https://doi.org/10.36100/dorogimosti2025.31.051

UDC 625.7/.8

Diana Bardhi[1], *Ph.D., https://orcid.org/0009-0002-6958-7770*
Altin Seranaj[2], *Ph.D., https://orcid.org/0009-0003-5511-1445*
László Gáspár[3], *D.Sc., Prof., https://orcid.org/0000-0002-0574-4100*
Zsolt Bencze[4], *Ph.D., https://orcid.org/0000-0003-2130-7864*

[1]*Department of Civil Engineering and Architecture, Metropolitan Tirana University, Tirana, Albania;*
[2]*Department of Building Constructions and Transport Infrastructure, Polytechnic Tirana University, Tirana, Albania;*
[3]*Széchenyi István University, Faculty of Civil Engineering, Győr, Hungary, and KTI Hungarian Institute for Transport Sciences and Logistics Non-Profit Ltd., Budapest, Hungary;*
[4]*KTI Hungarian Institute for Transport Sciences and Logistics Non-Profit Ltd., Budapest, Hungary*

REVIEW OF ROAD PAVEMENT PERFORMANCE IN VARIOUS COUNTRIES

Abstract

Introduction. High quality and durable highway pavements are one of the preconditions for the efficient road traffic in every country.

Problem Statement. The high-level and scientifical design, construction, maintenance, and rehabilitation of pavement structures — pavement management — can be taken as an important task of road owners — and in the case of state-owned roads, it is directly an obligation. An important subsystem of road asset management comprises several technical tools as pavement management systems (PMSs). Pavement performance models are an essential component of a PMS and have a direct impact on future pavement condition. Pavement structural design is always a rather responsible and hard task since it is obvious that the designer must forecast (predict) — using preferably scientifically based methodologies — the performance of pavement structures to be built in the future. The reliability of this forecast, of course, mainly depends on the accuracy of the design inputs applied. The complexity of the is-sue can already be characterized by the fact that, at least, traffic, environmental, raw material, construction, maintenance-rehabilitation, operation-related and financial parameters should be considered in the prediction of pavement performance (expected lifetime) during the design (selection) of optimum pavement structural variant. (The interrelationship of these influencing parameters just makes the situation even more complicated.

Purpose. The main aim of the article is to present various aspects of pavement performance in Hungary and Albania.

Materials and Methods. The paper outlines the role (the significance) of pavement performance models in the road asset management, especially in the scientifically based pavement structural design, pointing out the related challenges. After giving a short worldwide review of the topic, the presentation of the special theoretical and practical experiences on pavement performance models in two European countries (Hungary and Albania) are summarized, as case studies.

Results. At the end of the article, some conclusions are drawn, and several proposals are made on the creation and the utilization of pavement performance models including the high significance of a successful road asset management on national economy level; the importance of a scientifically based PMS in increasing the economy of road transport; the direct impact of pavement performance models on future pavement condition, as a major influencing factor of road traffic efficiency; the supporting role of Performance-based Maintenance and Safety Improvements to high volume roads performed in Albania can significantly support to medium-term road management decisions.

Keywords: road pavement, pavement management system, pavement performance model, Hungarian road management, Albanian road management.

Introduction

Pavement structural design is always a rather responsible and hard task since it is obvious that the designer must forecast (predict) — using preferably scientifically based methodologies — the performance of pavement structures to be built in the future. The reliability of this forecast, of course, mainly depends on the accuracy of the design inputs applied. The complexity of the issue can already be characterized by the fact that, at least, traffic, environmental, raw material, construction, maintenance-rehabilitation, operation-related and financial parameters should be considered in the prediction of pavement performance (expected lifetime) during the design (selection) of optimum pavement structural variant. (The interrelationship of these influencing parameters just makes the situation even more complicated). Of course, the actual pavement design techniques are worldwide quite different from each other, there are some typical groups of performance forecast: standardized structures (e.g., in Germany), computerized models, laboratory tests, accelerated loading, road section monitoring. After country-wide co-ordination, this latter one — monitoring — can result in the development of pavement performance models for the roads of the country in question, the most reliable tool of pavement design [1].

The paper outlines the role — the significance — of pavement performance models in the road asset management, especially in the scientifically based pavement structural design, pointing out the related challenges. After giving a short worldwide review of the topic, the presentation of the special theoretical and practical experiences on pavement performance models in two European countries are summarized, as case studies. Finally, some conclusions are drawn, and several proposals are made on the creation and the utilization of pavement performance models.

Role (use) of pavement performance models

As it is well-known pavement performance modelling constitutes an essential part of pavement management system (PMS), since it aims at efficiently predicting the need for maintenance, rehabilitation, or reconstruction of the road pavement, as well as its future deterioration process [2]. If the prediction accuracy of the estimation methods was considerably enhanced, it would obviously result in a more productive allocation of the financial resources, significant savings in costs, and improving the identification of different maintenance techniques.

The present and the predicted future condition of the road, as well as the knowledge about the actual condition improving effect of pavement maintenance treatments can be considered as important information s of road management systems including pavement management system.

Pavement performance modelling or pavement deterioration modelling is the study of pavement deterioration throughout its whole. The actual condition state of road pavement is assessed using various performance indicators. Some of the most well-known performance indicators as Pavement Condition Index (PCI), and Present Serviceability Index (PSI) are complex ones but single distresses such as unevenness characterized by International Roughness Index (IRI), rutting or the extent of surface defects are also used. Among the most frequently used methods for pavement performance modelling are mechanistic models, mechanistic-empirical models, survival curves and Markov models. Recently, machine learning algorithms have been used for this purpose as well.

The wide variety of methodologies suggested for the forecast of pavement performance measures can be either deterministic or stochastic. These methods have different model development concept, model formulation, and output format [3]. The deterministic approach in pavement performance modelling includes mechanistic models, mechanistic-empirical models, and regression models [4].

The general form of deterministic models can be formulated as follows (3):

$$PCS_t = f(P_0\ , ESAL_{st}, H_e \text{ or } SN, M_R, C, W, I), \quad (1)$$

where PCS_t — is the generalized pavement condition state (PCS) at year t;
P_0 — is the initial pavement condition state;
$ESAL_{st}$ — is the accumulated equivalent single axle loads ($ESAL_s$) applications at age t;
H_e — is the total equivalent granular thickness of the pavement structure;
SN — is the structural number index of total pavement thickness;
MR — is the subgrade soil resilient modulus;
W — is the set of climatic or environmental effects;
I — is the interaction effects of the preceding effects, and C is the set of construction effects.

The mechanistic models include the analysis of time-series pavement condition data, and consider parameters such as surface deflection, stress, or strain in the pavement performance model.

Due to the combined effects of various factors such as materials, traffic load, and environment, pavements generally deteriorate over time, which may affect road safety and cause additional user costs. That is why timely and suitable maintenance and rehabilitation treatments are necessary to improve pavement performance and extend its service life. As an essential component in pavement maintenance and rehabilitation decision-making, pavement performance models can help pavement managers predict future pavement conditions, select reasonable maintenance activities, and determine appropriate maintenance timing. Thus, a reliable pavement performance model that can accurately predict pavement performance is one of the preconditions for creating effective pavement management systems. Pavement performance models mainly describe the relationship between pavement performance and its influencing factors and can be used to explore the deterioration process and predict future pavement conditions. Generally, pavement performance models can be divided into three basic types: mechanistic models, empirical models, and mechanistic-empirical models [8]. Mechanistic models are usually based on mechanistic principles and analyse pavement responses to stresses, strains, and deflections. Empirical models mainly rely on observed data to explore the relationship between pavement performance and various influencing factors. Mechanistic-empirical models combine mechanistic principles and empirical analysis to study the relationship between response parameters and pavement performance. Empirical models are more commonly used in pavement management than the other two groups [1].

The development and the features of pavement performance models have been identified worldwide as a hot topic in the field of pavement management.

International survey in the field

Several pavement performance measures such as fatigue cracking, thermal (transverse) cracking, and IRI, for flexible and rigid pavements are estimated using mechanistic theories, and guides are presented in the Applied Research Associates Inc. [5]. For example, Saleh et al. [6] proposed a mechanistic longitudinal unevenness (in the USA roughness) model relating this pavement condition parameter with the asphalt layer thickness, number of load repetitions, and axle load. The model is based on the finite element structural analysis and estimates the change of surface roughness for each load repetition. The model is formulated as follows [6]:

$$IRI = -1.415 + 2.923\sqrt{IRI_0} + 0.00129\sqrt{ESAL_S} + 0.000113T - 5.485 \cdot 10^{-10}T\sqrt{ESAL_S} + \\ + 5.777 \cdot 10^{-12}P^4\sqrt{ESAL_S}\,, \qquad (2)$$

where IRI_0 — the initial roughness;

P — axle load;

T — asphalt thickness, and $ESAL_S$ number of load repetitions.

The mechanistic-empirical models usually concentrate on the relationship between roughness, cracking, and traffic loading. For example, Queiroz, in a study of flexible pavements [7], developed mechanistic-empirical models based on linear elasticity as an important constitutive relationship for the pavement materials investigated. Their results showed horizontal tensile stress, strain, and strain energy at the bottom of the asphalt layer. George et al. [4] created empirical-mechanistic performance models for the highways in an American state based on pavement condition data. These performance models were evaluated based on the rational formulation, behaviour of the models, and statistical parameters. It was found that the exponential and power functions of both concave and convex shapes happened to be the statistically significant functions.

Linear and non-linear regression models consider the associations between performance parameters such as riding comfort index, and the predictive parameters such as pavement thickness, material properties, and traffic loading [3]. These models have been extensively used earlier to estimate factors influencing pavement condition parameters (PCI, PSI, etc.). AASHO developed a model [8] for estimating the number of equivalent single axle loads applications; the independent variables in this model were subgrade strength, material properties and thicknesses of pavement structural layer, as well as environmental factors. World Bank experts [9] developed models to estimate roughness and distress (cracking, rutting, etc.) on flexible pavements for The Highway Design and Maintenance Standards as a function of subgrade strength, environmental factors, traffic load and time.

Nonlinear regression models (e.g., power function) have also been used for project design [10, 11]. Chan et al. [12] utilised data collected in an American state and used a regression model for the estimation of a power curve of the PCR; it is based on the age of pavement. Experts of Nevada state [13] created nine flexible pavement performance models, which modelled PSI as a function of material properties, traffic load and environmental factors.

Indiana researchers [14] developed models for the simultaneously prediction of change in performance and maintenance occurrence (i.e., decision to perform maintenance) as a function of traffic size and pavement age. A two-stage modelling scheme was applied.

Prozzi et al. [15] selected multivariate regression to estimate pavement riding quality (as a function of pavement longitudinal unevenness) utilizing mainly field data. Ramaswamy et al. [16] developed a model for Present Serviceability Index and three maintenance parameters, as sand seal maintenance, crack filling and chip sealing; besides, they also considered the issue of endogeneity. Madanat et al. [17] used probit models for the prediction of the deterioration of various bridge decks; at the same time, they accounted for panel data effect using random-effects model. It was shown that taking into consideration the heterogeneity coming from the panel effect results in an improved estimation accuracy. Prozzi and Hong [18] used seemingly unrelated regression estimation (SURE) model to estimate IRI and pavement rut depth while accounting for the correlation between the two parameters.

Other types of regression-based models used in pavement deterioration modelling include time series regression [19] stochastic duration models [20, 21], joint discrete-continuous models [22], and nonlinear mixed effects models [23, 24].

The deterministic approaches applied extensively have some limitations, since these models cannot explain [3]:

a) randomness of traffic loads and environmental conditions;

b) the difficulties in quantifying the factors influencing substantially pavement deterioration;

c) the measurement errors connected with pavement condition, and the bias coming from subjective pavement condition evaluations.

The probability-based pavement performance models (e.g. Markov probabilistic modelling options) can be considered as alternatives to the deterministic models, which do not provide probabilistic distributions of the existing values.

Typically, a stochastic model of pavement performance curve is represented by the Markov transition process, with full information about the “before” state of pavement, the Markov process predicts the “after” state [3 – 4]. This model initially transforms the pavement condition ratings into discrete condition states. Then, it defines a transition-probability matrix (TPM) to determine the probabilities that a pavement remains in the current state or changes to another one in the future. In general, both historical data and engineering judgments can be used to estimate the transition probabilities. For example, Wang et al. [25] developed the Markov transition-probability matrices for the roads of an American state and Gáspár for the Hungarian public highway network [26] by using a comprehensive set of measured pavement performance historical data with various initial pavement condition states.

Markov transition method is extremely useful for highway network level applications where historical databases and reliable regression equations are not available (for example [27, 28]). One of the main advantages of Markov models is that they use different distributions for the expected value of the dependent variable, which indicate the future performance on different sections and changes in performance regardless of time. The most important disadvantage is that no guidance is given to the actual causes for the condition deterioration of the road pavement in question, and that the transitional probabilities are not dependent on the actual age of the pavement [27]. This approach was applied first in the network-level maintenance, rehabilitation, and reconstruction decision-making process. Some other examples of Markov chains and Bayesian statistics in determining pavement condition measures can be found in Butt et al. [29] and Hong and Prozzi [30].

Other stochastic models use the Bayesian decision model that combine prior knowledge and information from actual historical data when predicting posterior pavement condition deterioration estimates by investigating and evaluating the main statistical characteristic of the parameters considered. The model parameters in this method were taken as random variables [19, 28]. The main advantage of this approach over the traditional regression analysis is that no comprehensive historical database is required for this methodology.

Chinese scientists reviewed a high number of empirical methods used to develop pavement performance models [31]. Their paper classifies the empirical methods into traditional and adaptive modelling methods presenting and evaluating their main characteristics, strengths, and weaknesses. It was clearly shown by them that however traditional, comprehensive modelling methods generally can well incorporate both temporal and spatial characteristics of pavement performance but their interpretation capability based on machine learning techniques needs to be enhanced; the adaptive modelling methods can characterise actual pavement performance deterioration in a more accurate way but it would be still necessary to improve the setting of updating conditions and the evaluation of updating effects.

Justo-Silva et al. [32] showed a framework for the classification of pavement performance models: as a function of their formulation types, pavement performance models can be divided into deterministic models and probabilistic models; depending on the application levels of performance models, they can be project-level and network-level performance models; besides, as a function of dependent variables types, they can be global dependent variable models and parametric dependent variable models; if the types of independent variables are taken into account, absolute independent variable models and relative independent variable models could be distinguished. The bibliometric analysis in the field clearly shows that development of pavement performance models has been identified as a hot topic related to pavement management [33].

A high number of research works have been conducted on establishing empirical pavement performance models [34-36]. It is well-known that the deterioration of pavement performance deterioration is a rather complex process with dynamic changes; hence, the regular updating of pavement performance models is essential to incorporate interim changes. Due to the rapid development of science and technology, several advanced data collection technologies [37-39] and analysis methodologies [39-42] have been developed and introduced in pavement management of various countries. This process obviously enhances pavement condition inspection techniques and provides opportunities for updating the existing performance models. In addition to it, intelligent road management also puts forward requirements of adaptive updating of empirical performance models.

Hungarian case study

In Hungary, some road and system engineers started to develop the first versions of pavement systems in the early 1990's [43 – 44]. However, the first PMSs related to the Hungarian public highway network of some 32,000 km total length were based on Markov transition probability matrices, a concentrated and long-term research initiated in 1990, drew attention to the usefulness of pavement performance models also at the national level.

It is well-known that the pavement structural design is faced with the problem of which methods can be used to predict the future performance of pavement structures with acceptable reliability. In principle, there are five options in this field, as follows:

- standardised pavement structures;
- computer models;
- laboratory tests;
- accelerated loading;
- section monitoring.

Table 1 presents the time required and accuracy (reliability) of each option mentioned before.

Table 1

Some features of pavement design methodologies

Design option	Time required	Accuracy (reliability)
Standardised structure	minutes	minimal
Computer model	days	limited
Laboratory tests	weeks	still acceptable
Accelerated loading	months	high
Road section monitoring	decades	very high

Lifetime engineering is an emerging science originally developed for buildings, bridges, and industrial infrastructures in Finland in the late 1980's [45]. Since its principles proved to be useful for the project types mentioned before, an attempt was made in several countries to use (adapt) these principles to highways, actually to road asset management. In Hungary, the adaptation of lifetime engineering principles to road network started already in the 1990's [46]. The lifetime engineering takes for granted the reliability of the future performance forecast of the facilities concerned (e.g., road pavements). For this purpose, it was obvious for the road experts that scientifically based pavement performance models must be developed. That is why, the yearly monitoring of 60 trial sections of 500 m length chosen of the national highway network started already in 1991 [47]. The major goal of trial section monitoring is the development of pavement performance models, the average (typical) deterioration curves in a road category ("road section class") of specified "pavement structure type – traffic volume – subgrade strength" combination. The performance models of the road categories can be attained by putting regression curves on the points representing condition parameter levels as a function of time. (Similar curves are determined as a function of the traffic passed).

To evaluate the reliability of the performance models an alternative method was also initiated. The pavement structure of a representative — altogether 3000 km long — part of the Hungarian national highway network was identified using geo-radar technique by more than 1,600 sections. Since then, condition parameters (including unevenness, rut depth, load bearing capacity and surface defects) of these pavement sections (representing 10 % of the total network length) have been yearly evaluated. The map (**Figure 1**) shows the location of the 1,600 representative sections as well as the 60 trial road sections on the national road network [48].

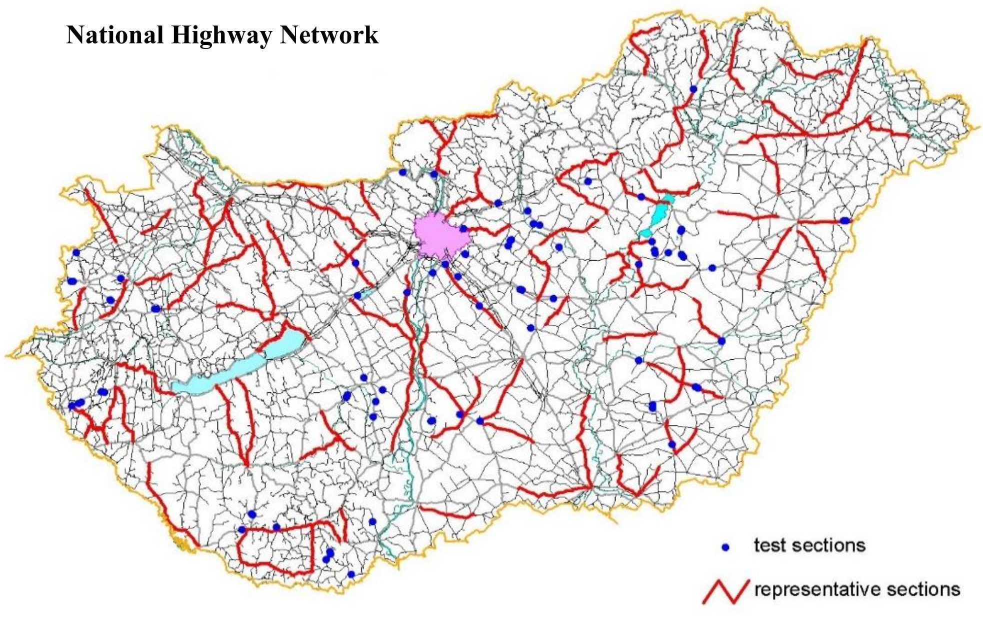

Figure 1 — The location of the Hungarian representative and trial sections

Based on the information coming from Hungarian National Road Data Bank, 14 road section classes were identified, which are typical for a considerable share of the 32,000 km-long Hungarian national highway network for its pavement structure, traffic size and subgrade soil strength [43]. Semi rigid, flexible and super-flexible (unbound base) pavement structure categories, three traffic categories (max 1500 pcu/day, 1501-3000 pcu/day, min 3001 pcu/day) and three environmental (subgrade soil strength) classes were considered. The realistic variants (combinations) of the parameters mentioned were represented by 3-5 trial sections to identify and to exclude the eventual outliers that cannot be considered at all as a representative of its road section class. (Box and Whiskers Plot [49] was applied to select and to exclude the outliers of the data series analysed). A point of a pavement performance model was calculated as the mean value of the 3-5 trial sections. A model point relates to a selected pavement condition parameter (e.g., rut depth) of a given road section class at a pavement age or traffic volume passed.

The more than two decades long data time series of the following condition parameters serve as the basis of the pavement performance models of 14 road section classes:

- unevenness (laser Road Survey Tester, RST);
- rut depth (laser RST);
- bearing capacity (KUAB Falling Weight Deflectometer);
- macro texture (laser RST);
- micro texture (laser RST);
- surface defects (Roadmaster, visually aided by a keyboard-type device).

The pavement performance models for each condition parameter have been developed as a function of traffic passed (in vehicle units) and pavement age (in years).

As an example, **Table 2** presents the performance models of a road section class. The function types applied in the development of the HDM-III model organised by the World Bank [46] were selected here for the condition parameters. (Exponential functions were chosen for unevenness and rut depth, while linear functions for the other condition parameters monitored). Age means the time passed after construction or past major maintenance and expressed in years. “Age” means in **Table 2** the time passed after construction or past major maintenance and expressed in years.

Table 2

Performance models of a road section class (certain pavement type, traffic volume and sub-grade strength) [45]

Condition parameter	Performance model as a function of	
	time	traffic
Bearing capacity	E = 529 – 10 AGE	E = 481 – 8TRA
Unevenness	IRI = exp (1.76 + 0.16 AGE)	IRI = exp (1.88 + 0.15 TRA)
Rut depth	RD = exp (4.13 + 0.03 AGE)	RD = exp (4.25 + 0.06 TRA)
Micro texture	MI = 0.22 – 0.004 AGE	MI = 0.24 – 0.005 TRA
Macro texture	MA = 0.39 – 0.02 AGE	MA = 0.44 – 0.02 TRA
Surface defects	SD = 2.46 + 0.06 AGE	SD = 2.42 + 0.05 TRA

As it was already mentioned, these pavement performance models were changed (finetuned) every year during the monitoring period between 1991 and 2018 as a consequence of the inclusion of latest measuring results in the calculation. **Table 3** presents the yearly updating of a pavement performance model of a selected pavement condition parameter (this time, longitudinal unevenness, the American roughness) highlighting the “successive approximation” methodology of the Hungarian pavement performance modelling.

Table 3

Yearly pavement performance model updating of a condition parameter (example)

Condition parameter	Year	Model (age)	Model (traffic)
Longitudinal unevenness (roughness)	1996	IRI = 0,52.exp (0,002 KOR)	IRI = 0,47.exp (0,008 FORG)
	1997	IRI = 1,55.exp (0,01 KOR)	IRI = 1,56.exp (0,01 FORG)
	1998	IRI = 1,54.exp (0,01 KOR)	IRI = 1,55.exp (0,015 FORG)
	1999	IRI = 1,53.exp (0,01 KOR)	IRI = 1,58.exp (0,017 FORG)
	2000	IRI = 1,48.exp (0,015 KOR)	IRI = 1,51.exp (0,018 FORG)
	2001	IRI = 1.53.exp (0,016 KOR)	IRI = 1,52.exp (0,021 FORG)
	2002	IRI = 1,89.exp (0,025 KOR)	IRI = 1,56.exp (0,039 FORG)
	2003	IRI = 1,94.exp (0,023 KOR)	IRI = 1,55.exp (0,036 FORG)
	2004	IRI = 1,97.exp (0,024 KOR)	IRI = 1,68.exp (0,031 FORG)
Longitudinal unevenness (roughness)	2005	IRI = 1,98.exp (0,026 KOR)	IRI = 1,69.exp (0,030 FORG)
	2006	IRI = 1,78.exp (0,028 KOR)	IRI = 1,97.exp (0,034 FORG)
	2007	IRI = 1,89.exp (0,028 KOR)	IRI = 1,93.exp (0,032 FORG)
	2008	IRI = 1,97. exp (0,029 KOR)	IRI = 1,81.exp (0,035 FORG)

The trial section monitoring in Hungary has been performed since 1991. During this rather long monitoring period, a considerable share of the sections deteriorated to such an extent that surface dressing, resurfacing by thin asphalt layer or pavement strengthening was needed. Then, the question arose, whether their pavement condition monitoring should be discontinued or not. It was decided to go on with the regular condition evaluation since the additional survey could provide other kinds of useful information. The condition parameter levels in the years before and after the intervention can be utilised for identifying of various pavement condition parameter levels, which could be considered as the "realistic" intervention level in Hungary. In addition to it, the determination of the actual condition improving effect of various major maintenance techniques in the present Hungarian road practice can also provide helpful information to road managers. Furthermore, the continuation of trial section monitoring for several more years can provide information about the deterioration trends after the intervention which can be compared to the tendencies during the former life cycle.

The deterioration curves of the trial sections before and after strengthening were also determined for IRI and rut depth. Based on the analysis of a high number of curves, the following generalised remarks could be made [51]:

— the unevenness during the period investigated generally changed only somewhat proving that this condition parameter is not critical among present Hungarian conditions (it means that usually level of another pavement condition parameter – for example, surface defects – worsens to its intervention level);

— in the case of overlaying of a section with rather uneven pavement surface is overlayed, the improving effect in longitudinal unevenness is much more pronounced, however, in most cases, a quick deterioration is to be expected;

— the trends of rutting process can be very different for various pavement sections depending on the different features of pavement structures;

— the typical rut depth values before condition improving intervention is in the range of 6 – 10 mm, 2 – 4 mm rut depth values can be expected most probably after pavement strengthening;

— the unevenness (roughness in the USA) and the rut depth data series (deterioration tendencies) obtained during the condition monitoring period do not show yet any sign of basically different life cycle trend from preceding one.

As another example, the influence of building a new thin asphalt layer resurfacing (thickness ≤ 40 mm) is presented on **Table 4** using some of their statistical parameters.

Table 4

Effect of thin asphalt layer resurfacing to visual pavement condition state note [46]

Statistical parameter	Visual condition state note		
	before	after	changing
Mean value	4.05	1.61	– 2.44
Maximum	5	2	– 3
Minimum	1	1	0
Standard deviation	1.10	1.45	+ 0.35

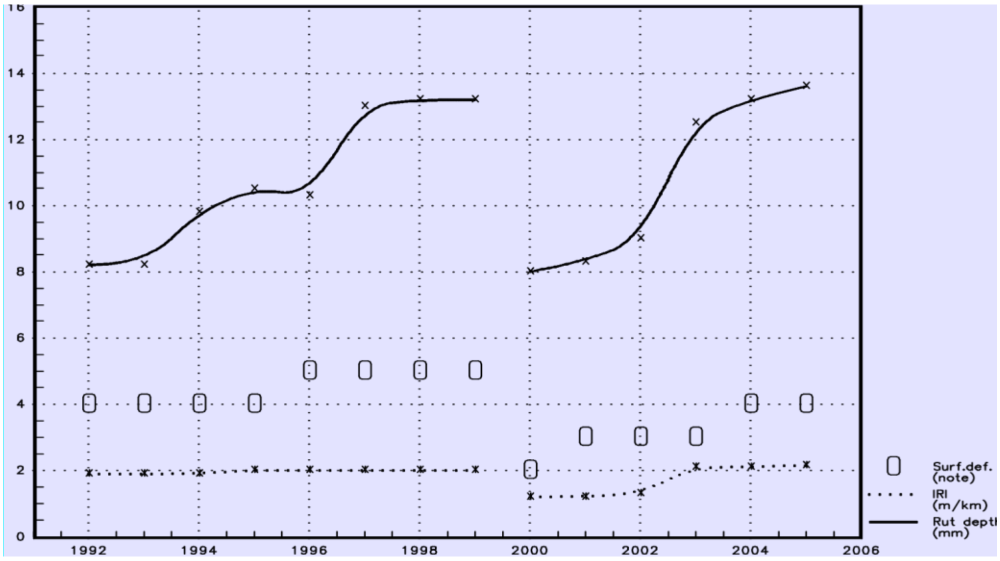

Figure 2 — Pavement performance models with thin layer resurfacing in 1999

Fig. 2 shows an example of the pavement performance model of a road section class on longitudinal unevenness (IRI, m/km), rut depth (mm) and surface defect (5-grade notes). The effect of the thin layer resurfacing in 1999 to the actual level of the condition parameters investigated can be clearly seen. **Fig. 3** introduces the pavement performance models of another road section class on the same 3 condition parameters; this case, the influence of pavement resurfacing on the actual pavement condition parameter levels can be highlighted.

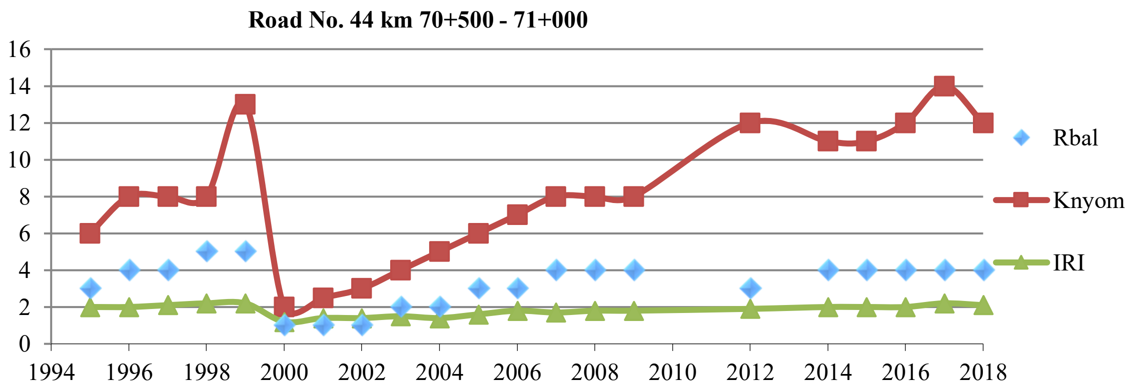

Figure 3 — Pavement performance models with strengthening in 1999

Besides, the traffic parameters of, and the eventual major maintenance actions on every trial section have been collected during the whole pavement condition monitoring period between 1991 and 2018 [50, 51].

The pavement bearing capacity basically differs from the other three condition parameters tested (longitudinal unevenness, rut depth and surface defects) by its eventual improvement as a consequence of environmental parameters, and it is true not only for the well-known seasonal changes (e.g. lower spring bearing capacity for most subgrade soil types due to the high moisture content compared to the bearing capacity in other seasons).

An earlier Hungarian research work [52] revealed that the bearing capacity of a pavement structure can considerably fluctuate during the consecutive years because of the basically different weathers during winter. In a country of continental climate like Hungary, the winter can be rather mild with few precipitations when the bearing capacity of roads with cohesive or intermediate subgrade soil can be considerably higher than in the preceding or penultimate spring after severe winters with rather low temperature and a lot of snow). The authors of the research mentioned [52] suggested the use of a so-called "yearly bearing capacity modifying factor" in addition to the traditional and widely applied "seasonal bearing capacity modifying factor".

Considering the forementioned considerations, it was investigated in which years took place the unexpected bearing capacity improvements looking for the eventual more frequent occurrence in one or more years. The numbers and shares of unexpected improvements in various years were investigated. The trial section with non-granular subgrade soil were investigated separately. It has been revealed that the improvements in bearing capacity between year 2 and 3 represented 70-80 % share proving that the improvements then can be (actually are) explained by environmental reasons.

Albanian case study

The project based on Performance-based Maintenance and Safety Improvements to high volume roads within the national network were taken place in Albania in 2014 to 2019. The Project Roads comprise the share of the national road network, classified as primary (P) and Primary-Secondary (PS) roads. The project will maintain 1,053 km of P roads, and 282 km of PS roads. The roads to be maintained are summarized in **Tables 5** below.

Table 5

Contract Costs of various Packages

Contract	Network Length (km)				Pavement Capital Works	
	P	PS	S	Total	(km)	(%)
A	216	73	0	289	139	48 %
B	242	58	0	300	119	40 %
C	282	94	0	376	103	27 %
D	314	57	0	371	193	52 %
Total	1,053	282	0	1,335	554	41 %

Table 6

Mean IRI performances, NPVs and Economic Internal Rate of Returns of Contract Packages

Contract	Roughess (IRI)		NPV (M EUR)	EIRR (%)
	2014	2019		
A	5.0	5.0	90	85 %
B	4.8	5.7	214	95 %
C	3.6	4.1	135	168 %
D	4.2	3.5	401	177 %
Total	4.3	4.5	840	135 %

Traditionally, the success of a regional road administration is measured by the degree of achievement of the objectives that have been set for them by top authorities, also by the quality of their products and services offered. Nowadays, the satisfaction of customers has been given more emphasis. A satisfied customer whose expectations have been fulfilled indicates efficient and high-quality performance of road service.

Road ID	Road Name	Contract Length (km)
SH1-N	Tiranë - Hani i Hotit (New)	132.43
SH2	Tiranë - Durrës (Autostrada)	32.50
SH3	Elbasan - Kapshticë	156.01
A3	Tiranë - Elbasan (New motorway)	36.84
SH4-N	Durrës - Fier (New)	78.20
SH4-O	Tepelenë - Kakavijë (Old)	82.90
SH4-N	Levan - Tepelenë (New)	77.71
SH5	Shkodër - Kukës	138.41
SH6	Milot - Skuraj - Peshkopi	117.90
SH7	Elbasan - Rrogozhinë	44.49
SH8	Fier - Vlorë	0.34
SH8	Pusi Mesinit - Sarandë	121.80
A2	Levan - Vlorë (New part of SH8)	24.61
SH9	Qafë Thanë - Doganë	3

Road ID	Road Name	Contract Length (km)
SH32	Lezhë - Shëngjin - Kune	11.40
SH41	Ura e Bunës - Muriqan	13.90
SH44	Jun. Road Nr.6 - Dogana Blladë	3.35
SH52	Vorë - K/Rinas - F. Krujë	11.50
SH60	Kryqëzim Rinas - Rinas - Qafë Kashar	9
SH64	Pogradec - Tushemisht	5.90
SH72	Lushnje - Berat - Çorovodë	87.98
SH85	K/Shkozet - Plepa	8.30
SH97	Ura e Kranesë - Konispol (Q. Botë)	33
SH99	Sarandë (Ura e Gajdarit) - K/Qafë Muzinë	22
208	Tamarë - Vermosh	35
22	Qafë Mali - Qafë Morinë	16.66
28	Melgushë (K - Mjedë	7.10
218	Maminas - Hamallaj - ShenPjeter	23
Total		1.335,23 km

Figure 4 — Project road elements on the Albanian national and secondary road network

Performance Indicators for the road sector at Albanian Road Authority were developed as a descriptive conceptual model for the road transport system and for the road administration's overall performance.

A methodology was worked out to put the model into practice through field testing and to allow comparison of the 15 performance indicators used in different countries. The final results are expressed as conclusions, recommendations and "best practice" methods.

The key issues facing road transport system and road administrations include:

— lower road budgets;
— the need for greater transparency in road administration performance;
— the road production and administration roles should be separated;
— the focus of customer has been changed, so expert should be aware of their best attitude;
— looking for greater efficiency in road performance management;
— demand for better results and quality;
— dmand for more co-ordination and co-operation in transport sector;
— demand for acquiring more data and performing more efficient data management.

Table 7 and **Figure 5** show the Net Present Values (NPV) and other economic indicators together with mean IRI values at the end of the contract (5 years) and of the reference period (20 years) on the network of project roads. (Financial costs given here are the sums of the financial costs during the 5 and 20-year periods).

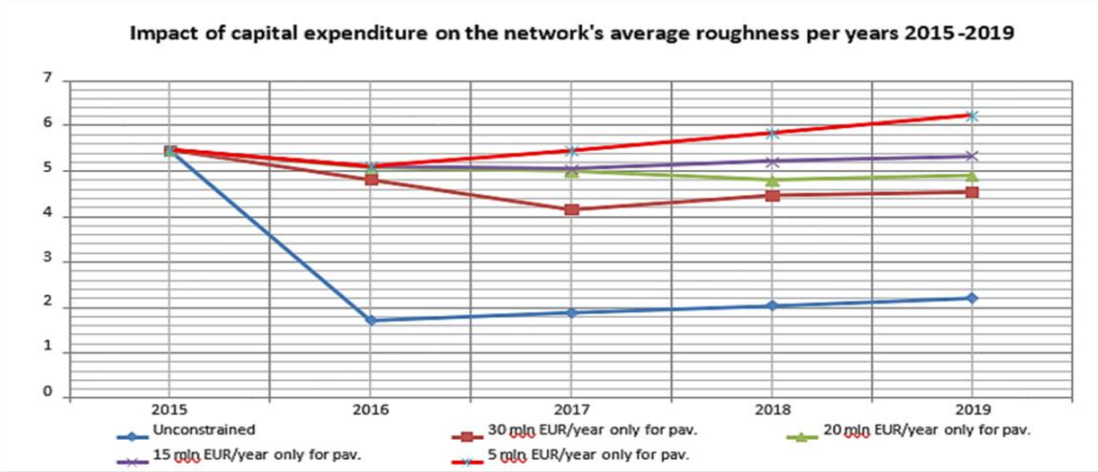

Figure 5 — Evolution of mean IRI on the project roads for different budget scenarios in the contract period 2015-2019 [53]

Table 7

Economic Indicators and IRI values in various budget scenarios [53]

Budget Scenario (pavements only)		Capital Exp. Years 1 to 5 (M€ per year)	Financial Cost (mln €)		Discounted Financial Cost (mln €)		NPV (M€)		NPV / Cost		IRR (%)		IRI (m /km)	
			5 years	*20 years*	*5 years*	*20 years*	*5 years*	*20 years*	*5 years*	*20 years*	*5 years*	*20 years*	*5 years*	*20 years*
Scenario 1	Unconstrained Scenario	Average 45	229.6	544.3	219.55	385.85	252.6	4,452.6	34,85	34,850	62.3	82.1	2.22	2.73
Scenario 2	30 mln €/year	30	141.8	504.8	179.15	373.49	131.7	4,200.9	34,85	2,967	63.3	89.5	4.54	3.52
Scenario 3	20 mln €/year	20	97.8	394.1	88.11	255.02	130.3	4,124.4	34,85	43,720	64.8	90.7	4.91	3.49
Scenario 4	15 mln €/year	15	71.5	294.4	64.42	184.59	115.7	4,073.0	14,75	2,9670	62.0	89.7	5.34	3.49
Scenario 5	5 mln €/year	5	21.2	290.8	19.12	164.10	93.3	3,692.3	43,15	43,150	58.40	85.5	6.23	3.53

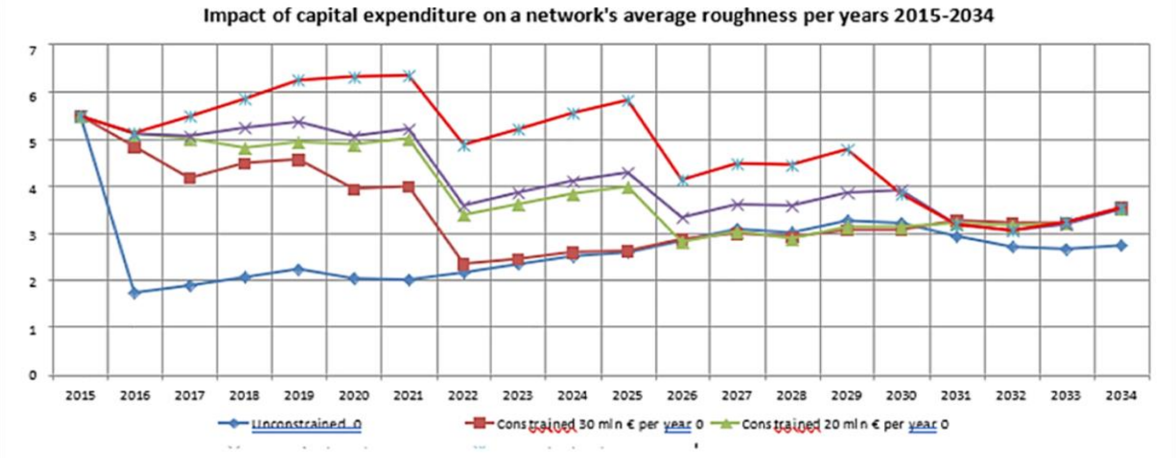

Figure 6 — The average value of IRI under different budget scenarios in short and long term [53]

On **Figure 6**, the short- and long-term longitudinal unevenness (roughness) data time series — expressed in IRI — are shown in the case of various budget scenarios.

Based on the outputs of data collection, a statistical analysis on the entire national road network wasperformed to characterise the network's current pavement condition, traffic volumes, geometrical features (rise & fall and curvature). As a first step, a suitable classification system (**Table 8**).

Table 8

Rutting and IRI classification [54]

Scale of evaluation	Rutting		
	frequency (%)	depth (mm)	IRI (m/km)
Very Good	F ≤ 5	D ≤ 10	IRI < 2,5
Good	F ≤ 10	D ≤ 25	2.5 ≤ IRI < 4,5
Fair	F > 10	10 < D ≤ 25	4.5 ≤ IRI < 7,0
Poor	F ≤ 10	D > 25	7,0 ≤ IRI < 10,0
Very Poor	F > 10	D > 25	IRI ≥ 10,0

At the end of this stage, it was possible to set up a reliable picture of the current statistics of the road network in terms of road condition, geometrical features and traffic sizes. The current pavement condition of the network is summarized below. Pavement condition is characterised by the values of IRI (International Roughness Index). Fit was also shown that the initial HDM-4 evaluation covering the entire network identifies that in case of an unconstrained budget scenario, the capital preservation expenditures and the fully elimination of the periodic maintenance backlog during the 2015-2019 period amounts to 230 million EUR, of which 54 percent is allocated to the P and PS networks. Under this scenario, the average network roughness decreases from the initial 5.5 IRI to 2.2 IRI in 2019, yielding a NPV of 4,453 million EUR. The evaluation also considered budget constraint scenarios of 30, 20, 15 and 5 million EUR per year for 2015-2019. **Figure 7** presents the overall network NPV and the average network roughness (IRI) in 2019 as a function of the budget constraint scenarios investigated.

Based on the analyses the results obtained, conducted that there is a significant improvement in service life when strict enforcement of legal axle limits is done. The various benefits arising from strict enforcement of legal limits are as given below:
- reduction in maintenance and rehabilitation cost of roads;
- more funds would be available for upkeep of pavements;
- the road pavements can be maintained at desired serviceability levels.

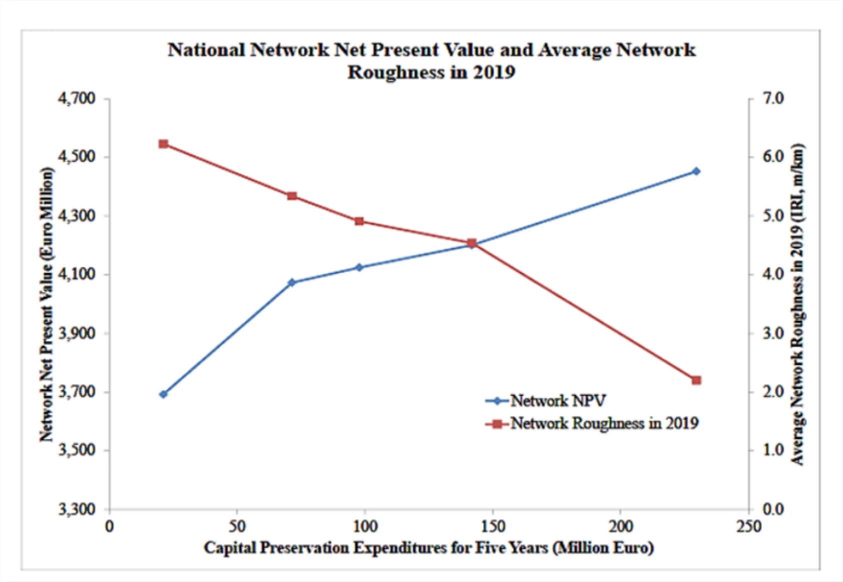

Figure 7 — National Network Net Present Value and Average Network Roughness in 2019 after 25, 75, 100, 150 and 235 million (unconstrained) EUR expenditures in the preceding 5 years

Based on the limited work results available, it would be still premature to quantify the savings in road pavement maintenance coming from load restrictions. However, the savings in maintenance costs could be roughly estimated at least in the order of 20 – 25 % of the present expenditures if legal road vehicle axle limits are enforced and no vehicle is allowed to carry loads beyond the permissible one. Savings of such magnitude would certainly help road organisations in providing better roads to the users.

Concluding remarks

After having presented some general facts and some country specific experiences on road pavement management the following main conclusions can be drawn:

- The successful road asset management has high significance on national economy level.
- The scientifically based PMS, as an essential element of road asset management, has a prominent role in increasing the economy of road transport.
- Development of pavement performance models are an essential component of a PMS and have a direct impact on future pavement condition, as a major influencing factor of road traffic efficiency.
- These statements are supported by the Hungarian and Albanian, pavement management related experiences presented before.
- The long-term monitoring of carefully selected trial section as a source of sophisticated pavement performance models can be highlighted.
- The project based on Performance-based Maintenance and Safety Improvements to high volume roads performed in Albania can significantly support the medium-term road management decisions.

References

1. L. Gáspár: Road management. Academy Press, 2003, 361 p. [In Hungarian].
2. R. Shabanpour: Pavement Performance Modeling: Literature Review and Research Agenda University of Illinois at Chicago, Illinois Asphalt Pavement Association, 2017, 8 p. [in English].
3. N. Li, W.-C. Xie, R. Haas: Reliability-based processing of Markov chains for modeling pavement network deterioration. Transportation Research Record, 1524, 1996. P. 203–213 [in English].
4. K. P. George, A. S. Rajagopal, L. K. Lim: Models for predicting pavement deterioration. Transportation Research Record 1215, 1989. P. 1–7 [in English].

5. Applied Research Associates Inc.: Guide for Mechanistic-Empirical Design for New and Rehabilitated Pavement Structures: NCHRP 1-37A Final Report. Prepared for NCHRP, Transportation Research Board, 2004, 424 p. [in English].

6. M. F. Saleh, M. S. Mamlouk, E. B. Owusu-Antwi: Mechanistic roughness model based on vehicle-pavement interaction. Transportation Research Record 1699, 2000. P. 114–120 [in English].

7. C. Queiroz: A Mechanistic Analysis of Asphalt Pavement Performance in Brazil. *Journal of Association of Asphalt Paving Technologists*, 52, 1983. P. 474–488 [in English].

8. AASHO: The AASHO Road Test Report 5: Pavement Research, Special Report 61 E. Highway Research Board, National Research Council, Washington, DC., 1962, 371 p. [in English].

9. Watanatada, T., Harral, C.G., Paterson, W.D.O., Dreshwar, A.M., Bhandari, A., Tsunokawa, K.: The highway design and maintenance standards model (Vol. 2): User's manual for the HDM-III model (English). URL: http://documents.worldbank.org/curated/en/615821468142166343/User-s-manual-for-the-HDM-III-model, 1987, 403 p. [in English].

10. A. Ferreira, L. Picado-Santos, A. Antunes, P. Pereira: A Deterministic Optimization Model Proposed for the Lisbon's PMS. Proceedings, MAIREPAV – Third International Symposium on Maintenance and Rehabilitation of Pavements, 2003, P. 555–564 [in English].

11. R. V. LeClerc, T. L. Nelson, T. L.: Washington State's Pavement Management System. Proceeding of the 5th International Conference on the Structural Design of Asphalt Pavements, 1982, P. 533–552 [in English].

12. P. K. Chan, M. C. Oppermann, S. Wu: North Carolina's experience in development of pavement performance prediction and modeling. Transportation Research Record, 1592, 1997, P. 80–88 [in English].

13. P. E. Sebaaly, A. Hand, J. Epps, C. Bosch: Nevada's Approach to Pavement Management. Transportation Research Record, 1524, 1996, P. 109–117 [in English].

14. D. P. Mohammed, K. C. Sinha, P. S. McCarthy: Relationship between Pavement Performance and Routine Maintenance: Mixed Logit Approach. Transportation Research Record, 1597, 1997. P. 16–21 [in English].

15. J. A. Prozzi, S. M. Madanat: Development of pavement performance models by combining experimental and field data. *Journal of Infrastructure Systems*, 10(1), 2004. P. 9–22 [in English].

16. R. Ramaswamy, M. Ben-Akiva: Estimation of highway pavement deterioration from in-service pavement data. Transportation Research Record, 1272, 1991. P. 96–106 [in English].

17. S. M. Madanat, S. Bulusu, A. Mahmoud: Estimation of infrastructure distress initiation and progression models, *Journal of Infrastructure Systems*, 1(3), 1995. P. 146–150 [in English].

18. J. A. Prozzi, F. Hong: Transportation infrastructure performance modeling through seemingly unrelated regression systems. *Journal of Infrastructure Systems*, 14(2), 2008. P. 129–137 [in English].

19. K. L. Smith, K. D. Smith, L. D. Evans, T. E. Hoerner, M. I. Darter, J. H. Woodstrom: Final report: Smoothness specifications for pavements. NCHRP Web Document 1, National Cooperative Highway Research Program, Washington, DC, 1997 [in English].

20. W. D. O. Paterson, A. D. Chesher: On predicting pavement surface distress with empirical models of failure times., Transportation Research Record, 1095, 1986. P. 45–56 [in English].

21. Z. S. Nakat, S. M. Madanat: Stochastic duration modeling of pavement overlay crack initiation, *Journal of Infrastructure Systems*, 14(3), 2008. P. 185–192 [in English].

22. S. M. Madanat, M. G. Karlaftis, P. S. McCarthy: Probabilistic infrastructure deterioration models with panel data, *Journal of Infrastructure Systems*, 3(1), 1997. P. 4–9 [in English].

23. A. R. Archilla: Repeated measurement data analysis in pavement deterioration modeling. *Journal of Infrastructure Systems*, 12(3), 2006, P. 163–173 [in English].

24. A. R. Archilla, S. M. Madanat: Estimation of rutting models by combining data from different sources, *Journal of Transportation Engineering*, 127(5), 2001. P. 379–389 [in English].

25. K. C. P. Wang, J. Zaniewski, G. Way: Probabilistic behavior of pavements. *Journal of Transportation Engineering*, 120(3), 1994. P. 358–375 [in English].

26. L. Gáspár: Highway performance modelling. Proceedings of International Conference on Developments in Road Engineering. National Institute of Technology, Rourkela, India, 2010, P. 24-36 [in English].

27. Finn, F. N., Kulkarni, R., Nair, K., 1974. Pavement Management System Feasibility Study, Final Report. Prepared for Washington Highway Commission, Department of Highways, Olympia, Washington. [in English].

28. Haas, R., Hudson, W., R., Zaniewski, J., P., 1994. Modern Pavement Management. Krieger Publishing Company, Malabar, Florida. [in English].

29. A. Butt, M. Y. Shahin, K. J. Feighan, S. H. Carpenter: 1987. Pavement Performance Prediction Model using the Markov Process. Transportation Research Record, 1123, 1987. P. 12–19 [in English].

30. F. Hong, J.A. Prozzi: Estimation of pavement performance deterioration using Bayesian approach. *Journal of Infrastructure System*, 12(2), 2006. P. 77–86 [in English].

31. A. Hu, Q. Bai, L. Chen, S. Meng, Q. Li, Z. Xu: A review on empirical methods of pavement performance modelling. Construction and Building Materials, 342, Part B, 2022, 127968. DOI: https://doi.org/10.1016/j.conbuildmat.2022.127968 [in English].

32. R. Justo-Silva, A. Ferreira, G. Flintsch: Review on machine learning techniques for developing pavement performance prediction models, Sustainability, 13(9), 2021, 5248. DOI: https://doi.org/10.3390/su13095248 [in English].

33. H. Pérez-Acebo, A. Linares-Unamunzaga, R. Abejón, E. Rojí: Research Trends in Pavement Management during the First Years of the 21st Century: A Bibliometric Analysis during the 2000–2013 Period. Applied Sciences, 8(7), 2018. DOI: https://doi.org/10.3390/app8071041 [in English].

34. N.E. Abdelaziz, R.A. El-, S. El-Badawy: International Roughness Index prediction model for flexible pavements, *International Journal of Pavement Engineering*, 21(6), 2018, P. 1–12. DOI: https://doi.org/10.1080/10298436.2018.1441414 [in English].

35. M.R. Kaloop, S.M. El-Badawy, J. Ahn, H.-B. Sim, J W. Hu, R.T.A. El Jakim: A hybrid wavelet-optimally-pruned extreme learning machine model for the estimation of international roughness index of rigid pavements, International *Journal of Pavement Engineering*, 23(3), 2022. P. 862–876. DOI: https://doi.org/10.1080/10298436.2020.1776281 [in English].

36. H. Pérez-Acebo, N. Mindra, A. Railean: Rigid pavement performance models by means of Markov Chains with half-year step time. *International Journal of Pavement Engineering*, 20(1), 2017. P. 1–14 [in English].

37. Y. Du, C. Liu, D. Wu, S. Li: Application of vehicle mounted accelerometers to measure pavement roughness, *International Journal of Distributed Sensor Networks*, 12, 2016, 8413146, 8 p. DOI: https://doi.org/10.1155/2016/8413146 [in English].

38. W. Aleadelat, K. Ksaibati: Estimation of pavement serviceability index through android-based smartphone application for local roads, Transportation Research Record, 2639(1), 2017. P. 129–135 DOI: https://doi.org/10.3141/2639-16 [in English].

39. M. M. Aydın, M. S. Yildirim, L. Farslöf: The use of smart phones to estimate road roughness: a case study in Turkey. Engineering Sciences, 13(3), 2018. P. 247–257 [in English].

40. K. Gopalakrishnan, S. K. Khaitan, A. Choudhary, A. Agrawal: Deep Convolutional Neural Networks with transfer learning for computer vision-based data-driven pavement distress detection, Construction and Building Materials, 157, 2017. P. 322–330 DOI: https://doi.org/10.1016/j.conbuildmat.2017.09.110 [in English].

41. H. Maeda, Y. Sekimoto, T. Seto et al.: Road damage detection and classification using deep neural networks with smartphone images: road damage detection and classification, Computer-Aided Civil and Infrastructure Engineering, 33(2), 2018, P. 1–15. DOI: https://doi.org/10.1111/mice.12387 [in English].

42. H. Zakeri, F.M. Nejad, A. Fahimifar: Image based techniques for crack detection, classification and quantification in asphalt pavement: a review. Archives of Computational Methods in Engineering 24(4), 2016. P. 935–977. DOI: https://doi.org/10.100/s11831-016-9194-z [in English].

43. L. Gáspár: Compilation of First Hungarian Network-Level Pavement Management System. Transportation Research Record 1455 Pavement Management Systems. National Academy Press, Washington, D.C., 1994, P. 22–30 [in English].

44. A. Bakó, M. Csicsely-Tarpay, T. Szántai, L. Gáspár: Multi-time Period Network-level PMS in Hungary Based on Markov Chains. Second International Conference on Road and Airfield Pavement Technology, Singapore, Vol 1, 1995, P. 384–392 [in English].

45. A. Sarja: A process towards lifetime engineering in the 5th and 6th Framework Program of EU. Proceedings of 2nd International Symposium ILCDES, Kuopio, Finland, 2003, P. 7–12 [in English].

46. L. Gáspár: Lifetime engineering in road asset management. Proceedings of 3rd European Pavement and Asset Management Conference, Coimbra (Portugal), Session B3, 2008, 10 p. [in English].

47. L. Gáspár: The utilisation of pavement performance data in the Hungarian road management. Proceedings of International Conference on Advanced Characterization of Pavement and Soil Engineering Materials, Athens, Vol. II, 2007, P. 1699–1707 [in English].

48. W.D.D. Paterson: Road Deterioration and Maintenance Effects: Models for Planning and Management. World Bank, Washington, D.C. 1987, 454 p. [in English].

49. URL: https://datavizcatalogue.com/methods/box_plot.html [in English].

50. L. Gáspár: Pavement condition before and after rehabilitation. The International Journal of Pavement Engineering & Asphalt Technology 5(1), 2004. P. 15–25 [in English].

51. L. Gáspár: Actual condition improving effect of major pavement maintenance treatments. Proceedings of 2nd European Pavement and Asset Management Conference, Berlin, 2004, 8 p. [in English].

52. E. Nemesdy, T. Boromisza, E. Zsiga Kiss: Evaluation of bearing capacity measuring methods. Transport Scientific Association, report № 87/89. Budapest, 1989. (In Hungarian) [in English].

53. D. Bardhi: Road Asset Management Assessment. *European Journal of Engineering and Formal Sciences*. 5(1), 2021, P. 25–36. DOI: https://doi.org/10.26417/646qpv23t [in English].

54. A. Golgota, D. Bardhi: Asset Management Public Assessment of Road Infrastructure. *European Journal of Multidisciplinary Studies*, 2016, 1, P. 172–179. DOI: https://doi.org/10.26417/ejms.v1i3. P. 172–179 [in English].

55. D. Bardhi: Aspects of Management and Road Maintenance in Albania. *European Journal of Multidisciplinary Studies*, 1(2), 2016, P. 266–279. DOI: https://doi.org/10.26417/ejms.v1i2 [in English].

56. A. Golgota, D. Bardhi: Road Investment and Regional Development Some Evidencies from Albania. *European Journal of Multidisciplinary Studies*, 1(1), 2016, P. 333–340. ISSN 2414-8377 [in English].

Діана Барді[1], *д-р філос., https://orcid.org/0009-0002-6958-7770*
Алтін Сераnадж[2], *д-р філос., https://orcid.org/0009-0003-5511-1445*
Ласло Гаспар[3], *д-р техн. наук, проф., https://orcid.org/0000-0002-0574-4100*
Жолт Бенче[4], *канд. техн. наук, https://orcid.org/0000-0003-2130-7864*

[1]*Департамент будівництва та архітектури, Університет Метрополітен Тирана, Тирана, Албанія*
[2]*Департамент будівельних конструкцій і транспортної інфраструктури, Політехнічний університет Тирани, Тирана, Албанія*
[3]*Університет Іштвана Сечені, будівельний факультет, Дьйор, Угорщина, та KTI Угорський інститут транспортних наук і логістики Non-Profit Ltd., Будапешт, Угорщина,*
[4]*KTI Hungarian Institute for Transport Sciences and Logistics Non-Profit Ltd., Будапешт, Угорщина*

ОГЛЯД ХАРАКТЕРИСТИКИ ДОРОЖНЬОГО ПОКРИТТЯ В РІЗНИХ КРАЇНАХ

Анотація

Вступ. Високоякісні та довговічні дорожні покриття є однією з передумов ефективного дорожнього руху в кожній країні.

Постановка проблеми. Науковий проєкт високого рівня, будівництво, технічне обслуговування та відновлення конструкцій дорожнього покриття — управління тротуарами — можна розглядати як важливе завдання власників доріг, а у випадку доріг державної власності це є прямим обов’язком.

Важлива підсистема управління дорожнім майном складається з кількох технічних засобів, таких як системи управління дорожнім покриттям (PMS). Моделі характеристик дорожнього покриття є важливим компонентом PMS і мають прямий вплив на майбутній стан тротуару. Проектування конструкції дорожнього покриття завжди є досить відповідальним і важким завданням, оскільки очевидно, що проектувальник повинен спрогнозувати (передбачити) — використовуючи бажано науково обґрунтовані методології — характеристики конструкцій тротуарів, які будуть побудовані в майбутньому. Надійність цього прогнозу, звичайно, головним чином залежить від точності застосованих проектних вхідних даних. Складність проблеми вже можна охарактеризувати тим фактом, що, принаймні, транспортні, екологічні, сировинні, будівельні, технічно-відновлювальні, експлуатаційні та фінансові параметри слід враховувати при прогнозуванні ефективності дорожнього покриття (очікуваний термін служби) під час проектування (вибору) оптимального конструктивного варіанту покриття. Взаємозв'язок цих параметрів, що впливають, тільки робить ситуацію ще більш складною.

Мета. Основною метою статті є представлення різних аспектів ефективності дорожнього покриття в Угорщині та Албанії.

Матеріали та методи. У статті описано роль (значущість) моделей ефективності дорожнього покриття в управлінні дорожнім майном, особливо в науково обґрунтованому структурному проектуванні дорожнього покриття, вказуючи на пов'язані з цим проблеми. Після короткого всесвітнього огляду теми, презентація спеціального теоретичного та практичного досвіду щодо моделей ефективності тротуарів у двох європейських країнах (Угорщина та Албанія) підсумовується як тематичні дослідження.

Результати. Наприкінці статті зроблено деякі висновки та надано кілька пропозицій щодо створення та використання моделей ефективності дорожнього покриття, включаючи високу важливість успішного управління дорожнім майном на рівні національної економіки; значення науково обґрунтованої PMS у підвищенні економічності автомобільного транспорту; прямий вплив моделей характеристик дорожнього покриття на майбутній стан дорожнього покриття, як основного фактора впливу на ефективність дорожнього руху; допоміжна роль технічного обслуговування на основі ефективності та покращення безпеки доріг великого обсягу, які виконуються в Албанії, може значно підтримати рішення щодо управління дорогами в середньостроковій перспективі.

Ключові слова: дорожнє покриття, модель ефективності покриття, система управління дорожнім покриттям, управління дорогами Албанії, управління дорогами Угорщини.