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EVALUATION OF A GENERAL PERFORMANCE INDEX FOR FLEXIBLE ROAD PAVEMENTS

BY

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Abstract. The paper presents the main features of a general performance index developed for flexible pavements in the frame of the COST Action 354 “Performance Indicators for Road Pavements”, as a result of combined performance indices. A significant case study for evaluation of this general performance index for representative sector of the County Road DJ 248 Iasi – Rebricea is also presented. Finally, technical recommendations for the implementation of this methodology in the current practice of road management from our country are proposed.

Key words: pavement management system; pavement condition index; general performance index.

1. Introduction

Specifying performance criteria from the perspective of the road users and operators is a key condition for the design, construction and maintenance of road pavements. In particular, the increasing use of life cycle analysis of the pavement as a basis for the selection of road pavement and the decision whether or not to put in place a system of road maintenance requires the evaluation of

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the objectives to be achieved and performance criteria that must be met. The extent to which objectives are achieved or performance criteria are met can be quantified by calculating the special index that characterizes the road pavements, which, in turn, allows an assessment of the effectiveness of the whole management.

Efforts to describe certain characteristics of the pavement, *via* indexes, were initiated more than a decade ago. These indices, which as a rule are evaluated from several components of information, are a measure of the observed effects by the road users, as well as a measure that reflects the structural condition of the pavement. The guide for the road management published by American Association of Highway and Transportation Officials (AASHTO) in 2001 uses the Present Serviceability Index (PSI), as a measure of comfort, together with structural indices – specifically about the Pavement Condition Index (PCI) and their use as part of the pavement management systems.

According to literature (COST 354, 2008) "Performance indices can be used specially in target criteria, in life-cycle assessments within the context of the design and/or systematic maintenance at a national and European level. Single performance indices allow an assessment of the effects of different maintenance strategies and design, but can also be a basis for predicting the performance of road and for the improvement and development of new models of prediction. Performance indicators are therefore an objective tool that can be used in road construction and maintenance at the various administrative levels, from local roads to highways". These indicators can be used in awarding contracts for the maintenance of private enterprises and, in particular, in new awarding procedures that are used in many European countries.

2. Definition and Calculation of a General Performance Index

The primary objective of COST Action 354 was the definition of performance indicators and indices for the pavement, taking in account the road users requirements and the needs of the road administration units.

A quantitative evaluation of performance indicators provides guidance on current and future needs in the design and maintenance of both national and European networks of existing roads. By specifying the limits and values (for example, target values, alert values, threshold values, etc.) for individual performance indicators, minimum requirements can be assessed for the road pavements.

Performance Indices are defined as dimensionless figures on a common 0 to 5 scale, with 0 representing a pavement in very good condition and 5 a failed one, with respect to a specific pavement condition property.

A set of single (individual) performance indicators was identified, for which were asigned coresponding "Performance Indices" (PI) for the assessment of key properties of road pavements such as longitudinal and transverse evenness, bearing capacity, cracking, surface defects.

Each single PI is related to one technical characteristic of the road pavement and can be derived from a "Technical Parameter" (TP) obtained from measurements by a device or collected by other forms of investigation. However, since cracking and surface defects both encompass a range of different individual defects it was necessary to develop "pre-combined performance indices" that combine the different forms of distress into a single value for each type.

With help of the single and the pre-combined performance indices, have been developed as combined performance indices (safety, comfort, structural and environmental indices) , relevant to road users and road operators.

Based on the combined performance indices, a general performance index (GPI) was defined as a mathematical combination of single and combined By using this information a general maintenance strategy can be derived. The general performance index can be used by the decision-makers to assess the general condition of the network and to evaluate future strategies and consequent funding requirements.

The combination of combined performance indices (CPIs) into a general performance index (GPI) takes into account the maximum weighted CPI value affected by biased values of other weighted CPIs.

Acording to COST 354 methodology, the following eq. has been selected to be used for one case study involving a representative road sector on the county road DJ 248 Iaşi – Rebricea.

$$\text{GPI} = \min\left[5; l_1 + \frac{p}{100} l_2\right], \tag{1}$$

where:

$$l_1 \ge l_2 \ge l_3 \ge l_4 \ge \ldots \ge l_n,$$

and

$$l_1 = W_1\text{CPI}_1;\ l_2 = W_2\text{CPI}_2;\ l_3 = W_3\text{CPI}_3;\ l_4 = W_4\text{CPI}_4;\ldots;\ l_n = W_n\text{CPI}_n,$$

p = 10...20% – influence factor, the weights Wi represent the influence of the different combined performance indices; CPI – combined performance index. The CPIs with the highest weight should always have a weighting factor of 1.0.

The eq.

$$x = \frac{1}{\max\left(W_1^{'}; W_2^{'};\ldots; W_n^{'}\right)},\ \ W_1 = xW_1^{'};\ W_2 = xW_2^{'};\ldots;\ W_n = xW_n^{'} \tag{2}$$

defines the weight transformation when the maximum weighting factor is lower than 1.

For the calculation of a general performance index using these eqs., it will be necessary to assign appropriate weighing factors to each of the combined performance indicators adopted, thus being able to choose a set of weighting factors that reflect his priorities.

Using the data gathered by the road operators and the road users, the weight factors recomended by COST 354 are given in Table 1.

Table 1
Weight Factors (COST 354, 2008)

Motorways			
Road safety	Riding comfort	Pavement structure	Environment
1.00	0.70	0.65	0.25
Primary roads			
Road safety	Riding comfort	Pavement structure	Environment
1.00	0.70	0.80	0.30
Secondary and other roads			
Road safety	Riding comfort	Pavement structure	Environment
1.00	0.65	1.00	0.35

3. Case Study. The Evaluation of a General Performance Index (GPI)

In this chapter an example of the application of COST 354 methodology on a representative sector of the county road DJ 248 Iaşi – Rebricea, km 8+000 – km 10+000, as shown in Fig. 1.

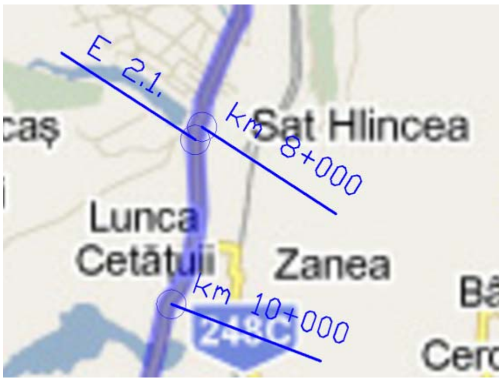

Fig. 1 – The investigated road sector for county road DJ 248 km 8+000 – 10+000.

In order to apply te COST 354 methodology, the following five research steps have been undertaken.

S t e p 1. *Evaluation of curent pavement condition*

The curent pavement condition of the road sector is presented in Table 2, for each distress type being considered its cantitative value based on the severity level.

Table 2

Technical Parameter Values from E2.1 Sample Unit

Technical parameter	Abbr./Unit	Severity	Value
Longitudinal evenness	IRI, [m/km]		2.2*)
Transverse evenness	RD, [mm]		7*)
Skid resistance	SFC		0.5*)
Texture	MPD, [mm]		0.5*)
Bearing capacity	SCI300, [μm]		300*)
Cracking			
longitudinal cracking	LC, [m]	1	550
			–
transverse cracking	TC, [m]	1	200
alligator cracking	AC, [m^2]	1	700
		2	600
block cracking	EC, [m^2]	–	–
Surface defects			
bleeding	BL, [m^2]		
patching	PTCH, [m^2]	1	1,000

*) These technical parameters values were assimilated according the COST 354 methodology and ASTM D 6433-99 standard.

S t e p 2. *The evaluation of the singular performance indices*

The evaluation of the singular performance indices and the transfer function equations are presented in Table 3.

Table 3

The Evaluation of Singular Performance Indices (*SPI*)

Technical parameter	Singular performace indices , (SPI)	PT value	Transfer function equation	SPI value
Longitudinal evenness	PI_E	2.2	PI_E = min(5;0.1733IRI^2 + 0.7142IRI– 0.0316)	2.37
Transverse evenness	PI_R	7	PI_R = min(5; –0.0015RD^2 + 0.2291RD)	1.53
Skid resistance	PI_F	0.5	PI_F = min(5; –17.600SFC + 11.205)	2.41
Texture	PI_T	0.5	PI_T = min(5; 6.6 – 5.3 MPD)	3.95
Bearing capacity	PI_B	300	PI_B = min(5; SCI300/129)	2.32

S t e p 3. *Evaluation of the pre-combined performance indices*

According to COST 354 methodology, two pre-combined penformance indices, cracking and surface defects, have been evaluated.

The technical parameter "cracking" is combined by: $\mathrm{TP}_{\mathrm{cr},A}$ for surface cracking (alligator and block cracking) and $\mathrm{TP}_{\mathrm{cr},L}$ for linear cracking (longitudinal and transverse cracking).

The evaluation of the cracking technical parameter, $\mathrm{TP}_{\mathrm{cr}}$, are presented in Table 4.

Table 4

The evaluation of surface cracking technical parameters

Cracking type	Weight, W'	Transformed weight, W'	Severity	Extent, [m^2]	Section area, [m^2]
Alligator cracking, [m^2]	0.9	1.0	1	700	37,500
			2	600	
Block cracking, [m^2]	0.8	0.89	–	–	
Longitudinal cracking, [m]	0.7	0.78	1	550	
				–	
Transverse cracking, [m]	0.7	0.78	1	200	

The evaluation of the cracking technical parameter, $\mathrm{TP}_{\mathrm{cr},A}$, based on surface cracking is made according to eq.

$$\mathrm{TP}_{\mathrm{cr},A} = \min\left\{100; \frac{1}{A_{\mathrm{ref}}} \sum_m \left[W_m \sum_i \left(S_{\mathrm{cr},A} A_i \right) \right] 100 \right\}, \tag{3}$$

i.e.

$$\mathrm{TP}_{\mathrm{cr},A} = \min\left\{100; \frac{1}{37,500} \left[1.0 \left(1 \times 700 + 2 \times 600 \right) \right] 100 \right\} = 5.06\%.$$

The evaluation of the cracking technical parameter, $\mathrm{TP}_{\mathrm{cr},L}$, based on linear cracking is made according to eq.

$$\mathrm{TP}_{\mathrm{cr},L} = \min\left\{100; \frac{1}{A_{\mathrm{ref}}} \sum_n \left[W_n I_{\mathrm{width},I} \sum_j \left(S_{\mathrm{cr},L,j} L_j \right) \right] 100 \right\}, \tag{4}$$

and consequently

$$\mathrm{TP}_{\mathrm{cr},L} = \min\left[100; \frac{1}{37,500} \left(0.78 \times 1 \times 550 + 0.78 \times 200 \right) 100 \right] = 1.56\%.$$

The value of the cracking technical parameter is the sum of the two parameters, $TP_{cr,A}$ and $TP_{cr,L}$

$$TP_{cr} = \min(100; 5.06 + 1.56) = 6.62\%.$$

The evaluation of the pre-combined performance technical parameter is made based on eq.

$$PI\_CR = \min(5; 0.1333TP_{cr}) = 0.89. \quad (5)$$

The evaluation of the "Surface defects" technical parameter is made by using the data from Table 5.

Table 5

The Evaluation of the "Surface Defects" Technical Parameter

Type of surface defect	Weight, W'	Transformed weight, W'	Severity	Extent, [m²]	Section area, [m²]
Bleeding, [m²]			–	–	37,500
Patching, [m²]	0.7	1.0	1	1,000	

$$TP_{sd,cat1} = \min\left[100; \frac{1}{37,500}(1.0 \times 1,000)100\right]2.66. \quad (6)$$

The evaluation of the pre-combined performance index is made based on eq.

$$PI\_SDcat\ 1 = \min(5; 0.1333TP_{SD}) = 0.35. \quad (7)$$

S t e p 4. *The evaluation of the combined performance indices*

a) *Confort index*

The evaluation of the confort index is made according to Table 6.

Table 6

The Evaluation of the Confort Index

Abbr. SPI	SPI value	Weight	Transformed weight , W'	Ii=Wi SPIi	SPI order
PI_E	2.37	1.0	1.0	2.37	1
PI_SD	0.35	0.6	0.6	0.21	5
PI_R	1.53	0.7	0.7	1.071	2
PI_T	3.95	0.4	0.4	1.58	3
PI_C	0.89	0.5	0.5	0.445	4

The value of the influence factor is $p = 20\%$;

$$\frac{l_2+l_3+l_4+l_5}{4}=\frac{1.071+1.58+0.445+0.21}{4}=0.9805.$$

The confort performance index can be calculated using data from Table 6 and using equation [8]:

$$\mathrm{CPI}_{\mathrm{comfort}}=\min\left[5;l_1+\frac{p}{100}\left(\overline{l_2,l_3,l_4,\ldots,l_n}\right)\right], \tag{8}$$

and consequently

$$\mathrm{CPI}_{\mathrm{comfort}}=\min\left[5;2.37+\frac{20}{100}0.9805\right]=2.5661.$$

b) *Safety index*

The evaluation of the safety index is made according to Table 7.

Tabelul 7

The Evaluation of the Safety Index

Abbr. SPI	SPI value	Weight	Transformed weight W'	I_i=W_i SPI$_i$	SPI order
PI_F	2.41	0.9	1.0	2.41	2
PI_R	1.53	0.9	1.0	1.53	3
PI_T	3.95	0.6	0.67	2.6465	1
PI_SD$_{\mathrm{cat1,bleeding}}$	0	0.6	0.67	0	–

The value of the influence factor is p = 20%;

$$\frac{l_2+l_3}{2}=\frac{2.41+1.53}{2}=1.97.$$

The safety performance index can be calculated using data from Table 7 and using eq.

$$\mathrm{CPI}_{\mathrm{safety}}=\min\left[5;l_1+\frac{p}{100}\left(\overline{l_2,l_3,l_4,\ldots,l_n}\right)\right]=\min\left(5;3.95+\frac{20}{100}1.97\right)=4.364, \tag{9}$$

c) *Structural index*

The evaluation of the structural index is made according to Table 8.

Table 8

The Evaluation of the Structural Index

Abbr. SPI	SPI value	Weight	Transformed weight, W'	I_i=W_i SPI$_i$	SPI order
PI_B	2.32	1.0	1.0	2.32	1
PI_CR	0.89	0.9	0.9	0.801	3
PI_R	1.53	0.5	0.5	0.765	4
PI_E	2.37	0.6	0.6	1.422	2

The value of the influence factor is p = 20%.

$$\frac{l_2+l_3+l_4}{3}=\frac{1.422+0.801+0.765}{3}=0.996.$$

The structural performance index can be calculated using data from Table 8 and using eq.

$$\text{CPI}_{\text{struct.}}=\min\left[5;l_1+\frac{p}{100}\left(\overline{l_2,l_3,l_4,...,l_n}\right)\right]=\min\left(5;2.32+\frac{20}{100}0.996\right)=2.5192. \qquad (10)$$

There will be no environment performance index evaluation because there is no data for it.

S t e p 5. *Evaluation of the general performance index*

The general performance index will be evaluated based on the combined performance indices evaluated

a) Safety performance index, $\text{CPI}_{\text{safety}}$ = 4.364.

b) Confort performance index, $\text{CPI}_{\text{comfort}}$ = 2.5661.

c) Structural performance index, $\text{CPI}_{\text{struct.}}$ = 2.5192.

Table 9

The evaluation of the general performance index

CPI	CPI_i	Transformed weight, W'	$I_i = W_i\ \text{CPI}_i$	CPI order
Safety	4.364	1.00	4.364	1
Confort	2.5661	0.70	1.79627	2
Structural	2.5192	0.65	1.63748	3

The value of the influence factor is p = 20%.

$$\frac{l_2+l_3}{2}=\frac{1.79627+1.63748}{2}=1.71688.$$

The structural performance index can be calculated using data from Table 9 and using eq.

$$\text{GPI}=\min\left[5;l_1+\frac{p}{100}\left(\overline{l_2,l_3,l_4,...,l_n}\right)\right]=\min\left[5;4.364+\frac{20}{100}1.71688\right]=4.707. \qquad (11)$$

4. Technical Recommendations for the Implementation of the COST 354 Methodology in the Road Practice from our Country

Within this paper a “General Performance Index” (GPI) has been defined as a dimensionless figure in a 0 to 5 scale with 0 representing a pavement in very good conditions and 5, in a very poor one.

For practical reasons, a useful comparison diagrame shown in Fig. 2 has been conceived.

PCI	Condition grading	PSI	GPI	Safety index	Comfort index	Structural index
100		5	0	0	0	0
	Excelent					
85		4.25	0.75	0.75	0.75	0.75
	Very good					
70		3.5	1.5	1.5	1.5	1.5
	Good					
55		2.75	2.25	2.25	2.25	2.25
	Mediocre					
40		2	3	3	3	3
	Poor					
25		1.25	3.75	3.75	3.75	3.75
	Very poor					
10		0.5	4.5	4.5	4.5	4.5
	Failure					
0		0	5	5	5	5

Fig. 2 – Scalar comparison of COST 354 indices with PCI and PSI indicators.

In the case study was applied the COST 354 method on the evaluated sector of county road DJ 248 Iaşi–Rebricea, resulting a very poor pavement condition, the GPI value being 4.707.

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EVALUAREA UNUI INDICE GENERAL DE PERFORMANŢĂ PENTRU IMBRĂCĂMINŢI FLEXIBILE

(Rezumat)

Se prezintă principalele caracteristici ale unui indice general de performanţă pentru îmbrăcăminţi flexibile conform prevederilor raportului COST 354 "Indicatori de performanţă pentru îmbrăcăminţi rutiere". Un studiu de caz semnificativ pentru acest indice general de performanţă s-a relizat pe un sector reprezentativ al drumului judeţean DJ 248 Iaşi – Rebricea. În final sunt propuse un număr de recomandări tehnice privind implementarea acestei metodologii în practicile curente de management rutier din ţara noastră.