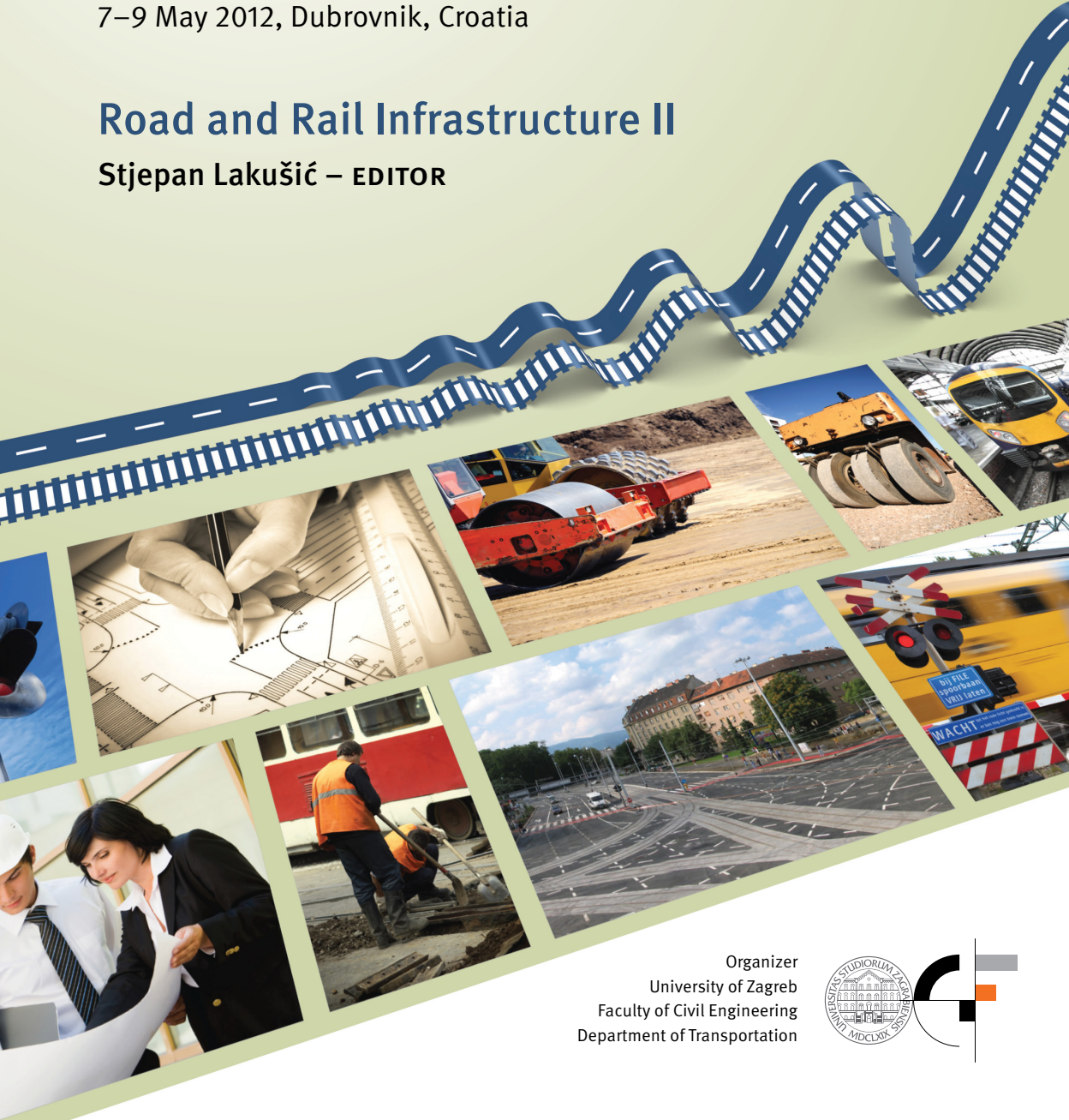# CETRA²⁰¹²

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Road and Rail Infrastructure II

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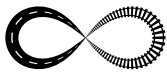
EFFECTIVE ROAD MAINTENANCE WORKS PLANNING

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Abstract

Systematic approach to the maintenance of road network section is a very important issue from the view of public costs. In a lot of countries Pavement management systems were developed based on various principles. The main goal is to ensure safety and continuity of road traffic. Article presents Pavement management system in Slovakia based on road construction diagnostics, traffic volume, climate factors and evaluation of maintenance works economics effectives by using of software tools like HDM-4 developed by World Bank.

1 Sustainable road maintenance in Slovak republic environment

Road administrators differ significantly with available budged, length of roads they are responsible for, demands put on their assets, demands put on acquisition of new assets and many other issues; yet their task is the same. Their task is to develop and maintain a safe, eco–friendly and efficient transport system.

1.1 Road network of SR

The road network of Slovakia consists of 391 km of limited access roads (motorways and express roads) and 174 367 km of 1st, 2nd and 3rd class roads. The main objective of motorway network is to provide transit according to Pan–European transport corridors, namely the IV., V. and VI. corridor. The purpose of express road network is to collect and transfer the transport generated by Slovak republic's regions and contra wise to distribute transport from foreign countries from motorways to the body of Slovak Republic. The 1st, 2nd and 3rd class roads fulfill the service task of transportation between and within regions of Slovak republic. On top of this network a network of urban communications and minor purpose communication is connected. Different types of roads have different owners and administrators with their executive offices. Their general task is to securing a fluent and safe transport on them entrusted roads by providing maintenance, winter service, repair, reconstructions and acquisition of new assets according to concept of development of road network of Slovakia.
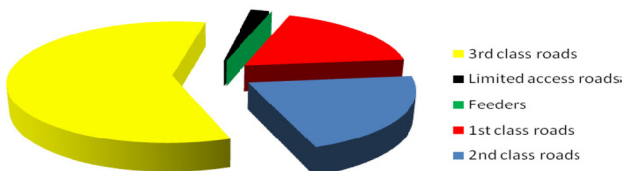

Figure 1   Composition of road network of Slovak republic.

This paper is aimed on the topic of road maintenance of low class road network (1st and 2nd roads) which constitutes the majority of the whole SR road network; therefore the viewpoint of administrators of this road network will be crucial.

1.2 Sustainable maintenance of a road network

The purpose of maintenance and repairs of asphalt pavements is to extend the useful life of the pavement, maintain a smooth riding surface, and prevent water from entering the underlying soil. Limited manpower and resources have increased the importance of maintenance and repairs to the life of a pavement. To keep a pavement in the best possible condition, it is important to use an effective pavement management system (PMS).
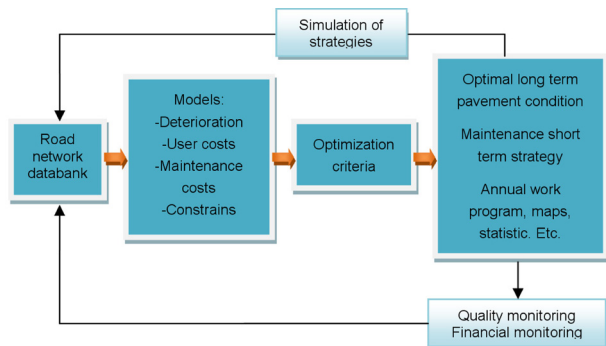
Figure 2   Basic PMS scheme

Pavement management system is a subsystem of asset management. It should ensure the right dividing of assigned funds coming from state budget and additional regional tax funds. These funds are very limited thus sustainability principles have to be implemented so the road network can provide the road users with socio–economical benefits. These boost the living standards of our society, which is then more prone to spending which means more taxation money.
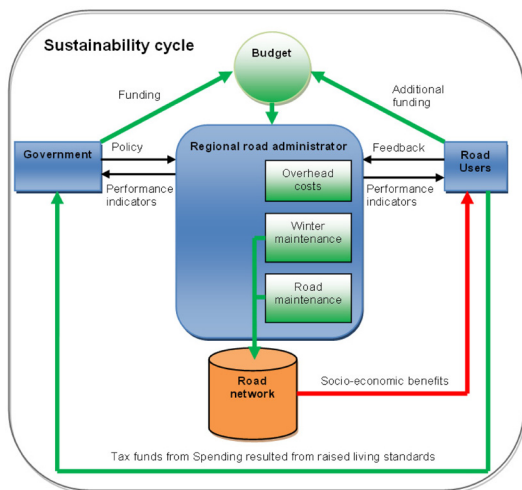
Figure 3   Principle of sustainability in road administration

From the economical viewpoint; the sustainability principle means to balance the spend funds with generated funds which again can be spend and so on in an infinite cycle.

2 Implementation of sustainable road maintenance in Slovak republic environment

At this time the ratio of pavement conditions on 2nd and 3rd class roads and the amount of accessible resources of road administrators of these networks begin to reach critical levels. While a complete effective road asset management even of motorways and 1st class roads is still far from completion a substitution solution have to be made to help road administrators of lower class roads. Since the 2$^{nd}$ and 3rd class roads aren't systematically surveyed and their state isn't stored and used as an input for PMS, the municipal administrators of these roads rely on fixed maintenance standard. The maintenance and repair procedures prescribed by fixed maintenance standard don't always correspond with the actual needs of the road conditions nor do they take into account the budget possibilities of the road administrator. It's merely an empirically based schedule of pavement treatment works which guarantees a good condition of the road throughout its whole life cycle. The downsides are obvious; the overall idea doesn't (mainly a high cost of this standard) correspond with the procedures described in asset management theory with all the impacts that fact has on effective road administration. Therefore a search for lower–cost maintenance standards and the process of assigning them to individual roads started as a part of research on University of Žilina. The aim is to assess the possibilities of cheaper maintenance while still providing a fair pavement quality to the society. This also means that instead of having part of road network maintained in sub–optimal and part in over–optimal condition, more homogenous ride quality on whole network will be achieved.

2.1 Maintenance standard chart

In the last part of research in our department we've assessed the suitability of lower–cost maintenance standards for lower class network.
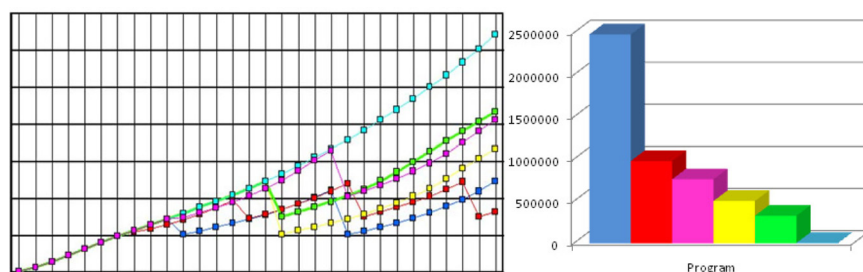
Figure 4   Maintenance standard effects and cost

Table 1   Maintenance overall ranking

Viewpoint	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5	Variant 6
Cost	6th	5th	4th	3rd	2nd	1st
Technical suitability	1st	2nd	5th	3rd	4th	6th
Economical effectiveness	4th	5th	3rd	2nd	1st	6th
Overall	3rd	4th	5th	2nd	1st	6th

The results in fig 4 and table 1 show five alternate variants, each with different cost and effects on pavement conditions. The ranking is only for orientation. Apart from the technical suitability the results also underlie to these conclusion witch account the technical issues of these proposals:

· Variant 1 – Current maintenance variant – Very expensive variant appropriate only for very burdened road sections.
· Variant 2 – microsurfacing based variant – safe to use on all 2nd and 3rd road class roads.
· Variant 3 – balanced cover layer exchange based variant – may be appropriate even for 2nd class roads with traffic load under 1000 AADT especially if they aren't suffering excessive high load vehicles encumbrance.
· Variant 4 – one major cover layer exchange based variant – fairly safe to use on all 2nd and 3rd road class roads.
· Variant 5 – one microsurface based variant – may be appropriate even for 2nd class roads with traffic load under 1000 AADT especially if they aren't suffering excessive high load vehicles encumbrance.
· Variant 6 – basic variant – is appropriate only for 3rd class roads which doesn't exceed the 1000 AADT limit and/or aren't suffering excessive high load vehicles encumbrance.

Table 2 Maintenance standard effects, NPV and IRR (economic effectiveness ranking)

	Name	Description	Costs	NPV	IRR
1	Current maintenance standard	5, 15 and 25th year 25mm microsurfacing with 10 and 20th year surfacing replacement.	2 480 085	1 691 695	13.9
2	Basic variant	Whole lifetime of only basic surface treatment.	2 643	0	0
3	Microsurfacing based variant	Basic surface treatment with 25mm microsurfacing in 7th 16th and 25th year.	977 588	1 723 229	12.1
4	One major cover layer exchange based variant	Basic surface treatment with 40mm cover layer exchange in 14th year	502 654	2 045 110	30.9
5	One microsurface based variant	Basic surface treatment with 25mm microsurfacing in 14th year.	327 279	1 588 528	37.9
6	Balanced cover layer exchange based variant	Basic surface treatment with 20mm cover layer exchange and 25mm microsurfacing in 8th 18th and 28th year.	760 652	1 236 838	15.6

The cost ranking is pretty self–explanatory; more interesting is the economical effectiveness ranking. It may seem tempting to always predict that the most economically effective standard is always the best choice. While it's clearly something that common sense says its right, one aspect shouldn't be neglected.

From the viewpoint of sustainable asset management a salvage value of assessed construction has to be considered. Residual or salvage value could be defined as an estimated value asset's worth that can be obtained from it after its useful life has ended. From this viewpoint we can add salvage value as another factor which influences the ranking of these maintenance standards. The impact this assumption is shown in table 3.

Table 3   Modified overall ranking of maintenance standards

Viewpoint	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5	Variant 6
Cost	6th	5th	4th	3rd	2nd	1st
Technical suitability	1st	2nd	5th	3rd	4th	6th
Economical effectiveness	4th	5th	3rd	2nd	1st	6th
Salvage value	2nd	1st	4th	3rd	5th	6th
Overall	3rd	4th	5th	1st	2nd	6th

It's important to address the issues which arise wit this step:
1   What if assessed roads sections don't have an initial starting IRI value?
2   Is IRI really the sole factor which influences the salvage value of an road section?
To answer first question; from a very simplified viewpoint we could add the actual IRI value to the value of IRI at the end of the road's life but since the roughness deterioration isn't linear, there will be a minor deviation which will get bigger as the starting IRI of a assessed road will be. Therefore we advise to take the salvage value factor in account only on roads which IRI doesn't exceeds 2.5 and add their actual IRI value to IRI at the end of the road's life.
To answer the second question, we did an experiment described in the next chapter.

3   IRI as a factors influencing operating speed of vehicles

As we know there are several factor influencing economical effectiveness of road maintenance and repair works. It's mainly the difference between technical parameters of maintained and unmaintained road generating socio—economic benefits for road users and the investment costs of these works. Since repair and maintenance works don't change the fixed technical parameters like geometrical alignments or width of communication; it's the variable para-meters which changes are bearing the weight of generating the benefits. It's assumed that the main variable parameter is the IRI (International Roughness Index) which usually is the main indicator of road surface condition. To prove this assumption we did an experiment in HDM—4 to show the influence IRI has on vehicle operating speed which change is the main indicator of road user benefits. We then transformed known mathematical equations used to calculate operating speed in relation to IRI to better suit the environment of 2nd and 3rd road network of Slovak Republic.

3.1 IRI as a factors influencing operating speed of vehicles

For this experiment first a straight and level road section was created. Very loose traffic in-tensity (1000 AADT) was set and the operating speed was calculated for different IRI ranging from 1 to 12 on this road. We've run the test both in urban and un—urban environment for private cars and lorries.
As an alternative a geometrically curvy variation of this road was made (resembling a typical alignment for lower class road section in SR environment). This way we could examine the speed difference between two different alignments to estimate the impact of curvature of the road. The third run raised the loose 1000 AADT traffic intensity to a 10000AADT.
The results shown in fig 5 showing that at low class road, neither the alignment nor intensity plays a marginal role in vehicle speed reduction. The mayor difference makes the IRI. The full results are shown in tabular format in table 4.
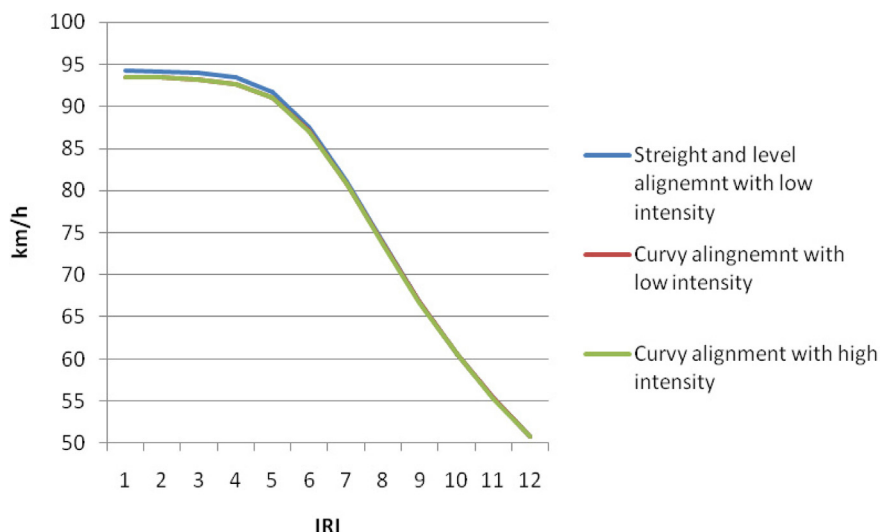
Figure 5 Operating speed depending on IRI

With the result in mind we draw the conclusion that IRI truly is the most important factor when it comes down to vehicle operating speeds. That also means that maintenance standard that keeps the road at the end of its life cycle with the lowest IRI keeps the road also with the biggest salvage value. Therefore when assessing the feasibility of maintenance standards for a road section the salvageable value of that road section it's recommended to take into account.

Table 4 Vehicle operating speed (km/h) depending on IRI (PC=personal car, L=lorrie; NU=non−urban, U=urban environment)

Condi-tions	Car category	Envir-onment	IRI											
			1	2	3	4	5	6	7	8	9	10	11	12
Straight and level alignment with low intensity	PC	NU	94.2	94.1	94	93.4	91.7	87.6	81.2	73.8	66.8	60.6	55.3	50.8
		U	54	54	54	54	53.9	53.9	53.7	53.2	52.4	51.1	49.3	47.1
	L	NU	86.2	86.1	86	85.7	84.7	81.3	74.6	66.9	60	54.1	49.3	45.2
		U	54	54	54	54	54	53.9	53.8	53.3	52.2	50.1	47.4	44.3
Curvy alignment with low intensity	PC	NU	93.5	93.4	93.2	92.7	91	87.1	80.9	73.7	66.7	60.6	55.3	50.8
		U	54	54	54	54	53.9	53.8	53.6	53.2	52.4	51.1	49.3	47.1
	L	NU	84.7	84.6	84.4	84.2	83.3	80.2	74.1	66.7	59.9	54.1	49.3	45.2
		U	54	54	54	54	54	53.9	53.8	53.3	52.1	45.2	47.4	44.3
Curvy alignment with high intensity	PC	NU	93.5	93.4	93.2	92.7	91	87.1	80.8	73.6	66.7	60.6	55.3	50.8
		U	54	54	54	54	53.9	53.8	53.6	53.2	52.4	51.1	49.3	47.1
	L	NU	84.7	84.6	84.4	84.2	83.3	80.2	74.1	66.7	59.9	54.1	49.2	45.2
		U	54	54	94	54	54	53.9	53.8	53.3	52.1	50.1	47.3	44.3

Acknowledgements

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