Cost 354 – European Harmonization On Performance Indicators For Road Pavements

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ABSTRACT

In 2004 the COST-Action 354 “Performance Indicators for Road Pavements” was initiated by the European intergovernmental scientific network COST (cooperation in the field of science and technology) with the main objective to define uniform European performance indicators and indexes for road pavements.

The specification of performance criteria from the perspective of road users and road operators is a key prerequisite for the efficient maintenance and management of road pavements. In the context of the Action single indicators as well as combined indicators are defined for different road networks and pavements taking into consideration functional and structural demands of road pavements as well as demands from the environmental point of view. These performance indicators should build the basis for the economic evaluation within PMS and PPP-contracts.

INTRODUCTION

About COST

COST (cooperation in the field of science and technology) is an intergovernmental network which is scientifically completely self-sufficient with nine scientific COST Domain Committees formed by some of the most outstanding scientists of the European scientific community. COST is one of the longest-running instruments supporting co-operation among scientists and

researchers across Europe. COST now has 35 member countries and enables to collaborate in a wide spectrum of activities in research and technology.

Background of the Action

The specification of performance criteria from the perspectives of both road users and road operators is a key prerequisite for the efficient design, construction, and maintenance of road pavements. Particularly the increasing use of life-cycle analysis as a basis for the selection of road pavements and the decision of whether or not to implement a systematic road maintenance scheme calls for an exact definition of the goals to be achieved and/or the performance criteria to be satisfied. The extent to which goals are reached or performance criteria satisfied can be quantified by calculating special indexes characterizing the road pavement, which in turn permits an assessment of the efficiency of certain approaches from both a commercial and a macro-economic standpoint.

For an Europe-wide harmonization of standards to be met by road pavements it therefore appears useful and appropriate to specify pavement characteristics in terms of uniform performance indicators for different road categories.

The COST-Action 354 “Performance Indicators for Road Pavements” was supported by FEHRL in close cooperation with the Institute for Road Construction and Maintenance of the Vienna University of Technology. It started with a kick-off meeting in March 2004, with a scheduled duration of 4 years. The interest for participation was and is still quite high from the very beginning. In the meantime a total of 23 European countries have signed the Memorandum of Understanding and have sent their delegates to the Working Group meetings and to the Management Committee (see FIGURE 1). In addition a strong link to the USA could be created and thus from 2005 a colleague from FHWA is joining the meetings (details can be seen under cost354.zag.si).

DESCRIPTION OF THE ACTION

Objectives of the Action

The main objective of the Action is the definition of uniform European performance indicators and indexes for road pavements taking the needs of road users and road operators into account. A quantitative assessment of individual performance indicators provides guidance regarding present and future needs in road pavement design and maintenance at both the national and the European levels. By specifying limits and acceptance values (e.g. target values, alert values, threshold values, etc.) for individual performance indicators minimum standards can be laid down for both projected and existing road pavements.

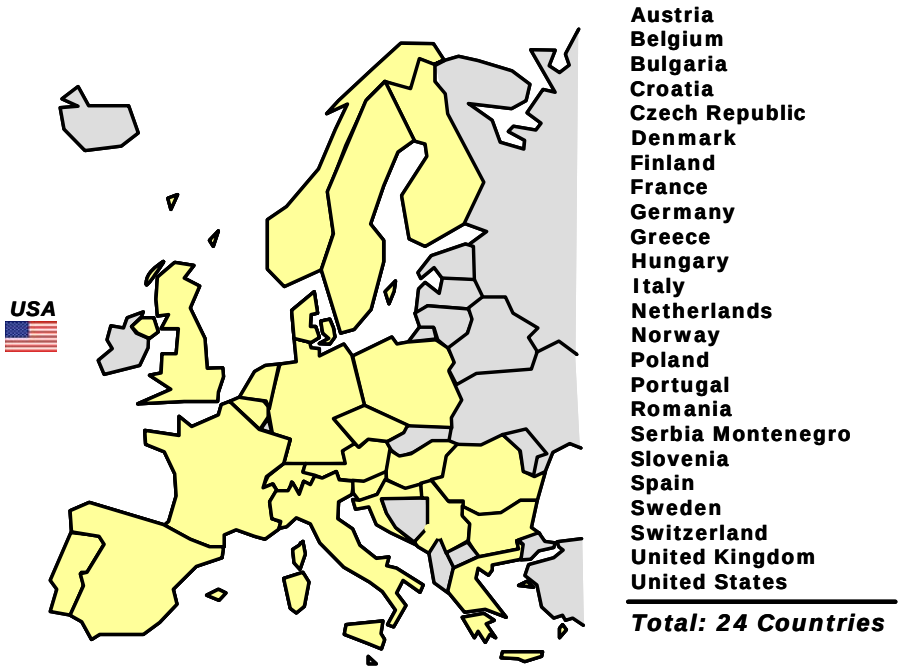

FIGURE 1 COST 354, participating countries

Performance indicators in form of "Technical Parameters" (e.g. rut depth, friction value) and dimensionless "Performance Indexes" (PI) should be defined for different types of pavement and road categories. A further objective is the grouping of these individual performance indexes into representative "Combined Performance Indexes "(CPI) as

- Functional Performance Indexes (demands made on road pavements by road users);
- Structural Performance Indexes (structural demands to be met by the road pavement);
- Environmental Performance Indexes (demands made on road pavements from an environmental perspective).

Finally, based on the Combined Performance Indexes a "General Performance Index" (GPI) will be defined for describing the overall condition of the road pavements, which can be used on the one hand for general optimization procedures and on the other hand as an overall value for decisions on policy level.

Benefits to different Stakeholders

The potential benefits arising from the Action are substantial for road operators and road users as well. The primary use of such indicators is for the comparison of different road networks and the identification of investment requirements where relevant minimum standards have been defined taking into account the requirements of road users.

For the development of international standards regarding to road pavement condition harmonized performance indicators are an essential prerequisite. In this context they can be used on the one hand for international and national road audit but also on the other hand for widening the market for supervision and construction within Europe and thus strengthen the competition. Performance indicators can be used in particular as target criteria in life cycle analyses within the context of pavement design and/or systematic road maintenance at the national and the European levels. Uniform performance indicators permit an evaluation of the effects of different design and maintenance strategies but they can also be used for predicting road performance and for

improving and developing new prediction models. Performance indicators are thus an objective tool for use in road construction and maintenance at various administrative levels.

In connection with increasing privatization of road construction and maintenance in Europe, the objective assessment of condition or performance indicators is gaining special importance. Such indicators may be used in awarding maintenance contracts to private enterprises and, in particular, within the framework of the new awarding procedures being contemplated in many European countries (private-public partnership contracts PPP, build-operate-transfer contracts BOT). Clearly defined harmonized performance indicators are an important precondition for the successful application of these new types of contracts.

Finally, benefits will arise through the innovative approach to be taken in the Action, concerning the derivation of factors reflecting the safety of road users, and appropriate environmental aspects. In the first instance, these benefits will accrue to road owners and operators, who will be in a position to give a weighting to these various factors, depending on national priorities, circumstances, funding arrangements, etc. Later, as these indexes are implemented, benefits will accrue to European citizens and industry, through the better accountability of road owners and operators for safety and environmental concerns.

Scientific Program and Organization

The Action aims at conducting the following work program and producing the related deliverables:

- Data base on individual pavement performance indicators used throughout Europe including limit values, classification systems and measurement and data collection procedures;
- Review of existing methods and practical guide for choice and application of individual pavement performance indicators (Technical Parameters and Indexes) including measurement and data collection procedures;
- Definition of an European assessment scale and of a proposal for the transformation of Technical Parameters into Single Indexes (normalization) for different performance indicators;
- Practical procedure for developing Combined Performance Indexes and proposed areas of application;
- Practical procedure for developing a General Performance Index and proposal for application;
- Final report of the Action.

The work is organized in 5 Working Groups. The organization can be seen in FIGURE 2.

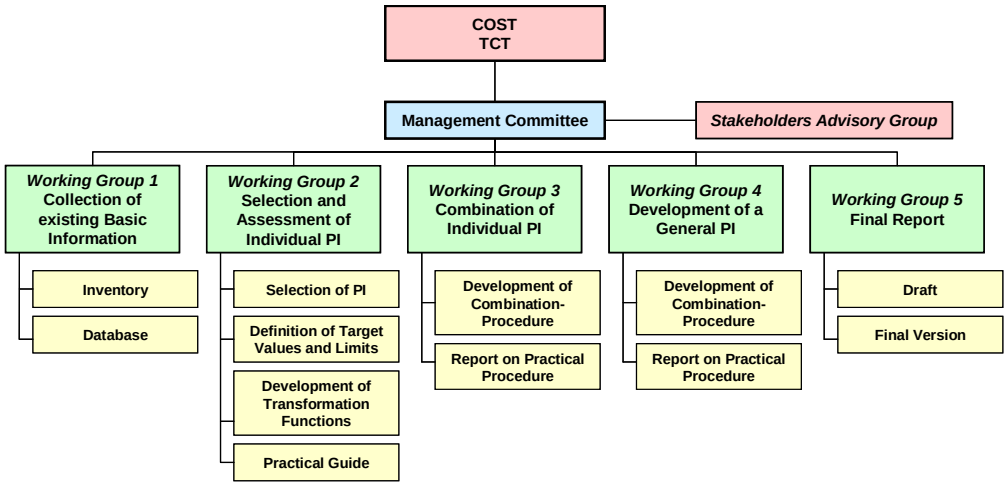

FIGURE 2 work breakdown structure of COST 354

WORK STATUS AND OUTPUTS

Collection of existing basic Information

The aim of this Work Package was to produce an inventory on performance indicators for road pavements used across Europe and USA, taking into account different road categories and pavement types. The inventory covers also information of each individual performance indicator about the target values and limits as well as applied transformation functions, classification systems and methods of measurement and data collection.

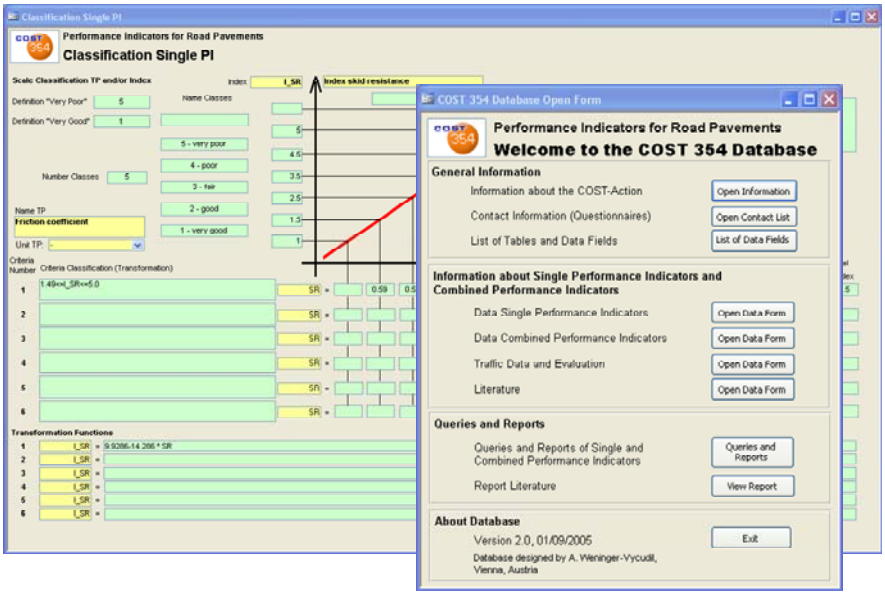

FIGURE 3 Front page of the COST 354 database

In order to obtain the data the technical approach to the work in this Work Package was to produce an electronic questionnaire and to make subsequent discussion by the technical experts of the Action. The questionnaire was designed to enable data to be collected from the countries participating in COST Action 354 in a structured manner in order to input into a special database with the information on the individual pavement performance indicators. The purpose

of this COST 354 database (see FIGURE 3) is to provide the input for the subsequent Work Packages, in particular Working Group 2 to 4.

Selection and Assessment of Individual Performance Indicators

The aim of Working Group 2 (WG2) was to identify a set of indexes to represent in a dimensionless scale the following performance indicators:

- Longitudinal evenness;
- Transverse evenness;
- Macrotexture;
- Friction;
- Noise;
- Air pollution;
- Bearing capacity.

Within the Action a "Performance Index" (PI) has been defined as a dimensionless figure in a 0 to 5 scale with 0 representing a pavement in very good conditions and 5 a very poor one, with respect to a specific pavement condition property. A Performance Index can usually be derived from a "Technical Parameter" (TP) that is a physical characteristic of the road pavement condition obtained from measurements by a device or collected by other forms of investigation (e.g. rut depth, friction value, etc.).

In this context a "Performance Indicator" for road pavement is the superior term of a technical road pavement characteristic, that indicates the condition of it (e.g. transverse evenness, skid resistance, etc.). A performance indicator can be defined in the form of Technical Parameters (dimensional) and/or in form of dimensionless indexes. The planned activities for WG2 were:

- Select suitable performance indicators;
- Define target values and limits;
- Develop transformation functions from Technical Parameters to Performance Indexes;
- Provide a practical guide for the calculation of the performance index.

Given the wide variety of potential users of the COST 354 final procedure it was deemed necessary to develop a procedure that could be applied at all different levels depending on the type of measurement and analysis approach already in place in the road authority applying the procedure. The different levels can be summarized as follows:

- The user provides the value for the Technical Parameter identified as the "most suitable" by WG2 and, by means of the transfer functions developed by WG2, derives a value for the dimensionless Performance Index;
- The user provides the value for the Technical Parameter identified as the "most suitable" by WG2 but applies a different transfer function to derive a value for the dimensionless Performance Index (always in the same 0 to 5 scale as above);
- The user provides the value for a different Technical Parameter and applies his own transfer function to derive a value for the dimensionless Performance Index (always in the same 0 to 5 scale as above);
- The user provides directly a value for the dimensionless Performance Index (always in the same 0 to 5 scale as above).

The selection of the "most suitable Technical Parameter" for a specific performance indicator, was made by means of a set of criteria defined by the COST 354 Management

Committee (e.g based on European standard, standard practice or used only for research, device independent).

Based on the analysis of each single indicator described above a set of "selected" Perfromance Indexes have been identified and are summarized in TABLE 1. For each of the selected Performance Indexes (PI) the transfer function that leads from the Technical Parameters (TP) into the dimensionless index is also included in TABLE 1.

TABLE 1 Synthesis of the selected indicators

Performance Indicator	TP	PI_index	Transfer Function
Longitudinal Evenness	IRI (mm/m)	PI_evenness (PI_E)	PI_E = MIN (5;0.1733·IRI^2+0.7142·IRI-0.0316) (more restrictive) PI_E = MIN (5; 0.816·IRI) (less restrictive)
Transverse Evenness	Rut depth [RD] (mm)	PI_rutting (PI_R)	For all road classes: PI_R = -0.0016·RD^2 + 0.2187·RD [for RD < 29.0 mm] PI_R = 5 [for RD ≥ 29.0 mm] For motorways and primary roads: PI_R = -0.0015·RD^2 + 0.2291·RD [for RD < 26.4 mm] PI_R = 5 [for RD ≥ 26.4 mm] For secondary and local roads: PI_R = -0.0023·RD^2 + 0.2142·RD [for RD < 46.9 mm] PI_R = 5 [for RD ≥ 46.9 mm]
Skid Resistance	SFC (0 to 1) at 60 km/h LFC (0 to 1) at 50 km/h	PI_friction (PI_F)	PI_F = MAX(0;MIN(5;-17.600*SFC+11.205)) PI_F = MAX(0;MIN(5;-13.875*LFC+9.338))
Macro-texture	MPD (mm)	PI_macrotexture (PI_T)	For motorways and primary roads: PI_T = 5.3·MPD – 1.6 For secondary roads: PI_T = 6.9·MPD – 2.0
Bearing Capacity	Residual life/ Design life [R/D] SCI_{300} (µm)	PI_bearing capacity (PI_B)	PI_B = 5·(1- R/D) PI_B = SCI_{300}/129 for weak bases PI_B = SCI_{300}/253 for strong bases
Noise	-	-	-
Air Pollution	-	-	-

The evaluation of the data contained in the COST 354 database has highlighted some basic problems (e.g. noise, air pollution) that could be addressed by additional research or that can lead to a change in the selection of the PIs in a close future.

Combination of Individual Performance Indexes

Based on the results of the previous Work Packages, Working Group 3 (WG3) focused on the development and the definition of Combined Performance Indexes (CPI) with regard to the demands of a pavement construction.

In a first step Combined Performance Indexes for cracking and surface defects were defined, which includes the different appearance forms of cracking (linear, alligator, reflective, etc.) and surface defects (potholes, bleeding, ravelling, etc.). The combination procedures of both, cracking (PI_CR) and surface defects (PI_SD), are based on modular formulations, which takes into account the different distress types, the different units (area, length, number, etc.), and the amount of influence in form of different weights.

To fulfill the Action objectives WG 3 defined four Combined Performance Indexes as follows:

- Riding comfort;
- Road safety;
- Structural status;
- Environmental status.

The combination of single indexes (PIs) into Combined Performance Indexes is based on an advanced maximum criteria. It takes into account the distribution on a value basis of the variables (PI) by using an influence factor (p, within 10 and 20%) as well as the influence of the variables itself in form of different weights (w, within 0 and 1). The following general formulation is the basis of all combination procedures for Combined Performance Indexes (CPI):

$$CPI_i = \min\left[5; I_1 + \frac{p}{100} \cdot \overline{(I_2, I_3, ..., I_n)}\right]$$

where $I_1 \geq I_2 \geq I_3 \geq ... \geq I_n$ and $I_1 = w_1 \cdot PI_1, I_2 = w_2 \cdot PI_2, ..., I_n = w_n \cdot PI_n$.

To handle the different availability of single indexes in practice three levels of application and requirements were defined as follows:

- Minimum requirements;
- Standard requirements;
- Optimum requirements.

TABLE 2 shows the used Single Performance Indexes for the calculation of the four Combined Performance Indexes subject to the level of application.

TABLE 2 Variables Combined Performance Indexes

Level	Riding Comfort	Road Safety
Minimum	PI_E	PI_F
Standard	PI_E, PI_SD, PI_R	PI_F, PI_R, PI_T
Optimum	PI_E, PI_SD, PI_R, PI_T, PI_CR	PI_F, PI_R, PI_T, PI_SD (bleeding, potholes)
Level	Structural Status	Environmental Status
Minimum	PI_B	-
Standard	PI_B, PI_CR	-
Optimum	PI_B, PI_CR, PI_R, PI_E	PI_E, PI_T, noise, air pollution

Because of a lack of available information related to the single environmental indicators only a textual description for the definition of the Environmental Combined Performance Index was given by WG3.

General Performance Indexes

Based on the results of Work Package 3 a General Performance Index (GPI) was defined by Working Group 4 (WG4). The General Performance Index should enable to describe the overall condition of a pavement construction in form of one single value, which contains finally the information of each single index and the Combined Performance Indexes.

This special index will have an important function with regard to decisions on policy level or high administrative level. Furthermore it can be used as optimization criteria (target function) in optimization processes of PMS.

The combination of the Combined Performance Indexes into a General Performance Index is based on the same advanced maximum criteria. It takes into account the distribution on a value basis of the variables (CPI) by using an influence factor (p, within 10 and 20%) as well as the influence of the Combined Performance Indexes itself in form of different weights (w):

$$GPI = \min\left[5; J_1 + \frac{p}{100} \cdot \overline{(J_2, J_3, J_4)}\right]$$

where $J_1 \geq J_2 \geq J_3 \geq J_4$ and $J_1 = w_1 \cdot CPI_1, J_2 = w_2 \cdot PI_2, J_3 = w_3 \cdot CPI_3, J_4 = w_4 \cdot CPI_4$.

The weights (w, within 0 and 1) can be selected individually by the road administration authorities dependent on the type of the road network, the importance of the road, the traffic volume, etc.

Short Term Scientific Missions

Besides the activities in the Working Groups five “Short Term Scientific Missions” (STSM) took place in this Action. The objective of all missions was to provide the Action with information and to support especially the work of WG 2, 3, and 4 in the context of the structural assessment of pavement constructions and the practical application of the proposed procedures as follows:

- STSM 1: Structural performance indicator based on GPR and bearing capacity measurements;
- STSM 2: Detection of structural damages based on GPR measurements;

- STSM 3: Bearing capacity data evaluation for PMS purposes based on comparative measurements;
- STSM 4 and 5: Practical application of combination procedures and development of a practical guide.

In practice the missions were carried out by young researchers (applicants) at different places in Europe (hosts). After finalization of the missions the outputs were discussed in the Management Committee and in the Working Groups and could be implemented into the results of the Action.

CONCLUSION

The COST Action 354 Performance Indicators for Road Pavements is an important future orientated step in the ongoing European harmonization process. The results of this Action enable to assess European road networks on an uniform basis. Decision makers can compare and finally decide on which condition level these networks should be provided to the road users all over Europe in the future.

The practical application of the results of this Action (e.g. in PMS) is still in the scope of the authorities of each single European country. All procedures for the calculation of Single Performances Indexes (PI), Combined Performance Indexes (CPI), and the General Performance Index (GPI) show a flexible structure where existing limits, local settings, and already applied methods can be integrated easily. Furthermore it is a basis for countries which will or have been started recently with the implementation of condition measurements and systematic road maintenance.

In addition this Action provides a basis to underline necessary investments into the road networks from the national point of view as well as from the European perspective (e.g. Trans European Road-networks TEN).