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Road Network Management: Repair Action Plans for Self-governing Regions

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Abstract

The article describes road network of Slovak republic and structure of administration of this network. Road Network Management System is explained as a pavement management system used by road administrators of main trunk roads and limited access roads. Finally, the article describes the reasons and consequences of lacking pavement management system for regional roads - road administrators of self-governing regions and municipal authorities. Three different approaches of pavement management system (or its substitution) implementation are explained addressing limited pavement data collection capacities, and/or lack of technical experience of regional road administrations.

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Keywords: Pavement Management System, Road Administration, Road Network Management System, Maintenance Repair and Rehabilitation Standard

1. Introduction

Roads are the primary asset of any country in the world. Efficient and well-maintained infrastructure systems are essential for societal stability and for promoting economic growth and environmental sustainability. Research [1] identified a very strong association between economic development, measured as per capita gross national product (GNP), and road infrastructure. Furthermore, the World Bank's research [2] showed that the economic development

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of nations correlates to a high extent with the countries' infrastructure systems. Sound public infrastructure plays a vital role in encouraging more productive and competitive national economies.

The road network of Slovakia consists of 741 km of limited access roads (motorways and express roads) and 17 278 km of 1st, 2nd and 3rd class roads. [3] 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. This road network is connected to a network of urban communications and minor purpose communications. Different types of roads have different owners and administrators with their executive offices. This paper focuses on the topic of pavement management for Regional Road Administrations and Municipal Authorities.

2. Road Administrations of SR

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. This may be seen as 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. [4]
The main functions of road network administrators are:

1. road management and creating conditions for safe traffic on responsible road network;
2. increasing traffic safety and reducing harmful environmental impact of vehicles;
3. organization of traffic and public transport;
4. state and owner's supervision over road construction and road maintenance, road usage, the service level of roads and organizing state supervision over compliance with the requirements established by legislation;
5. keeping road databank of roads, vehicles and public transport; observing special requirements established by legislation;

participating in the elaboration of policies, strategies, and development plans of road development.

Table 1: Road network administrators of Slovak republic [4]

Type of communication	Owner	Administration and maintenance	Executive administration office
Motorways	State	National Highway Agency	Minister of Transport, Construction and Regional Development
Expressways	State	National Highway Agency	Minister of Transport, Construction and Regional Development
1st class roads	State	Slovak Road Administration	Regional transportation offices
2nd class roads	Regional administrations	Regional Road Administration	District transportation offices
3rd class roads	Regional administrations	Regional Road Administration	District transportation offices
Urban roads	Municipal authorities	Municipal authorities	Municipal offices
Minor purpose communications	Municipal authorities	Municipal authorities	Municipal offices

3. Road Network Management

Various systems and models generally referred to as Pavement Management Systems (PMS) are being developed to ensure effective management of road network. PMS used in Slovakia – „Road Network Management System" (RNMS) – is one of the systems. However, it includes a number of original solutions and algorithms to make the standard systems more accurate. Primarily, by application of the analytic – experimental design method and experimental Two-point Bending Test. The test was used for definition of local physico-mechanical pavement material properties and fatigue coefficient formulae. A two new algorithm are introduced, one for selection of repair methods; second, for Life Cycle Cost Analysis (LCCA) based on pavement performance models ascertained on a Circular Test Track (CTT) facility. Finally, an original optimization model is presented for the calculation of time at which a repair action achieves the most benefits. The RNMS operates at:

- Road Network Level - prioritization and optimization of Maintenance Repair and Rehabilitation (MR&R) actions and optimization of MR&R strategies.
- Project Level - optimization of Rehabilitation and Reconstruction (R&R) actions and assessment of new infrastructure investments.

At network level, in contrast to the well established standards, RNMS includes much more detailed data regarding pavement structure evaluation such as residual service life and overlay thickness, which are the base for decision whether maintenance, rehabilitation or reconstruction actions is appropriate. This decision, if done properly, will allow for considerably more realistic MR&R policies, programming, and schedules.

Operations on project level are based mainly on the diagnostic and evaluation of the pavement structure. Data from the trailer mounted dynamic impulse loading device KUAB FWD – falling weight defelectometer – are supplemented by measurements of complex modulus of elasticity on samples extracted from asphalt layers of the analyzed pavement section [5]. Subsequently, local influences are assessed in relation to the repair technologies and their durability, as well as regional pricing specifications e.g., market prices charged by contractors of the repair actions. The output is an exactly defined list of appropriate MR&R actions, according to this schedule, road network administrators can prepare contract for suppliers of MR&R works.

Decision making process is performed at two levels; the RNMS consists of two sub-models for each particular level of decision making: prioritization sub-model and optimization sub-model. In practical terms, prioritization program is a necessity, as it is required by road administrators; road administrators are obliged to deal with insufficient funding, they are also responsible for maintaining the road network in satisfactory condition. Therefore, priorities have been established; these priorities include: functional categorization of road communications, blackspots, extreme traffic volume, extent, severity of pavement distresses and cost effectiveness.

Optimization program, in addition to establishment of general options for optimal treatment for each possible combination of performance variables, deals with optimization of timing of R&R actions. The program is based on a mathematical model for calculation of optimal repair time. This model consists of cost optimization, namely, calculation of construction costs and subsequent sum of annual maintenance costs for the duration of residual service life. However, the requirement of this calculation is the application of an analytical calculation of the residual service life and calculation of the overlay thickness in each year of the residual service life. Subsequently, user costs are calculated for each R&R variant and each year of its possible implementation. The optimal variant and year is the one with the lowest sum of construction, maintenance and user costs.

4. Road Administration for Self-governing Regions

Although road administrators of self-governing regions no doubt have similar operational and organizational needs and face the same general challenges as National Highway Agency or Slovak Road Administration, they lack any sophisticated planning and decision making for pavement management. The RNMS is successfully applied on motorway network, limited access road network and 1st class road network. Municipal road administrators and road administrators of self-governing regions however still rely on reactive repair planning. We know for a fact that this approach is wasting resources as repairs are conducted on roads near the end of their lifespan, repair in this advanced state of deterioration means a high-cost repair or full-blown reconstruction action. Regardless of whether this is due

to the lack of adequate resources to establish the initial database and set up the system, or whether there is a general lack of technical expertise to implement the program, local agencies are in need of a methodology for effectively managing the various components of their pavement network. There are three approaches how to implement a PMS for road administrators of self-governing regions:

- Implementation of the existing RNMS
- Use of a simplified PMS (fixed repair plans)
- Preparation of pre-computed repair plans and their variants using an external software tool

4.1. RNMS implementation for regional road administrators

Currently the internal data regarding pavement are being stored in a data warehouse They are currently collected by Slovak road administration for 1st class roads in a road databank. They also collect the data for limited access roads as contractual agreement with National Highway Agency. The division of Road databank of Slovak road administration is also responsible for keeping the database up to date. The problem lays in 2nd a 3rd class road network which volume exceeds the capabilities of Slovak road administration and their data collecting capacities. The solution to this problem may lie in procurement of Automated Data Collection Vehicle (fig 1.). The vehicle should be equipped with Road Profiler, Line Scan Camera, Thermo camera, Ground Penetrating Radar and Global Positioning System. This would greatly expand the effectiveness of data collection and expand the capacity of roads which can be surveyed and kept updated. [6]

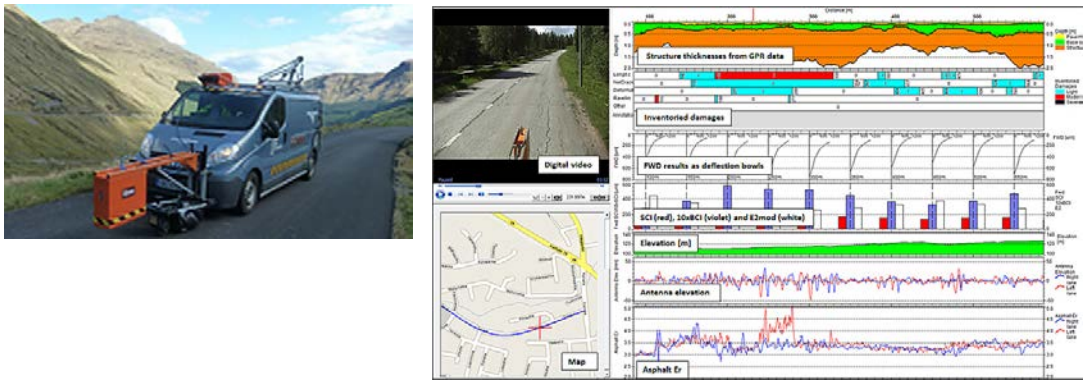

Figure 1. Automated Data Collection Vehicle and its output

4.2. Use of a simplified PMS (fixed repair plans)

Simplifying PMS to the form of fixed repair plan may be a good subsidiary and temporary solution. [7] Maintenance standard is a schedule of repair and maintenance works which also represents the allowable limit for road deterioration. A standard is based on road class, characteristics of traffic and general operational practice. Generally, when roughness reaches close to the standard (fixed International Roughness Index, IRI), any treatment is required to restrain road roughness to go beyond the standard. Standards have to optimum considering cost and road condition, and should be set at network level. The fixed maintenance standard prescribes the maintenance and repair procedures to certain years are shown in table 2.

Table 2: Common pavement repair technologies

Technology	Period	Description	Effect
Basic surface treatment	1 year	Pothole patching and Crack sealing according to administrators available technologies.	A local defective part of pavement is treated for re-acquiring of lost geometry and structural properties.
Microsurfacing regeneration	5 year	Microsurfacing is a cold mixed polymer modified thin asphalt layer lied with traveling paving truck.	Microsurfacing restores lost surface properties and protects and preserves, extending pavement life.
Cover layer exchange	10 year	Upper part of the road is milled off and replaced with a new bituminous layer. The thickness may vary.	Continuous regaining of geometric, structural and surface properties.

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. Nevertheless, it is 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 correspond with the procedures described in pavement management system theory with all the impacts that fact has on effective road administration. Pavement operational capability represented as IRI is shown for different fixed repair plans in figure 2.

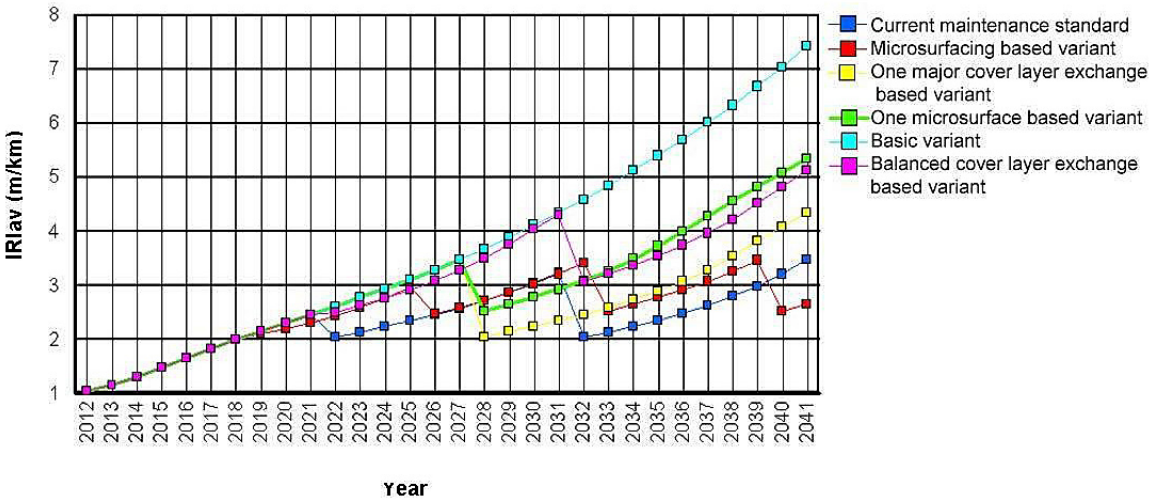

Figure 2. Calculation results - Average roughness by project for various fixed repair plans

4.3. Pre-computed repair plans

This approach deals primarily with the prioritization of a defined long list of candidate road projects into a one-year or multi-year work program under defined budget constraints. It is essential to note that here; we are dealing with a long list of candidate road projects selected as discrete segments of a road network. The selection criteria will normally depend on the maintenance, improvement or development standards that a road administration may have defined (for example from the output produced by the strategy analysis application). Examples of selection criteria that may be used to identify candidate projects such as periodic maintenance thresholds like in fig 3. HDM-4

software was used to draft the repair plan in tab 4, fig 3 is MR&R standard proposed by Slovak Road Administration for trunk roads.

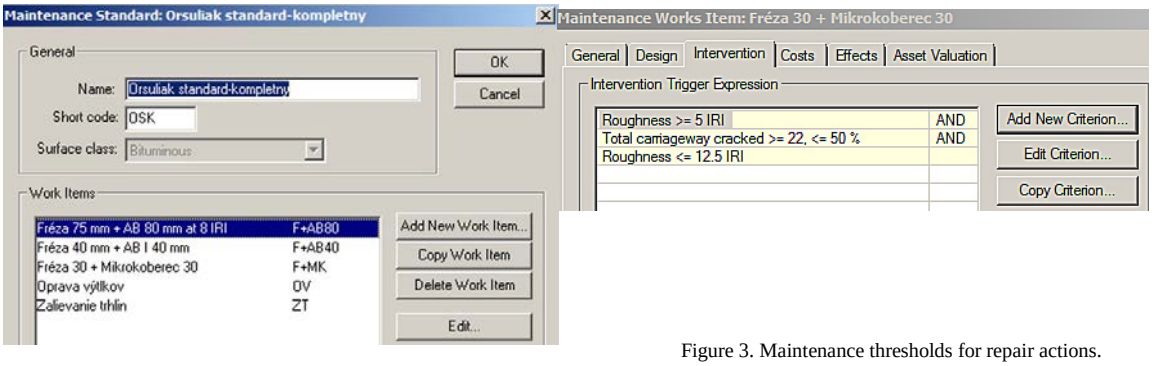

Figure 3. Maintenance thresholds for repair actions.

When all candidate projects have been identified, the HDM-4 program analysis application can then be used to compare the life cycle costs predicted under the existing regimen of pavement management (that is „without project case") against the life cycle costs predicted for the periodic maintenance, road improvement or development alternative (that is "with project case"). This provides the basis for estimating the economic benefits that would be derived by including each candidate project within the budget timeframe.

For this approach, the problem can be posed as one of seeking that combination of treatment alternatives across a number of sections in the network that optimized an objective function under budget constraint. Each budget constraint defines a Budget Scenario.

The amount of financial resources available to a road agency determines what road investment works would be affordable. The level of budget is not always constant over time due to a variety of factors. This variation of budget levels over time affects the functional standards as well as the size of road network that can be sustainable. Pre-computed repair plans are prepared for several budget scenarios to be specified and optimized simultaneously. This permits comparisons to be made between the effects of different budget scenarios and to produce desired reports. A budget scenario represents the available resources defined for each budget period, excluding the costs of annual routine maintenance and special works [8].

5. Conclusion

This paper describes the road network of SR and its road administrators. It describes the problematic of pavement management and gives an insight into road network management system. As presented, the implementation of pavement management system for road network administrators of self-governing regions is possible. An educated guess would be, that best solution would be to adopt the RNMS, the two other possibilities presented in this article could make for temporary or backup solutions. Road Network Management System was accepted by international financial institutions on providing investment credits for rehabilitation of road network. At present, when the system is in operation for more than 15 years, we can draw on results achieved in practice.

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