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Selection of optimal asphalt wearing course type for heavy traffic

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1. Introduction

- Various asphalt pavement types on TEN-T roads (most heavily trafficked European routes)

- EU FP7 DURABROADS project (innovative, cost-effective, durable pavements)

- WP2: optimization of asphalt pavement type on heavily trafficked European roads

2. Synergistic climatic and mechanical loads on European road network I.

- Identification and evaluation of constraints on road materials to withstand road challenges.
- Synergistic effect of climate change impacts and the high vehicle load of freight corridors.
- Holistic approach using lifetime engineering principles.
- Four (Northern, Western, Southern and Central) European regions with different climatic and traffic features for separate analyses.

2. Synergistic climatic and mechanical loads on European road network II.

Region	Climate	Traffic Level
Northern Europe	Cold	Medium
Western Europe	Humid	High
Southern Europe	Hot	Medium
Central Europe	Continental	Low

European questionnaire survey (17 countries) to select typical wearing course types for high heavy road traffic:

- Northern Europe: AC– SMA.
- Western Europe: AC– SMA– PA – HRA.
- Southern Europe: AC – SMA– BBTM.
- Central Europe: AC– SMA.

3. Competing asphalt pavement types I.

Five alternatives for analysis:

- Asphalt concrete (AC)
- Very thin asphalt concrete (BBTM)
- Hot rolled asphalt (HRA)
- Porous asphalt (PA)
- Stone mastic asphalt (SMA)

Main surface characteristics:

- Skid resistance (traffic safety, tyre wear, fuel consumption).
- Transverse and longitudinal evenness (users' comfort).
- Noise inside and outside road vehicles.
- Light reflection on pavement surface (safety of night and wet pavement driving).
- Surface drainage (aquaplaning, water splash or spray).

3. Competing asphalt pavement types II.

Typical deterioration processes because of repeated traffic and environmental loads:

- Disintegration (scaling, ravelling, cracking, pot-holing, etc.).
- Deformation (longitudinal and transversal pave-ment deformation, rutting etc.).

Critical (characteristic) failure types :

- Northern Europe: disintegration.
- Western Europe: disintegration.
- Southern Europe: deformation.
- Central Europe: disintegration and deformation.

4. Optimization of heavy duty asphalt pavement types I.

Five steps of multi-criteria decision-making methodology:

- *Defining* the decision making problem (decision making tree and set of alternatives)
- *Processing* of the questionnaire answers (preparation, release and analysis of answers)
- *Weighting* of criteria (pairwise comparison and aggregation)
- *Assessment* of alternatives (literature review, characterization and ranking)
- *Sensitivity analysis* (weighting of criteria)

4. Optimization of heavy duty asphalt pavement types II.

The candidate variants were assessed according to the concept of *lifetime engineering*.

The *integrated lifetime engineering methodology* concerns the development and the use of technical performance parameters to guarantee that the structures meet throughout their whole life cycle all of the requirements coming from *human conditions, economy, cultural, social and ecological* considera-tions.

4. Optimization of heavy duty asphalt pavement types III.

Requirements, criteria and indicator forming the decision making tree.

Requirements	Criteria	Indicators
Economy	Cost	LCCA
		Initial investment
Environment	Resource efficiency	Aggregate usage
		Bitumen usage
	Consumptions	Energy consumption
	Emissions	CO_2 emissions
Society	Comfort	Ride quality
		Noise
	Safety	Skid resistance
		Aquaplaning
Technique	Mechanical resistance	Disintegration resistance
		Deformation resistance

4. Optimization of heavy duty asphalt pavement types IV.

Approaches considered *for rating the alternatives* with respect to each criterion:

- Profound revision of technical *literature*.
- *Opinion of experts* collected through specifically designed questionnaires.
- An *environmental assessment/life cycle assessment* of all alternatives.
- A *life cycle cost assessment* considering all the alter-natives.

4. Optimization of heavy duty asphalt pavement types V.

Questionnaires on the weights of criteria and the rating of alternatives were filled in by DURABROADS partners and 81 worldwide highly recognized experts from 52 European insti-tutions.

The *alternatives* were *ranked* from the processing of their assessments for each qualitative or quantitative criterion. *Qualitative* variables were processed using *fuzzy logic*, while *quantitative* variables were modelled through *Monte Carlo simulations*. The results served as inputs to establish their *final ranking* using the Technique for Order of Preference by Similarity to Ideal Solution (*TOPSIS*).

4. Optimization of heavy duty asphalt pavement types VI.

Fuzziness was handled by the use of triangular fuzzy numbers (TFN) that represent linguistic terms

Linguistic term	TFN
Extremely poor	(1, 1, 2)
Very poor	(1, 2, 3)
Poor	(2, 3, 4)
Medium poor	(3, 4, 5)
Fair	(4, 5, 6)
Medium good	(5, 6, 7)
Good	(6, 7, 8)
Very good	(7, 8, 9)
Extremely good	(8, 9, 9)

4. Optimization of heavy duty asphalt pavement types VII.

The expert *ratings* regarding the performance of the qualitative variables were also *synthesized* considering the ratings proceeding from literature.

Quantitative variables were handled *stochastically* from ranges of likely values by using the *Monte Carlo methods* (probability of achieving different performances according to a given range of estimates).

4. Optimization of heavy duty asphalt pavement types VIII.

The principle of *TOPSIS method*: the preferred alternative to a given multi-criteria problem is not only characterized by having the shortest distance to the positive ideal solution, but also the longest distance to the negative ideal solution.

Main *steps*:

1) *Define* the decision-making matrix.
2) *Normalize* the decision-making matrix.
3) *Construc*t the normalized weighted decision-making matrix.
4) *Determine* the positive ideal solution and negative ideal solution.
5) *Calculate* the distance of each alternative from A^+ and A^-.
6) *Calculate* the relative closeness from each alternative to the *ideal solution*

4. Optimization of heavy duty asphalt pavement types IX.

Outputs of analysis:

- *Expert prioritization*: functional, environmental, safety and economic performance.

- *Wearing course ranking*: SMA, HRA, BBTM, AC, PA.

- The effect of potential *climate change* in the selection of alternatives is *noticeable.*

5. Concluding remarks

Evaluation of the *constraints* on current road materials to withstand *climate change* impacts and the *high vehicle load* of freight corridors provides to highway managers with more affordable, safer and environment-friendly practices for *road asset management* purposes.

The new *decision support model* has shown its usefulness for decision-makers in selecting the most suitable wearing course according to sustainable development criteria based on the use of the principles of *lifetime engineering.*

Thank you for your kind attention!