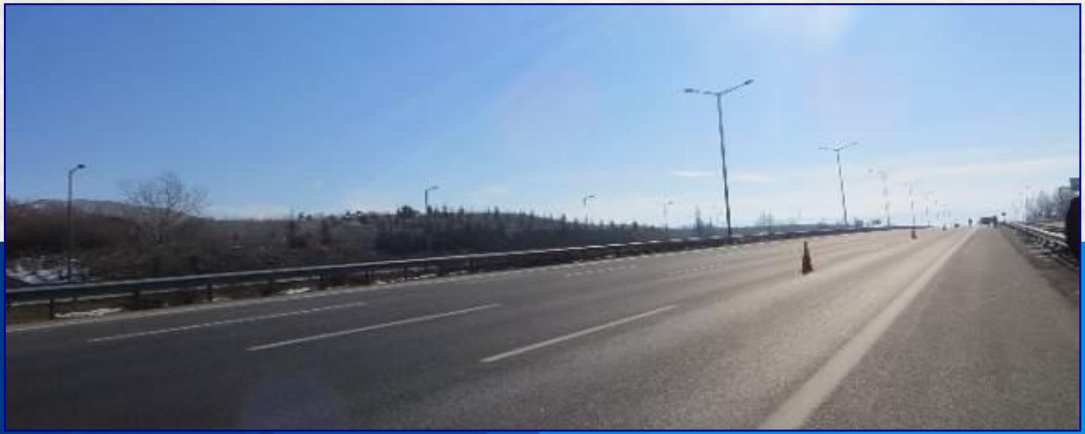
D5.1 - Turkish Road Case Study - Asphalt Road

Technical KPIs results for Turkish road cases

Roughness measurement of road cases



Measurements on both WMA and HMA sections have been taken on the SMA surface layer in February 2016.



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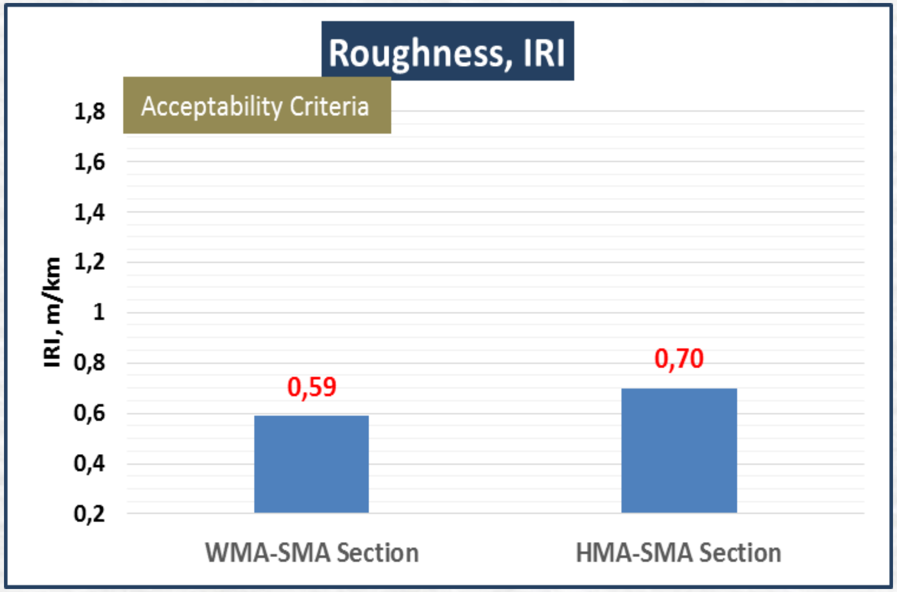
D5.1 - Turkish Road Case Study - Asphalt Road

Average roughness of WMA and HMA sections



D5.1 - Spanish Road Case Study - Cement-based Road

In Spain, the concrete road between Vic and Ripoll has been selected by **IECA** as a real case study of a concrete road. The road is divided road into four lanes for each direction (2X4).

IECA has selected a concrete road case with two road sections,

- inside a tunnel (676 m) and
- an open-pit section of 236 m long.

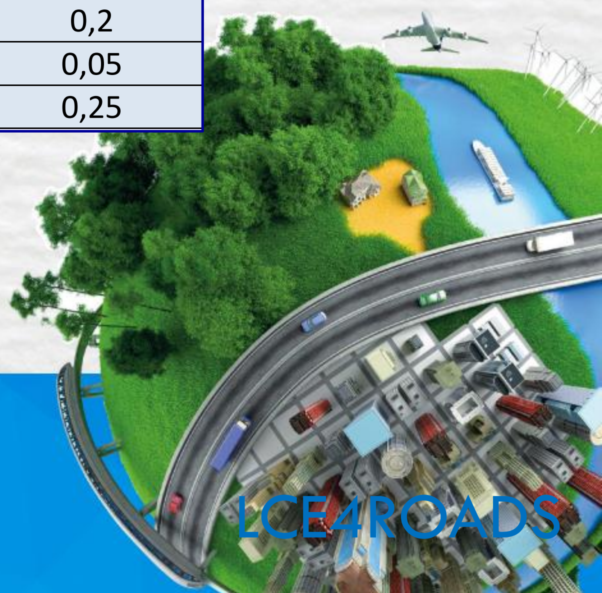
Both sections are a two-layer concrete pavement with exposed aggregate texture.

D5.1 - Spanish Road Case Study - Cement-based Road

General information about Spanish road case

Geometry of the road	
Section length (m)	912
Number of lanes in one direction (without emergency lane)	2
Lane width (m):	3,5
Lane width of the emergency lane (m):	2,5
Total pavement width in one direction (m):	10,5
Total pavement surface [m2]	9576

Pavement design		
Layers	*Material - name*	*Thickness (m)*
Wearing course	Concrete wearing course	0,05
Base course	concrete base course	0,2
Subbase course	Mixture AC20	0,05
Subgrade course	Stabilized soil	0,25



D5.1 - Spanish Road Case Study - Cement-based Road

Geometry of the road	
Section length (m)	912
Number of lanes in one direction (without emergency lane)	2
Lane width (m):	3,5
Lane width of the emergency lane (m):	2,5
Total pavement width in one direction (m):	10,5
Total pavement surface [m2]	9576

Pavement design		
Layers	*Material - name*	*Thickness (m)*
Wearing course	Concrete wearing course	0,05
Base course	concrete base course	0,2
Subbase course	Mixture AC20	0,05
Subgrade course	Stabilized soil	0,25

D5.1 - Spanish Road Case Study - Cement-based Road

Technical KPIs results for Spanish road case

IRI measurement

% of hectometres whose IRI value is under:	Right lane			Left lane		
	IRI left	IRI right	IRI middle	IRI left	IRI right	IRI middle
<1,5	50%	80%	70%	50%	50%	50%
<1,8	70%	90%	80%	70%	70%	70%
<2	80%	100	100%	90%	90%	100%
<2,5	100%	100	100%	100%	100%	100%
<3	100%	100	100%	100%	100%	100%
<3,5	100%	100	100%	100%	100%	100%

Transverse friction coefficient values

Transverse friction coefficient (average value)	Right lane	Left lane
% of total length	77,0	75,6
CRT < 60	0 %	0 %
60 > CRT > 65	0 %	0 %
CRT > 65	100 %	100 %

Noise measurement

(Close-Proximity Method values at 80 and 100 km/h)

Stretch	Characteristics	Noise dBA	
		80 Km/h	100 Km/h
1	Inside tunnel 1 (297 m long)	99	103
2	Inside tunnel 2 (379 m long)	99	103
3	Open-pit	99	102

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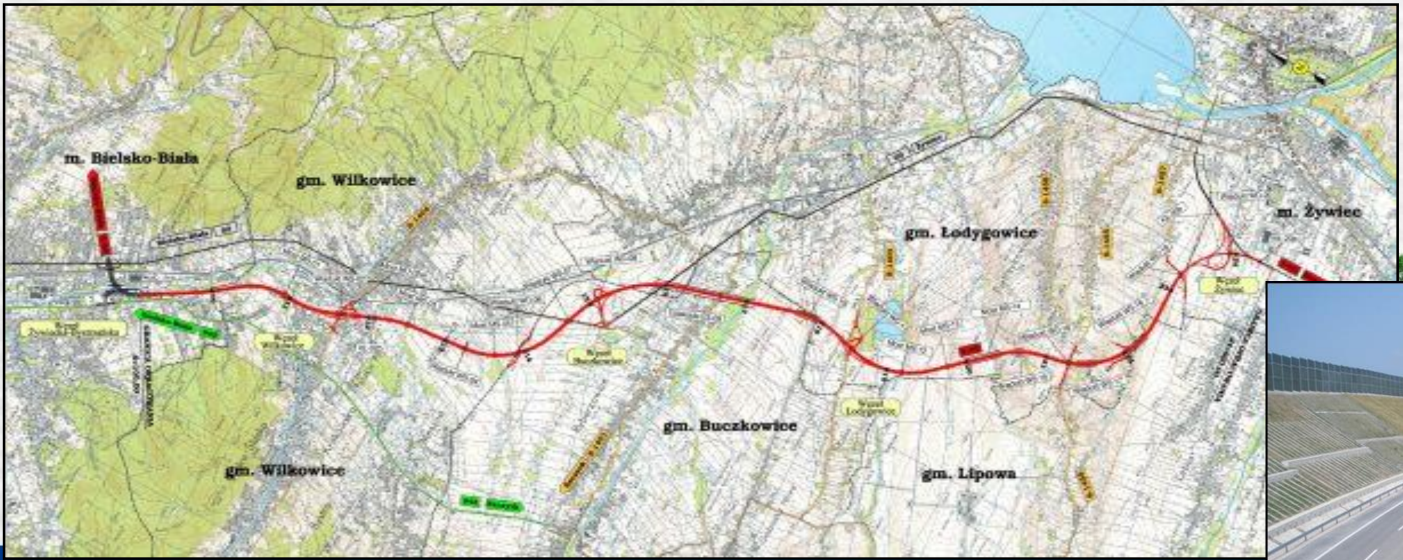
D5.1 - Polish Road Case Study - Asphalt Road

The selected case study is an expressway section of 15,6 km situated in the Southern Poland, Silesia Region. It is a pass between two important cities Bielsko-Biala and Zywiec, lying in the mountain range of Silesia Beskids. Poland is generally a flat region, with only little part of mountainous terrain, therefore this road situation may be considered as typical. However, LCE4ROADS methodology focuses only on pavements, and pavement used in this project is a typical construction for Poland – **asphalt pavement.**



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D5.1 - Polish Road Case Study - Asphalt Road

Geometry of the road

Geometry of the road	
Section length (m)	15 600
Number of lanes in one direction (without emergency lane)	2
Lane width (m):	3.5
Lane width of the emergency lane (m):	2.5
Total pavement width in one direction (m):	10.5
Total pavement surface [m2]	327600

D5.1 - Polish Road Case Study - Asphalt Road

Waste generated on the construction site

	Name of the waste	Quantity [ton]	Hazardous waste [Yes/No]	Procedures related to the waste generated on construction site (standard)
1	Tetrachloroethylene + asphalt (residue after the extraction) - waste code 160305	0.0053	Yes	Waste act of 14 December 2012 (2013-2015)
2	Packaging containing hazardous substances - waste code 150110	0.08	Yes	Waste act of 14 December 2012 (2013-2015)
3	Concrete waste and concrete rubble from demolitions and renovations - waste code 170101	1785.1	No	Waste act of 14 December 2012 (2013-2015)
4	Iron and steel - waste code 170405	23.774	No	Waste act of 14 December 2012 (2013-2015)
5	Construction materials containing asbestos - waste code 170505	4.53	Yes	Waste act of 14 December 2012 (2013-2015)
6	Mixed waste from construction and demolition other than those mentioned in the waste code 170901, 170902, 170 903 - waste code 170904	5650	No	Waste act of 14 December 2012 (2013-2015)
7	Municipal waste not listed in other subgroups - waste code 200399	20.72	No	Waste act of 14 December 2012 (2013-2015)
8	Insulation materials other than those mentioned in the waste code 170602 and 170603 - waste code 170604	2.084	No	Waste act of 14 December 2012 (2013-2015)
9	Wood	6.1	No	Waste act of 14 December 2012 (2013-2015)
10	Mixed packaging waste - waste code 150106	13.6	No	Waste act of 14 December 2012 (2013-2015)

D5.1 - Polish Road Case Study - Asphalt Road

Economic KPIs results for Polish road case

Cost of the materials used in the construction of each layer

Layer	*Material - name*	*Thickness (m)*	*Density (kg/m3)*	*Cost [PLN/m2]*
Wearing course	bituminous mix SMA 11 45/80-55	0.04	2498	31.04
Binder course	bituminous mix AC WMS 16 25/55-60	0.08	2540	50.39
Base course	bituminous mix AC WMS 16 Bitrex 35/50	0.14	2420	75.37
Subbase	mixture of crushed aggregate 0/31,5 mm	0.3	2720	20.87
Antifrost layer	mixture of natural aggregate 0,31,5 mm	0.3		22.78
Improved subgrade layer (m2)	ash-slag mixture UTEX BP 5	0.15	1490	8.08
Other layers	lime stabilised subgrade at depth of 0,5 m	0.5	not applicable	13.35

Conclusion

- **KGM, TNO, INVESTEKO** and **NAPE** selected five asphalt road projects while **IECA** selected a concrete road project.
- In these cases studies, in accordance with the LCE4ROADS methodology and KPIs list, required data for complete certification try to collect for the selected road cases. As a result, not only data about materials, courses, transport and costs during construction but also data about pavement characteristics (IRI, skid resistance, noise, surface texture) after road construction were collected.

- It was not possible to calculate economic KPIs for all the selected real road cases. As a national road authority, only **KGM could access to economic KPIs; other partners could not collect all the economic data.**

Conclusion

CERTIFICATION STAGES		
CS1	CS2	CS3
Planning and design	Construction	Operation

- Case studies are carried out for **CS2**, After-Construction stage.

- It is thought that there would be no difficulty to collect data or to perform the necessary measurements regarding the environmental, social, economic and technical KPIs in case road authorities require the need to have a LCE certificate in their bidding contracts.

Conclusion

CERTIFICATION STAGES		
CS1	CS2	CS3
Planning and design	Construction	Operation

- However, for the **CS3**, Operation stage, in case **the operator is a private company**, it would be possible if it is required to have LCE certificate in the contract.

- **If the operator is the road authority**, it is thought that it would be difficult to have LCE certificate because their priority is usually the road construction and maintenance activities, especially for the countries with high workload and/or low budget.

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