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Research title:

Evaluation of Ecologic and Economic Impact of Composite Materials During the Road Constructions Life Cycle

Content

1. General description of the research topic
2. Life Cycle Analysis (LCA) methodology state-of-art
3. Environmental Impact Assessment – Case Study

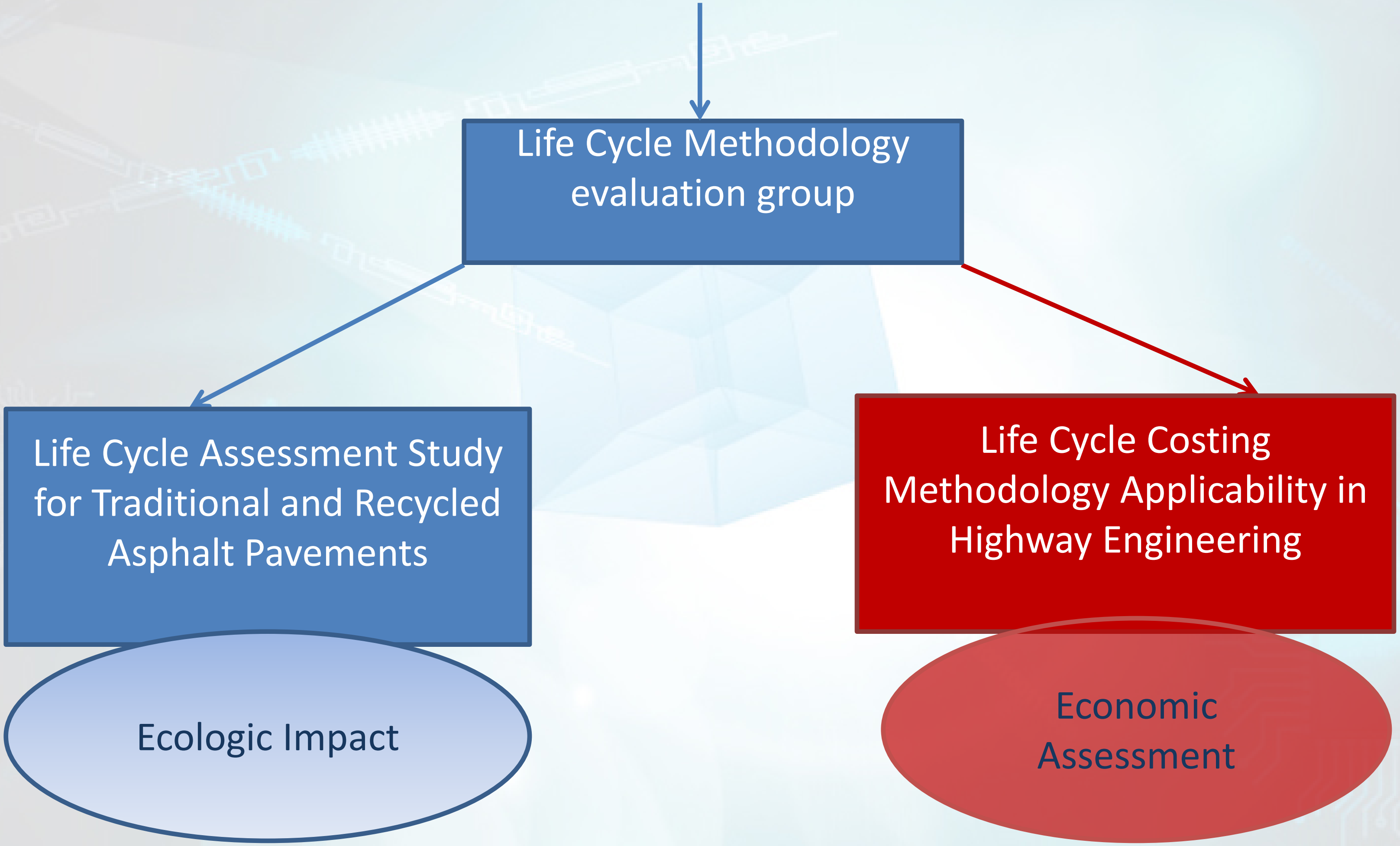
Evaluation of Ecologic and Economic Impact of Composite Materials during the Life Cycle of Road Constructions

Objective: development of an evaluation frame for composite materials used in roads construction process that complies with the sustainability process and life cycle analysis methodology.

The research implies:

1. Usage of a methodology: Life Cycle Analysis (LCA), Life Cycle Cost (LCC)
2. A computer software applicability: asPECT – Asphalt Pavement Embodied Carbon Tool
3. A product system: experimental road pavement structure
4. Data, values: from the local roads construction company

Evaluation of Ecologic and Economic Impact of Composite Materials during the Life Cycle of Road Constructions



LIFE CYCLE ANALYSIS METHODOLOGY

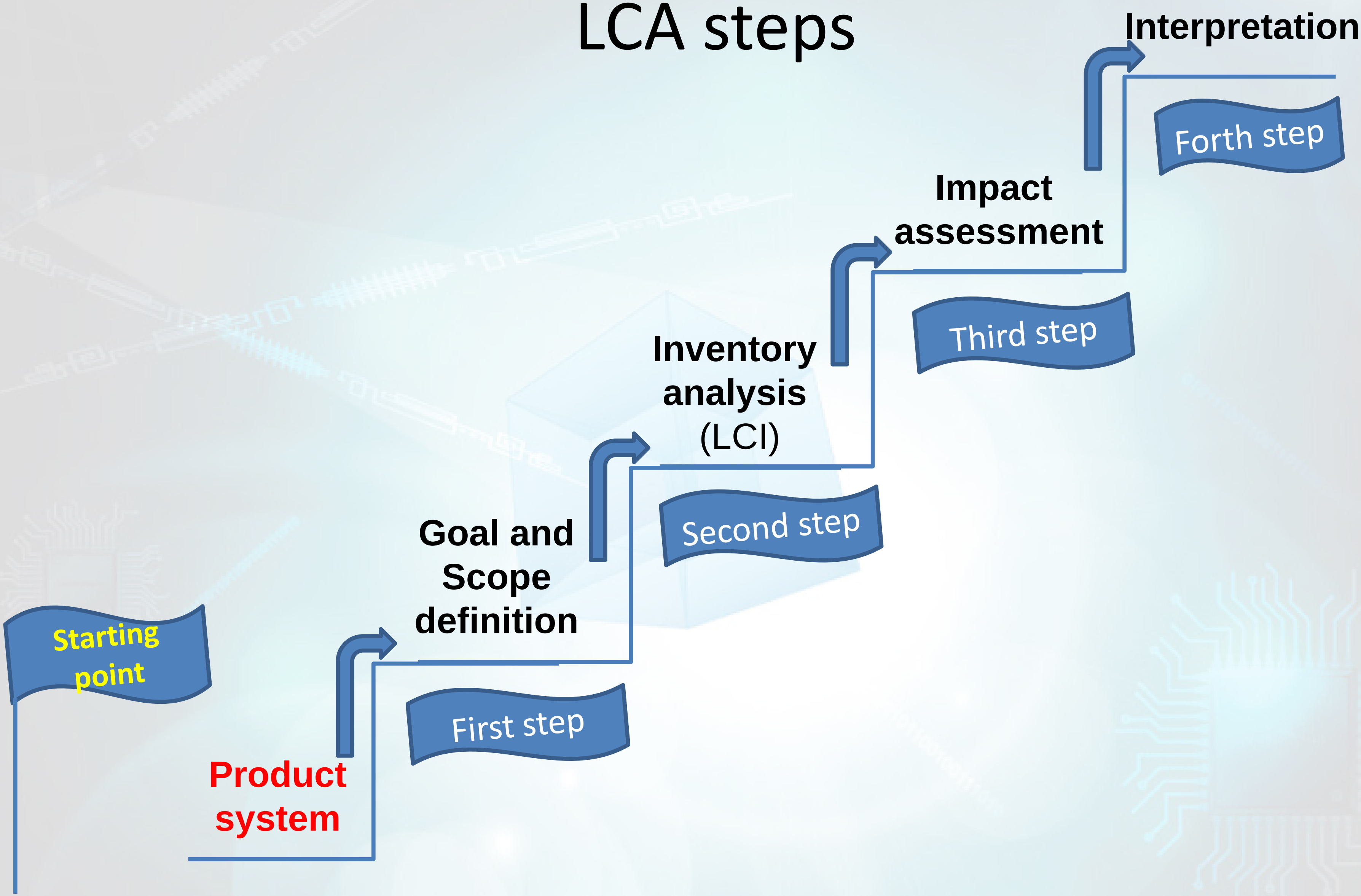
Definition (ISO 14040): LCA represents the compilation and evaluation of the inputs, outputs and the potential **environmental impacts** of a **product system** throughout its **life cycle**.

LCA implies:

- Identifying opportunities to improve the environmental performance of products at various points in their life cycle,
- Informing decision-makers in industry, government and organizations in the area of strategic planning, priority setting, product design or redesign,
- Selection of indicators for environmental performance,
- Marketing as for implementing an ecolabel scheme, making an environmental claim, producing an environmental product declaration.

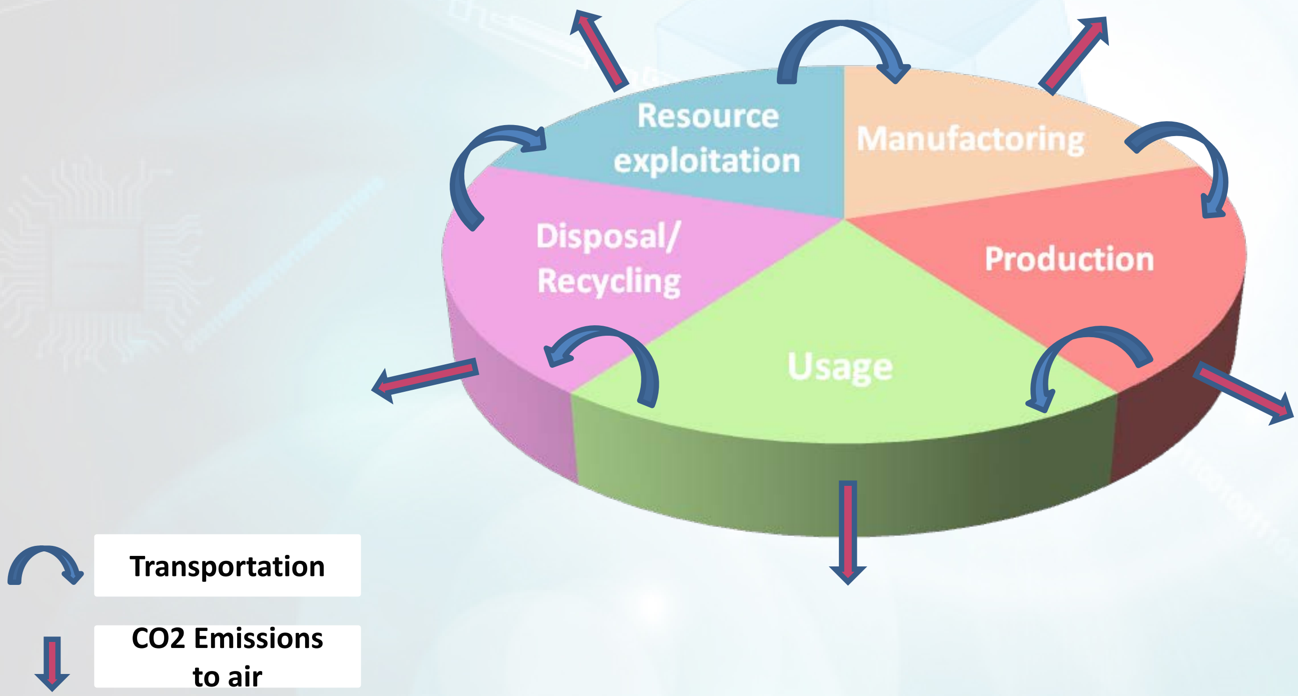
It is sustained by ISO Standards.

LCA steps

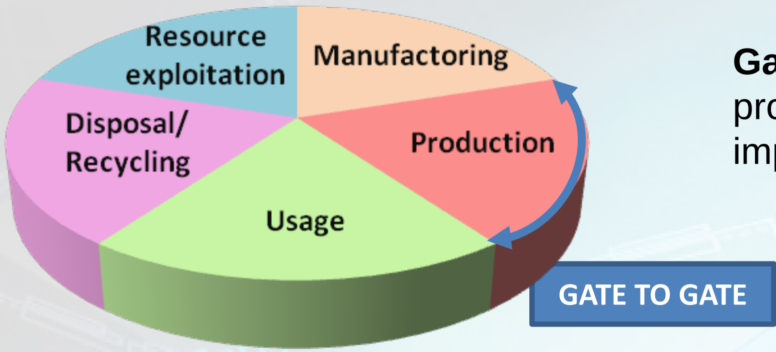

Interpretation
Forth step
Impact assessment
Third step
Inventory analysis (LCI)
Second step
Goal and Scope definition
First step
Starting point
Product system

All product systems under Life Cycle Analysis are evaluated in a „cradle to“ perspective. Depending on the extent of the analysis performed (the system phases that are included) the perspective can differ.

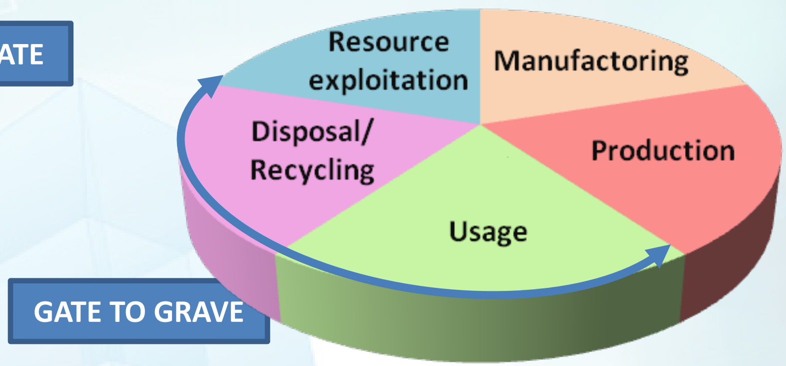
Product system life cycle phases:



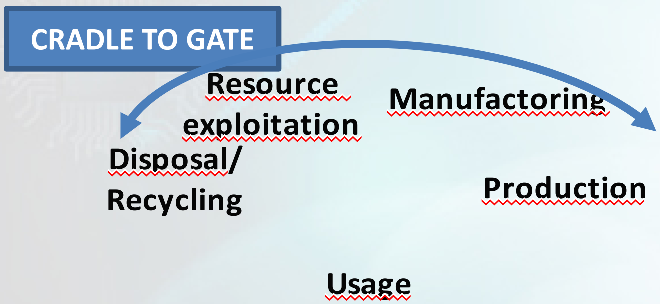
„Cradle to“ perspectives:



Gate to Gate: implies the processes that take place in the production phase, in order to establish the ecological impact for a single production step.

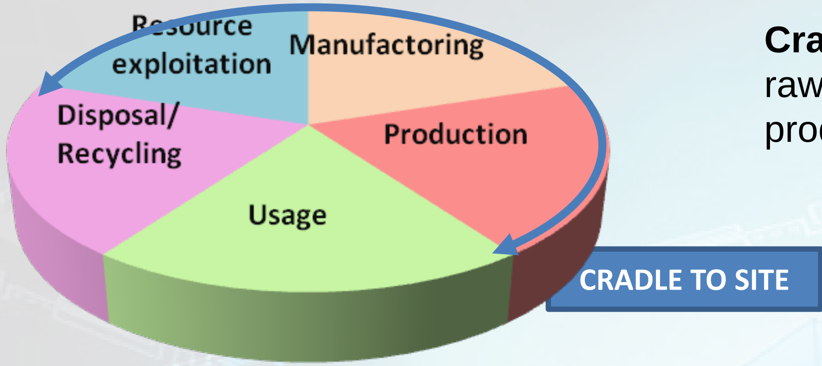


Gate to Grave: starts with the product usage phase (the moment when the product leaves the plant) till the end of the service life;



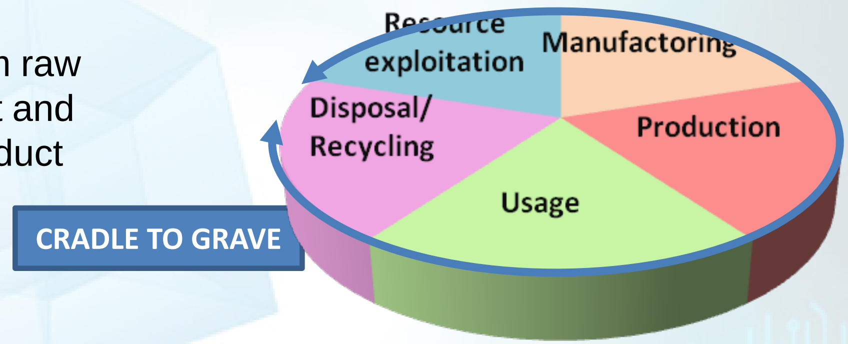
Cradle to Gate: designates the process phases starting with raw materials extraction till production (plant gate)

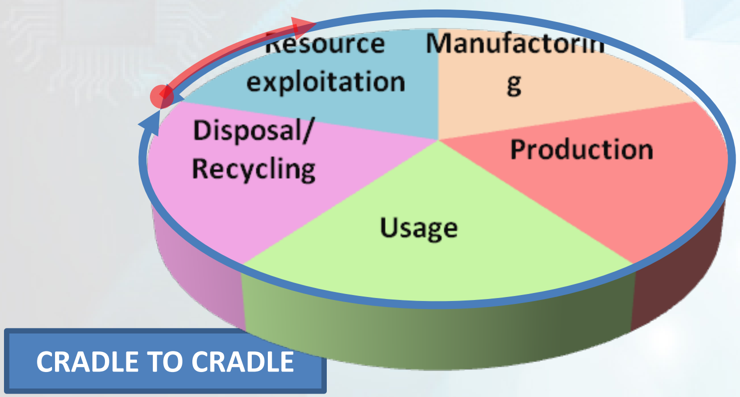
„Cradle to" perspectives:



Cradle to Site: characterises the process starting with raw materials extraction phase, their transport to plant, production and transport to site;

Cradle to Grave: contains the process chain from raw materials extraction towards production, transport and usage phase, including specific activities to a product end of life;

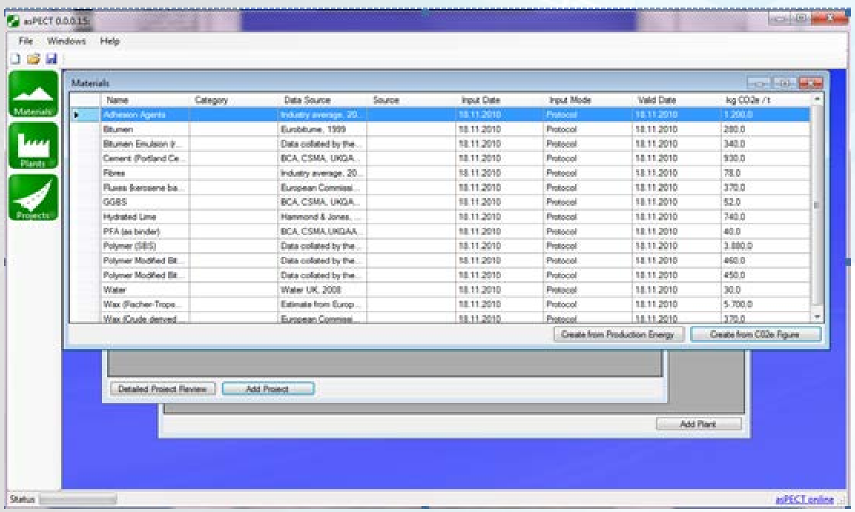


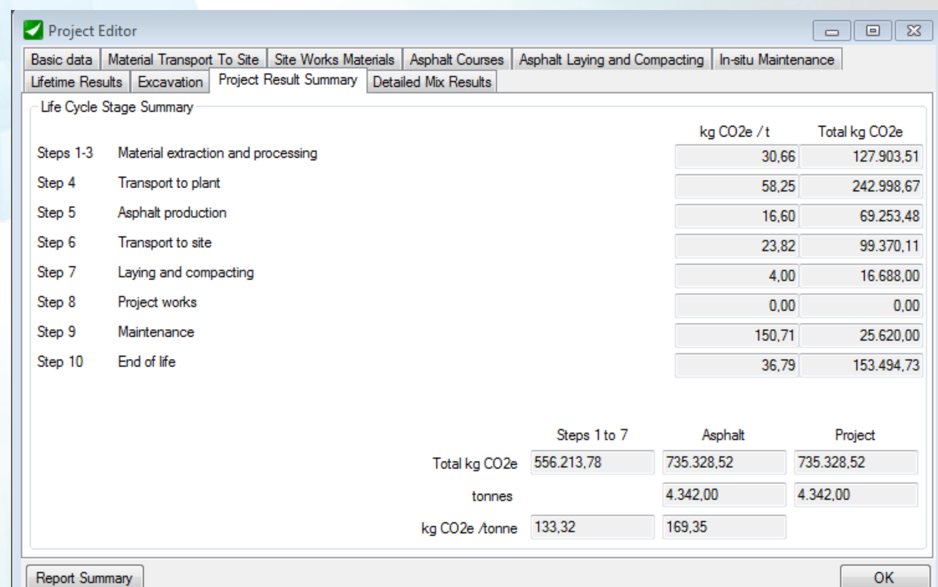


Cradle to cradle: an approach to the design of systems which models the industry on nature's processes in which materials are viewed as nutrients. It suggests that industry must protect and enrich ecosystems while also maintaining safe, productive technical metabolism for the high-quality use and circulation of materials. It is an economic, industrial and social framework that seeks to create systems that are waste free.

Environmental Impact Analysis for Roads Pavements

- The evaluation has been performed based on a “cradle to site” and “cradle to grave” perspective.
- In general, the LCA methodology uses extended computer software applicability and databases, in order to reduce the analysis time and improve efficiency.
- For the particular case of evaluating the environmental impacts of road asphalt mixtures has been used asPECT (Asphalt Pavement Embodied Carbon Tool) .





Case study processes

Ten steps asphalt pavement life cycle

Cradle to site

Cradle to grave

Life Cycle stage		Description
1	Raw material acquisition	Acquiring raw materials from the natural environment
2	Raw material transport	Transporting acquired raw materials to processing
3	Raw material processing	Crude oil refining, rock crushing and grading, recycled and secondary material reprocessing
4	Processed material transport	Transporting raw materials to the site of manufacture of bitumen bound highway components
5	Road component production	Production of bitumen bound mixtures
6	Material transport to site	Delivery of materials to site
7	Site preparation, laying and compacting	Placing materials at the construction site, mobilisation of plant and labor
8	Scheme specific works	Installation of other specified materials ex. geosystems and materials specific to traffic management
9	Maintenance	Interventions to maintain the road structure. Re-surfacing, surface dressing works, patching, haunching etc
10	End of life	Dismanting and material management

Case study on assessment of environmental impact of traditional and recycled asphalt mixtures

Evaluation and comparison of the environmental impact (expressed in kg CO2 emissions) during the service life of a road asphalt pavement , for two cases: using the traditional asphalt mixture composition and a new type of mixture based on 75% recycled material and a low bitumen percentage.

The evaluation can be performed for one up to three asphalt layers, depending on the milled surface depth.

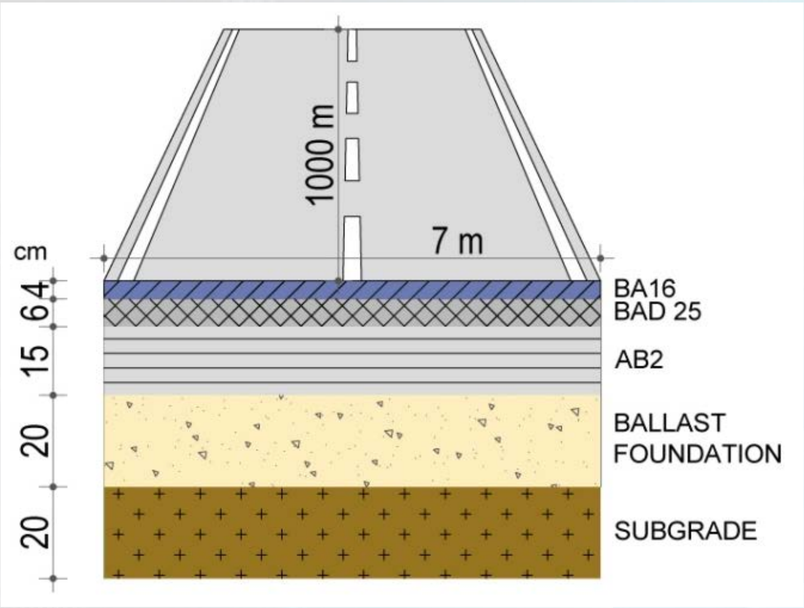
For the present case study has been considered the construction of one asphalt layer for a structure of 1000 m length and 7 m carriage wag.

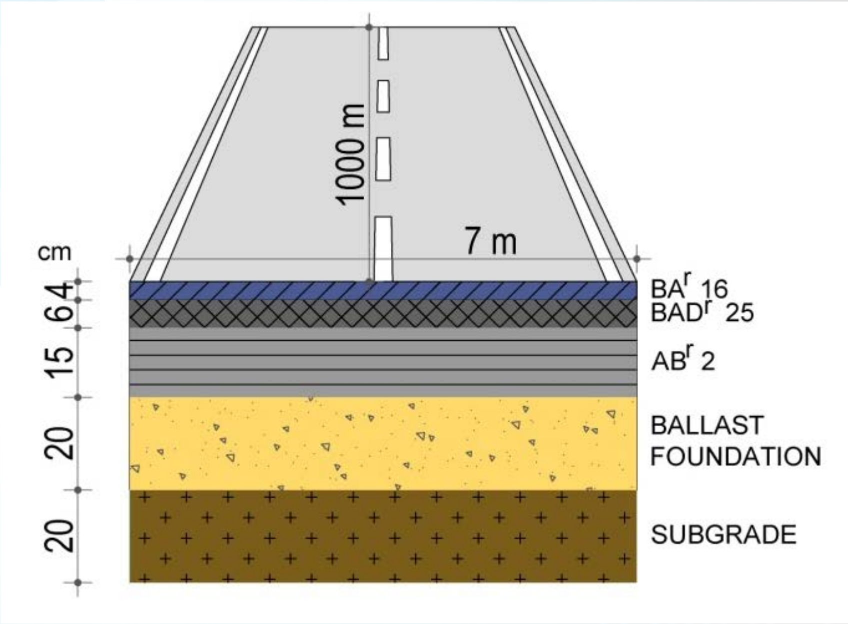
Process: construction/reconstruction of a pavement structure using:

- A_1: traditional asphalt mixtures compositions (BA 16, BAD 25 and AB 2), (table 1),
- A_2: recycled asphalt mixtures (BA^r16, BAD^r 25 and AB^r 2) (table 2).

The analysis allows environmental impact comparative analysis between alternatives (traditional vs recycled), between asphalt layers (BA 16 vs BA^r16, BA 16 vs AB 2 etc) or LCA phases in order to identify the most eco friendly material or process.

Road structure by asphalt mixtures





Case study on assessment of environmental impact of traditional and recycled asphalt mixtures

Table 1: Traditional asphalt layers mixtures and specific materials composition

No	BA 16	%
1	Bitumen	6
2	Chippings 8-16	24,4
3	Chippings 4-8	14,1
4	Crushed sand	45,1
5	Filler	10,4

Table 2: Recycled asphalt layers mixtures and specific materials composition

No.	BA^r 16	%
1	BA 16	75
2	Bitumen	2
3	Chippings 4-8	10
4	Crushed sand	10
5	Filler	3

Table 3 Project Impact Summary in a "Cradle to Site" perspective

Life Cycle Stages Summary Results (Tonnage 644)					
No.	Steps categorization	BA 16		BA^r 16	
		Total kg CO_2e	kg CO_2e/t	Total kg CO_2e	kg CO_2e/t
Step 1-3	Material extraction and processing,	25914,15	40,24	27012,76	41,95
Step 4	Transport to plant,	63249,37	98,21	29970,16	46,54
Step 5	Asphalt production,	16754,62	26,02	15799,78	24,53
Step 6	Transport to site,	14519,57	22,55	14519,57	22,55
Step 7	Laying and Compacting	2576,0	4,00	2576,00	4,00
Total		**123013,71**	**191,02**	**89878,27**	**139,56**

Case study on assessment of environmental impact of traditional and recycled asphalt mixtures

- The results in table 3 are for a "cradle to site" evaluation of a single asphalt layer construction, compared for a traditional asphalt mixture vs a recycled one.
- The software allows to continue the analysis in a "cradle to grave" perspective, with the specific works, maintenance and rehabilitation and end of life phase.

- In a "cradle to site" perspective was obtained a 27% reduction of CO2 emissions, while in a "cradle to grave" perspective the CO2 emissions reduction is 21%.

Table 4 Project Impact Summary in a "Cradle to Grave" perspective

Life Cycle Stages Summary Results (Tonnage 644)					
No.	**Steps categorization**	**BA 16**		**BA^r 16**	
		Total kg CO_2e	**kg CO_2e/t**	**Total kg CO_2e**	**kg CO_2e/t**
Step 8	Project works	0	0	0	0
Step 9	Maintenance and rehabilitation	43500,0	217,5	36000,0	180,0
Step 10	End of life	30657,34	47,6	30657,34	47,6
Total		**197171,05**	**233,61**	**156535,61**	**185,47**

Case study on assessment of environmental impact of traditional and recycled asphalt mixtures

If the analysis is performed for more than one asphalt layer, the results of the environmental assessment can be broken down for each of them.

Table 5. The environmental impact assessment broken down for each type of mixture

Layer thickness	Quantity of mixture (t)	Layer	Consumption kg CO_2e/t	Total consumption kg CO_2e/km road (7000 m^2)	Layer	Consumption kg CO_2e/t	Total consumption kg CO_2e/km road (7000 m^2)
4	644	BA 16	7307,8	4.706.191	BA^r 16	4372,9	2.816.143
6	1008	BAD 25	7302,3	7.360.677	BAD^r 25	4370,2	4.405.148
15	2520	AB 2	7294,7	18.382.680	AB^r 2	4379,7	11.036.830
25	**4172**	TOTAL	**21.904,8**	**30.449.548**	TOTAL	**13122,8**	**18.258.121**

Complementary analysis has shown decrease of the environmental impact expressed in CO2 emissions, racking from 15% - 40%, in favor of recycled asphalt mixtures.

Benefits of asphalt mixture recyclability

Environmental:

- Reduces quarring, mining, oil consumption,
- Reduces exploitation and consumption of scarce natural resources,
- Reduces the consume of fuel, equipments, transportation, labor,

For contractors:

- Increases profitability,
- Eliminates RAP – Recycled Asphalt Pavement disposal costs,
- The equipments have the ability to produce hot mix material 24/7,
- Reduces the reliance on hot mix plants,
- The number of companies that create and sale stationary and mobile recyclers and plants has increased.

Durability: if properly graded and created, the recycled mixture can perform nearly identical to traditional asphalt mixtures.

Life expectancy: should be similar to that of traditional mixtures if the site is properly prepared and the mixture has an adequate compaction.

Limits/Obstacles for asphalt mixture recyclability

- Durability and road service life. If the material composition doesn‘t reach an optimum, shall be faced the situation of often maintenance and rehabilitation works, shortage of the road service life.
- This leads to an increase in costs and high environmental impact.
- Lack of proper equipments: for this type of activities are necessary adequate technical equipments and plants. This implies complementary costs and investments of the local road agencies.
- Lack of data, information and specialized personnel.
- The companies traditionalism can be considered the greatest obstacle for the recyclability process.

Conclusions

- LCA methodology is a tool that evaluates the environmental impact of different product systems in order to find the most eco-friendly.
- Also:
  - Facilitates the decision taking process,
  - Takes into consideration the product service life with characteristic phases,
  - Is highly adaptable and
  - Based on computer software application,
- LCA is accompanied by the “cradle to” perspective that had a developing trend towards “cradle to cradle”, based on the idea of product reuse maximization.
- For road pavements construction, the analysis sustains the benefits of asphalt recyclability process,
- The experimental analysis has shown that a high percentage of recycled material of 75% and a reduced percentage of bitumen in composition can result in a significant reduction of CO_2e emissions.

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ACKNOWLEDGEMENT:

The research is supported by the project "Develop and support multidisciplinary postdoctoral programs in primordial technical areas of national strategy of the research - development - innovation" 4D-POSTDOC, contract nr. POSDRU/89/1.5/S/52603, project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.

Dezvoltarea şi susţinerea de programe postdoctorale multidisciplinare în domenii tehnice prioritare ale strategiei naţionale de cercetare - dezvoltare - inovare

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