DEVELOPMENT OF PAVEMENT DEVELOPMENT OF PAVEMENT PREDICTION PERFORMANCE MODEL IN THE OF REPUBLIC OF SERBIA

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ABSTRACT

The research of the pavement performance models in the Republic of Serbia road network consists of the selection of representative road sections by parameters of pavement structure, their age and by characteristics of traffic load. Based on the reviewing of the types and mechanisms of pavement damage, as well as the factors contributing to their appearance and progressing, 24 test sections have been selected in the highway network of the Republic of Serbia, and a plan and program have been defined for the periodical experimental research on such test sections for the purpose of gathering the relevant data so that the pattern of pavement performance in the road network of the Republic of Serbia could be determined. With the final aim and the purpose of this research in mind, the special attention has been paid to the calibration of pavement performance models, contained within the HDM-4 model. The starting model of pavement performance within the HDM-4 model has been determined based on the data on pavement condition from the previous years and the analysis of the sensitivity of results.

KEY WORDS

PAVEMENT / MAINTENANCE / PREDICTION PERFORMANCE MODEL / CALIBRATION

1. METHODS OF RESEARCH ON THE EXPERIMENTAL SECTIONS

The manner and procedures of formulating the performance models in management systems depend on the very purposes of systems and of types of models to be defined. At a formative stage of a management system, the basic approach to the formulation of a model implies an analysis of the existing models and a determination of possibilities for their direct application, and then defining ones' own models most often through an interpretation of the results of the experimental research.

Testing on sample stretches of road network consists of selection of the representative road sections by parameters of pavement structure, their age and by characteristics of the traffic load.

2. SELECTION OF TEST SECTIONS IN THE ROAD NETWORK OF THE REPUBLIC OF SERBIA

Test sections are representative of the Republic of Serbia road network by type of pavement structure, by characteristics of material used in the pavement structure, by average and accumulated traffic load, as well as by climate characteristics in individual regions of the Republic of Serbia.

Test sections have been selected for periodical survey – observations to be regularly done twice a year in the next ten years. Based on the test results in the first five years, a preliminary proposal of the model of pavement deterioration will be made. It represents a minimal statistical sample for an analysis of the results obtained (the period of five years during which observation will be undertaken twice a year on the selected test sections). The period of the next five years is planned for the verification of the proposed models for change of individual types of pavement damage, with continued periodical monitoring of the pavement performance.

On highway network of the Republic of Serbia, a selection of 24 test sections has been made that meet the predetermined criteria. The basis for the pre-selection of test sections were the meteorological charts of the Institute of Hydrometeorology of the Republic of Serbia (charts of average monthly precipitation and frost penetration depths) and the existing data base on roads and traffic, as well as a video-archive of the Republic of Serbia road network.

On completion of field tests the test sections not fulfilling the requirements set will be eliminated. On such final number of test sections, periodical tests will be performed twice a year (in the spring and in the fall), according to a pricisely determined plan and methodology of testing.

For the selection of test sections the reliable data must be available. Therefore, before the selection of test sections it was necessary to define parameters and criteria for identification of test section, based on which a test sections' matrix was formed.

2.1. Parameters for the selection of test sections

In view of the difficulties expected in identification of adequate test sections, the parameteres easily identified in the field have been chosen, for which data can be collected (Table 1).

Table 1 – Parameters for the selection of test sections

1.	TYPE OF PAVEMENT STRUCTURE	Original pavement structure	AB over BNS
			AB over CS
		Strengthened pavement structure	AB over AB
			AB over BNS
			BNS over BNS
2.	TRAFFIC LOAD / FREQUENCY	Medium	PGDS < 1500 vehicles/day
		Heavy	PGDS > 1500 vehicles/day
3.	AVERAGE ANNUAL DOWNFALL	Little (dry climate)	PGP < 800 mm/p.a.
		Extensive (moist climate)	PGP > 800 mm/p.a.
4.	PAVEMENT CONDITION	Good	< 10% of surface
		Medium/bad	> 10% of surface
5.	FROST PENETRATION DEPTH	Small	< 50 cm
		Big	> 50 cm
6.	PAVEMENT AGE	New	< 5 years
		Old	> 5 years
7.	LEVEL OF PAVEMENT MAINTENANCE	Regular	Regular maintenance of pavement every year
		Intensified	Regular maintenance every year + intensified maintenance of pavement
		None	

Based on the above described parameters for the selection of test sections, a minimal number of test sections has been defined (Table 2):

Table 2 – Number of test sections by parameters determined

TRAFFIC[1]	*Mediumi/Heavy*			
AVERAGE DEPTH OF FREEZING[2]	*Small/Big*			
AVERAGE ANNUAL DOWNFALL	*<800 mm/p.a.*		*> 800 mm/p.a.*	
PAVEMENT CONDITION	*Good*	*Medium/Bad*	*Good*	*Medium/Bad*
Original pavement structure	2	2	2	2
Pavement reinforcement up to 5 years	2	2	2	2
Pavement reinforcement older than 5 years	2	2	2	2
TOTAL (∑=24)	6	6	6	6

Figure 1 shows the sythetic chart of roads, traffic load in 1990. and average annual downfall. With the help of this synthetic chart a selection as made of the required number of 24 test sections, so that data could be established on all determined parameters.

The precise location of test sections has been determined on reviewing the video-archive of the highway and regional road networks of the Republic of Serbia, in accordance with the system of references, and observing the criteria determined for the identification of test sections.

2.2. The criteria for identification of test sections in the field

For identification of test sections in the field the following criteria have been observed:

1). Test sections must be on a highway and 1 km long.
2). Test sections must have a flexible pavement structure.
3). Test section must be in the direction, both in horizontal and in vertical plane.
4). Test section must not be near crossroads or other access roads.
5). Test sections must not be located in city or suburban areas.
6). Test sections in cuttings are to be avoided.
7). Background data on test section is essential.
8). Longitudinal and cross features of sections must be uniform.
9). Test sections are selected with different traffic load.
10). It is desirable that cross sections be on lowlying grounds, with maximal inclinaton of 4%.

[1] As test sections are located on highways and regional roads of the Republic of Serbia, (PDGS >1000 vehicles/day), the traffic is not divided into two suibgroups.

[2] As average depth of ground freezing in the Republic of Serbia is mostly larger than 50 cm , this parameter is also not divided into two subgroups.

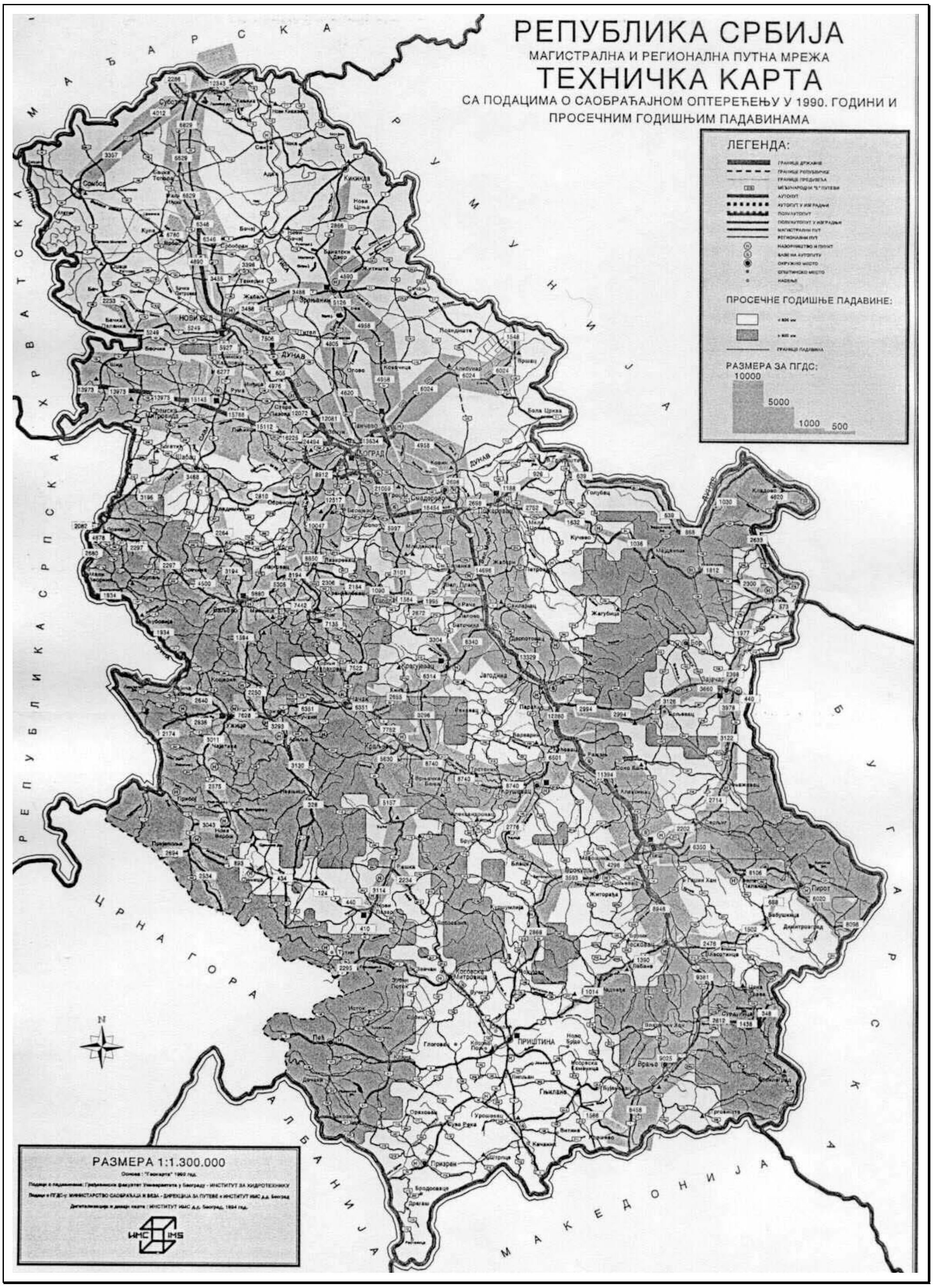

Figure 1 – Syntheric technical chart of highways and regional roads, the traffic load (1990) and average annual downfall.

3.3. The data collected for the previous identification of test sections

3.3.1. <u>Data on pavement condition at the test section</u>

Based on visual check, the type and spread of damage on pavement surface are determined, such as cracks, repairs, pot holes, wheel track depth, delevelling, etc.

For the pre-selection of test sections, these data were taken over from the existing Roads Data Base.

3.3.2. Background data on test section

- year of construction, and specifications,
- year of pavement reinforcement and specifications,
- year of last renewal of the wearing layer,
- pavement condition before reinforcement or renewal of the wearing layer,
- geological data on grounds,
- data on traffic counting in the last 5 years,
- data on monthly downfall during last 3-4 years,
- technical maintenance measures implemented on test section, by quantity and by quality, in accordance with the maintenance standards and norms.

3.4. Matrix of test sections

Based on the predetermined parameters, criteria and data collected, 24 test sections have been selected on the road network of the Republic of Serbia. For each section the data have been collected and systematically organized on the basis of the existing data and polls carried out with the road enterprises.

For each test section the data have been collected by data classes as follows (Figure 2.) :

1. REFERENCE DATA
2. METEOROLOGICAL DATA
3. PAVEMENT STRUCTURE
4. TRAFFIC
5. PAVEMENT CONDITION
6. BACKGROUND
7. VIDEO-ARCHIVE

3.5. Detailed data to be collected in the field for final identification of test sections

For final identification of sections the following additional data should be collected on the condition of pavement surface, unevenness of pavement surface, deflections and composition of pavement structure.

Based on the samples taken from the trial pit, the following data should be established and colleclted:

- Bitumen layers: The thickness of bitumen layers, qualitative estimate of layer density and adhesion to the lower layer. In laboratory tests the bitumen percentage and granulometric composition of the mixture should be determined.

- Granular GNS: Layer thickness, qualitative and quantitative estimate of density, quality of built in material, quality and quantity of filler.

- Granular DNS: Thickness of layers, qualitative estimate of material and layer density.

Table 2 – Inventory list for test sections

REFERENCE DATA	ROAD REF.	*M-18*	TEST SECTION	*04*	
	SECTION ID	*2081*	Beginning(km)		End (km)
			20.100	*149+759*	*21.100* / *150+759*
	NODE, START	*2070*	*BAČ*		
	NODE, END	*2037*	*BAČKA PALANKA 1 (BAČ)*		
	ROAD ENTERPRISE	*D.D. "VOJVODINAPUT-BAČKAPUT" NOVI SAD*			

METEOROLOGIC. DATA	GEOGRAPHICMETEOROLOGICAL STATION	*NOVI SAD*
	SECTION HEIGHT ABOVE SEA LEVEL	*75m*
	AVERAGE ANNUAL DOWNFALL	*650 / 700mm/p.a.*
	AVERAGE ANNUAL HEIGHT OF SNOW	*20 / 40 cm*
	AVERAGE ANNUAL MAX. TEMPERATURE	*22 / 24 °C*
	AVERAGE ANNUAL MIN. TEMPERATURE	*0 / -2 °C*
	AVERAGE ANNUAL MAX. DEPTH OF GROUND FREEZING	*70 / 90cm*

PAVEMENT STRUCTURE			Thickness	Type
	REINFORCEMENT OF PAVEMENT STRUCTURE		*-*	*-*
	ORIGINAL PAVEMENT STRUCTURE		*30mm*	*AB*
	BEARING LAYERS		*300 mm*	*Granular*
	SUB-GRADE	CBR	*3%*	*CL*
		DENSITY	*95%*	
	TOTAL THICKNESS OF PAVEMENT/ TOTAL THICKNESS OF ASPHALT LAYERS		*30mm/330mm*	
	BEARING CAPACITY OF PAVEMENT (*Benkelman*)	Date of measuring	Rep. deflection	SNC
		-	*-*	*1.688*

TRAFFIC	AUTOMATIC TRAFFIC COUNTER		ID Number	Name of counter			Type
			0211	*BAČ*			*SBH*
	NUMBER OF VEHICLES IN 1990..	PA	BUS	LT	ST	TT+AV	PGDS
		1072	*50*	*246*	*336*	*433*	*2233*

PAVEMENT CONDITION			Measure	Date of measuring
	FLATNESS OF PAVEMENT SURFACE (*IRI*)		*4.060*	*1994g.*
	ALL CRACKS		*9%*	*1994g.*
	WIDE CRACKS (> 3mm)		*7%*	
	POT HOLES		*4%*	
	STUMPING		*5%*	
	REPAIRS		*3%*	
	WHEEL TRACKS	Mid values	Stand. departure	Date of measuring
		30mm	*20mm*	*1990*

BACK-GROUND		Year	Activity
	CONSTRUCTION	*1964*	
	REINFORCEMENT	*-*	
	MAINTENANCE	*-*	*Regular maintenance*

VIDEO-ARCHIVE

NOTA BENE:

- *Average annual downfall:* *< 800 mm/p.a.*
- *Condition of pavement:* *Good (< 10 %)*
- *Pavement structure:* *Original without reinforcement*

On the basis of the above mentioned data a list of test sections' candidates was established (Table 3):

Table 4 – List of test sections candidates:

Ord. No.	Road Ref.	Identification code of section	Beginning of section	End of section	Chainage of section beginning	Chainage of section end	ID – Number of test section
1	M-3	2039	23.040	24.040	533+974	534+974	T-01
2	M-17.1	2076	16.700	17.700	108+920	109+920	T-02
3	M-3	2054	20.100	21.100	149+759	150+759	T-03
4	M-18	2081	4.700	5.700	81+915	82+915	T-04
5	M-24	2139	11.600	12.600	190+706	191+706	T-05
6	M-7.1	2066	11.200	12.200	78+221	79+221	T-06
7	M-19	0169	13.200	14.200	102+668	103+668	T-07
8	M-22	0228	4.150	5.150	236.876	237+976	T-08
9	M-1.11	0048	8.400	9.400	8+985	9+985	T-09
10	M-5	0119	9.300	10.300	717.074	718+074	T-10
11	M-25	0321	1.600	2.600	267+876	268+876	T-11
12	M-5	1403	4.000	5.000	821+000	822+000	T-12
13	M-21	0197	0.270	1.270	236+519	237+519	T-13
14	M-21.1	0211	7.350	8.350	51.090	52.090	T-14
15	M-4	0075	1.560	2.560	575+418	576+418	T-15
16	M-21	0190	13.500	14.500	171.599	172+599	T-16
17	M-22	0241	11.400	12.400	338+399	339+399	T-17
18	M-19.1	0174	10.250	11.250	55.879	56.879	T-18
19	M-8	0133	3.000	4.000	3+000	4+000	T-19
20	M-25.1	0325	1.540	2.540	50+310	51+310	T-20
21	M-1.13	0062	1.400	2.400	30+156	31+156	T-21
22	M-2	0065	4+040	5+040	1176+102	1177+102	T-22
23	M-24	0285	15.200	16.200	387+520	388+520	T-23
24	M-1.12	0056	6.400	85+751	7.400	86+751	T-24

- <u>Subgrade:</u> Laboratory test should determine:
  - Granulometric composition,
  - Aterberg's consistency limits (flowing limit, plasticity limit)
  - Density after Proctor and optimal moisture content,
  - CBR (field and laboratory)

- <u>Embankment:</u> Volume weight in natural state and natural moisture of material built into the embankment.

On the basis of the above indicated detailed additional tests on the pre-selected sections, a definite number of test sections will be established on which periodical tests on pavement structure will be performed.

4. PLAN AND PROGRAM OF MONITORING PAVEMENT STRUCTURE PERFORMANCE ON TEST SECTIONS.

Periodical monitoring of pavement condition is planned with semi-annual measuring during April/May and October/November every year for five years. Periodical viewing (measuring) will include gathering of the following data:

1). Damage of pavement surface

2). Evenness of pavement surface

3). Pavement deflection under load measured by *Benkelman* beam (JUS U.E8.016 and JUS U.E8.018)

4). Resistance against sliding of pavement surface (JUS U.C.4.018)

5). Changes in pavement cross profile (wheel tracks)
(JUS U.E.4.014.)

6). Moisture of subgrade material (JUS U.B1.010 and 012)

7). Depth of frost penetration into the pavement structure (JUS U.B9.010 and JUS U.B9.012)

8). Counting of traffic by vehicle structure

9). Measuring of axle load

4.1. Damage of pavement surface

Each test section is divided into a 50 m long segments. The surfaces of pavement with a certain type of damage, are separately chalk-marked within one segment in a form of rectangular surfaces and are measured with a measuring tape. In case of individual longitudinal or cross cracks, the surface is calculated as the effective length x 0.5 m

The depth of wheel tracks is measured on all positions of measuring deflections, which are permanently marked with a yellow line by means of a screed board and a measuring rod, on the tracks of left and right wheels, and on each traffic lane.

In addition to the length and width of each surface with a certain type of damage present, the data on intensity and frequency of damage are also included in the form, for gathering the data on damage of pavement surface.

Pavement damage comes in different forms such as pavement destruction, pavement deformation, cracks or desintegration of pavement surface. Each of these forms of pavement damage may occur in one of several different ways, which are called the types of pavement impairment.

For the purpose of collecting the data on pavement damage on test sections, the different types of pavement impairment are classified into two basic groups:

- Damage on surface of pavement structure
- Structural damage of pavement structure

Damage on surface of pavement structure are the impairments on surface layers of the pavement structure that mostly occur due to the faults in the construction of the pavement structure or due to inferior quality of the materials built into the upper layers of pavement structure. This group of damage consists of cracks (which occur due to fatigue of material in pavement overlay, pavement deformity (wheel tracks and folds without the appearance of cracks, mostly only the plastic deformity of the pavement overlay), and other defects of the pavement surface (stumping, slipperiness, bitumen emerging to the pavement surface).

Structural damages of pavement structure are the impairments pointing to a disturbance in the structure itself, i.e. to the fact that the bearing capacity of the pavement structure is in jeopardy. Such damages occur at the second stage of progressing of pavement surface damage due to the increased traffic load, and due to the action of climate factors, as well as for lack of timely measures for pavement repairs. These kinds of damage are often looked into by measuring of deflections so that a correct conclusion could be made on the condition of the pavement structure, as to the extent of jeopardy or of insufficient bearing capacity. This group of damage includes the cracks of higher intensity, followed by delevelling of pavement, deformity of pavement of higher intensity, other defects of the pavement surface of higher intensity and the disturbances of longitudinal and/or cross profile of the pavement.

The characteristic types and descriptions of some pavement damages are defined in the instructions (the catalogue of damages) for classification and evaluation of some of pavement damages.

4.2. Unevenness of pavement surface

This indicator concerns the longitudinal evenness of pavement structure. The parameter measured will be that of «Index of unevenness» (*m/km*), with the "*Bump Integrator*", along the tracks of left and right wheels on each traffic lane.

Measuring and processing of data will be done in accordance with the intructions of the device manufacturer, with a determined frequency (twice a year) during the period of data observation.

4.3. Pavement deflections

Measuring of bearing capacity of the pavement structure will be done by means of the *Benkelman*-beam.

The measuring of deflections with the *Benkelman* beam will be done on the basis of current Yugoslav standards JUS E.8.016. and JUS U.E8.018

The selection of spots where tests will be made depends on the condition of the pavement structure, its width and inclination (longitudinal and cross) of road. As the strongest stress in pavement overlay take place closer to the outside edge of pavement, mostly at 0.60 to 0.80 m off edge, the test should be performed on these distances from pavement edge (preferably at 0.80m).

4.4. Resistance against skidding of pavement structure

The following parameters will be measured:

- Resistance against skidding on wet pavement structure;

- Depth of macro-texture.

The SKID RESISTANCE TESTER (herein called the SRT pendulum) is used to measure the resistance against skidding on wet surface of the wearing layer of asphalt or concrete pavement.

The resistance against skidding will be measured by the SRT pendulum along the track of wheels on each traffic lane and will be expressed in SRT value, in all aspects in accordance with the current Jugoslav standard JUS U.C.4.018.

The measuring sections and test spots are determined depending on the purpose of tests, primarily on the spots where increased resistance against skidding is required, or on «black spots» (in curves, in front of crossroads, traffic lights etc.).

The medium depths of macro texture «DT» (mm) will be measured by a sand blasting method, on all the places where resistance against skidding is measured, and in all aspects in accordance with the current Yugoslav standard JUS U.C.4.018.

The measuring will be performed in determined frequency (twice a year) on the same spots (which will be permanently marked on the ground) during the period of data observations.

4.5. Changes in cross profile of pavement

The irregularities in cross profile of pavement are measured with a flat board 4 m long and with a measuring wedge. On the board underside there is a steel plate, the purpose of which is to avoid any bending. The measuring is performed on the basis of the current Yugoslav standard JUS U.E.4.014.

4.6. Moisture of material in subgrade

Moisture of material in subgrade should be determined twice a year in accordance with the current Yugoslav standards JUS U.B1.010 and JUS U.B1.012. It is recommended that the samples be taken on the profile where trial pits were digged out.

4.7. Depth of frost penetration

The depth of frost penetration into the pavement structure should be continually monitored in accordance with the current Yugoslav standards (JUS U.B9.010 and JUS U.B9.012) and with the "Wybo" for the measurements of depth of frost penetration.

4.8. Counting of traffic by vehicle structure

The test sections have been selected in such a way so as to be in the vicinity of the existing automatic traffic counters placed along the road network of the Republic of Serbia. Where there are no automatic counters in the vicinity of a test section, the interpolation of data will be done or a physical counting of traffic by vehicle structure. The physical counting of traffic is done on the random sample basis, by measuring during the representative seven days in the spring and seven days in the fall.

4.9. Measuring of axle load

On test sections, axle load measurements should be performed. For this kind of measuring it is best to use portable plates for measuring of load below the wheel of a vehicle. The equipment consists of a measuring platform sized 50cm x 70 cm with the measuring capacity up to 10,000 kg.

The measuring of axle load is performed on the basis of sampling, by measuring during the representative seven days in the spring and seven days in the fall.

5. THE INITIAL MODEL OF PAVEMENT PERFORMANCE

The initial model of the occurence and progressing of the damage on pavement is formed for each type of pavement damage based on historical data on pavement damage, obtained on the basis of reviewing the pavements in the preiod from 1991. to 1998. for the purposes of establishing of the Roads Data Base (BPP) of the Republic Road Directorate (Roads Institute a.d. Beograd and the IMS Institute a.d. Beograd).

Model calibration has been performed through an analysis of the sensibility of results for different factors of influence for each model of pavement performance (each type of damage).

In that way at least two measured values in different times are obtained for the Roads Data Base.

For interpolation of results an exponential curve was used.

The Figure 2. shows an example of calibration of the change of unevenness of the pavement over time, based on historical data from the Roads Data Basew.

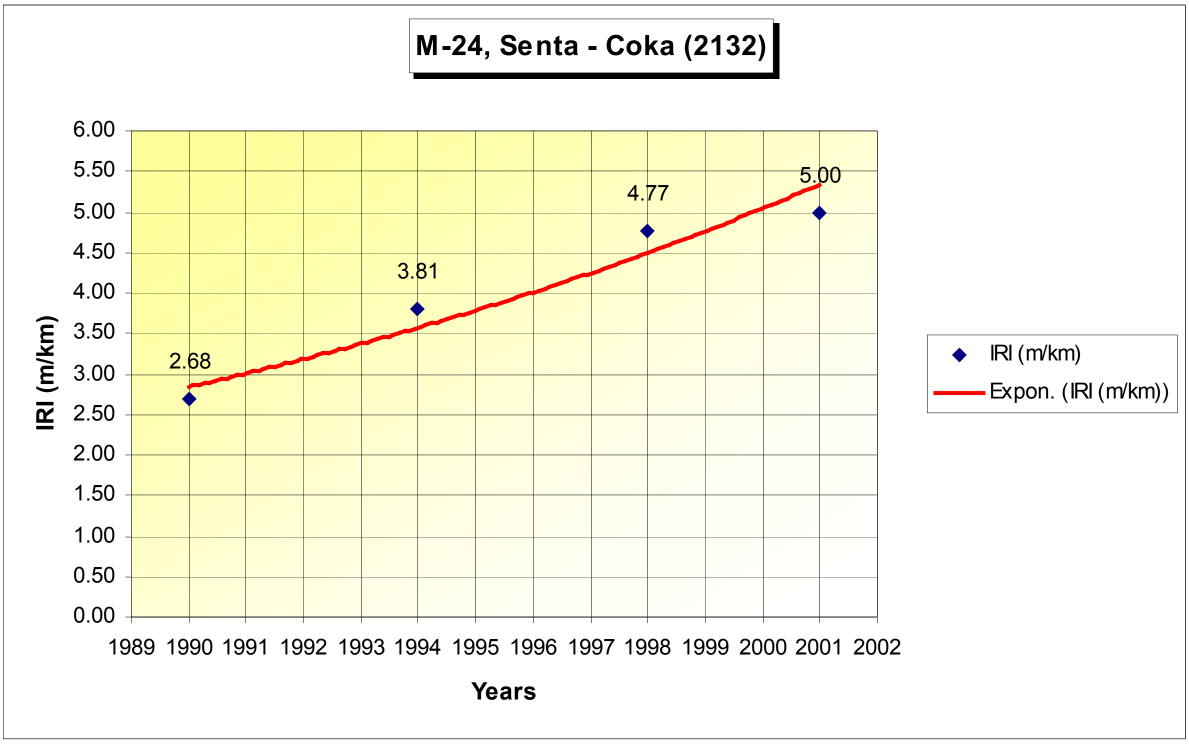

Figure 2 - Calibration of the pavement deterioration model based on historical data

6. CONCLUSION

On the basis of the technical and exploitation characteristics of road network, the local condtions of climate (first of all regarding the annual rain downfall and the depth of frost penetration into the ground), the available data on type and composition of the pavement structure, 24 test sections have been pre-selected and a plan and program of testing was given so that the patterns of pavement deterioration could be established through observation over several years.

A lot of attention must be paid to the systematic and methodologically defined procedure of data gathering for the purpose of verificaton and regualar model interpretation, which is the basic theme of this paper.

By means of the empirical models it is not easy to manage the changes over the time unless there are sufficient data in frequent intervals to enable a correct interpretation of the changes that take place over the time (eg. the changes of models in layers of pavement structure during different seasons).

All these limitations must be considered with caution during the forming of pavement performance models.
The pavement performance models can best be developed with full respect of the scientific approach in designing of the model. The principles of statistics (experimental design) and the pavement mechanics should always be used as the columns onto which the structure and form of models of pavement performance are leaned.

On the other hand, the well formed performance models, developed in compliance with the scientific approach, will provide a significant support to the road economy and its economics, and will enable a better technical efficiency and equity.

In closing, the development of pavement performance models should be a continual activity, aimed at constant improvements of model properties and a better use of data available.

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