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IMPLEMENTATION OF ROAD ASSET MANAGEMENT SYSTEM FOR THE PUBLIC ENTERPRISE FOR STATE ROADS IN NORTH MACEDONIA

ИМПЛЕМЕНТАЦИЈА НА СИСТЕМ ЗА УПРАВУВАЊЕ СО ПАТИШТА ВО ЈАВНОТО ПРЕТПРИЈАТИЕ ЗА ДРЖАВНИ ПАТИШТА НА СЕВЕРНА МАКЕДОНИЈА

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Abstract

Public Enterprise for State Roads (PESR) started with the implementation of Road Asset Management System (RAMS) in 2017 with the main goals to establish a RAMS software, collect missing road data, do road network evaluation and perform strategic and program level analyses. The project started with the definition of a new road reference system (RRS) for state roads including detailed definition and alignment of roads, road sections and nodes (junctions); beside the upgrading description in tabular form (names, alignment, category, length, etc.) also a graphical (GIS) presentation was established. Core of the RAMS IT system present Road Data Bank (RDB) software that is strongly integrated with WEB GIS and based on new RRS. RAMS Portal was established as common entering point with all information, news and metadata. All existing digitally available road data were reviewed and transformed to new RRS and imported into the RDB. To collect missing road structure data Ground Penetration Radar (GPR) measurement was done on whole state road network (4384 km). Also 14-days Weight In Motion (WIM) measurement was done on 20 locations to collect traffic structure data. As last step in RAMS implementation evaluation of the road network was done using HDM-4 to support programming of road works – first strategic analyse following with a three-year road works program.

Key words

GIS, Ground Penetration Radar, HDM-4, Macedonian state road network, Road Asset Management System, Road Data Bank, Weight In Motion

Апстракт

Јавното претпријатие за државни патишта (ЈПДП) започна со имплементација на Системот за управување со патишта (RAMS) во 2017, со следниве главни цели: воспоставување на RAMS софтвер, собирање на податоци што недостасуваат за оценка на состојбата на патиштата, правење проценка на патната мрежа и вршење анализи на стратешко и на програмско ниво. Проектот започна со дефинирање на нов референтен систем на патишта (RRS) за државните патишта, кој вклучува детално дефинирање и траса на патот, патни делници и јазли (клучки); покрај ажурирањето на описот во табеларна форма (имиња, траса, категорија, должина и др.), исто така изработена е и графичка (GIS) презентација. Јадрото на RAMS IT системот го претставува софтверот Банка на податоци за патиштата (RDB) кој е цврсто интегриран со WEB GIS и се заснова на новиот RRS. RAMS порталот е воспоставен како заедничка влезна точка која ги содржи сите информации, вести и метаподатоци. Беа разгледани сите расположливи податоци во дигитална форма за патиштата и трансформирани во новиот RRS и внесени во RDB. За да се соберат податоците кои недостасуваат за дефинирање на конструкцијата на патот, беа извршени мерења со Ground Penetration Radar (GPR) на целата државна патна мрежа (4384 км). Исто така, беа извршени 14-дневни мерења на тежината во движење – Weight in Motion (WIM) на 20 локации, со цел за се соберат податоци за сообраќајната структура. Како последен чекор во имплеметација на RAMS-от беше направена евалуација на патната мрежа со употреба на HDM-4 софтверот за поддршка на програмирањето на работите на патот – прва стратешка анализа која резултира со тригодишен план за работи на патиштата.

Клучни зборови

GIS, Ground Penetration Radar, HDM-4, македонска државна патна мрежа, Систем за управување со патишта (RAMS), Банка на податоци за патиштата (RDB), Weight In Motion (WIM)

1. INTRODUCTION

The paper gives overview of the project activities and results for establishment of Road Asset Management System (RAMS) for Public Enterprise for State Roads (PESR) in North Macedonia [1]. PESR started with the implementation of RAMS in 2017 with the main goals to establish a RAMS software, collect missing road data, do road network evaluation and perform strategic and program level analyses for multi-year road maintenance program.

The project started with the definition of a new road reference system (RRS) for state roads including detailed definition and alignment of roads, road sections and nodes (junctions). The next step was implementation of Road Data Bank (RDB) software based on new RRS as core of the RAMS IT system. For road data presentation WEB GIS was implemented and integrated with RDB. RAMS Portal served as common entering point with all information, news and metadata. All existing digitally available road data were reviewed and transformed to new RRS and imported into the RDB. To collect missing road structure data Ground Penetration Radar (GPR) measurement was done on whole state road network. Also 14-days Weight In Motion (WIM) measurement was done on 20 locations to collect traffic structure data. As last step in RAMS implementation, evaluation of the road network was done using HDM-4 to support programming of road works – first strategic analyse following with a three-year road maintenance program. Also, capacity building plays important role in project; PESR established RAMS team that was trained to use the RAMS and participated in execution of all project activities.

The development phase of project finished in June 2018. Now RAMS is in operational phase operating by PESR RAMS team and supported by RAMS provider. Road data update is done on daily basis inside of RDB and GIS geodatabase, regarding the changes of road network (new motorways), changed road characteristics and quality (road reconstruction), etc. Also new road pavement quality measurements were done with Dynatest Road Surface Profiler [2], based on collected pictures new visual inspection of road surface quality was done, new traffic data for 2018 collected and new three-year program of road maintenance prepared.

2. ROAD REFERENCE SYSTEM

Main goal was to check and upgrade the existing location reference system for state roads. Existing road reference system includes only road definition and based on that new RRS as digital spatial database (geodatabase) was established, defining road sections as basic objects (road centrelines with road section identifiers, direction and length) and nodes (representing start and end of road sections) based on existing definitions of roads. Methodology for road section definition and digitalization was defined in first step and based on that digitalization of road centrelines for state roads was done; Open street maps were taken as basic data source for setting the road centrelines. Through the digitalization of road sections, a lot of questions regarding the exact alignment of the road section, especially in the urban areas, start and end of sections, road and section lengths, etc. were resolved.

To spread available information about state roads, especially for engineers working on state roads (design, planning, construction and maintenance, control, etc.), data on state roads are published public. List of roads and road section (http://www.roads.org.mk/221/patna-mreza), with links to prepared PDFs with information on road sections and nodes are available (Fig. 1). Also public WEB GIS application with road section data is available at the same location.

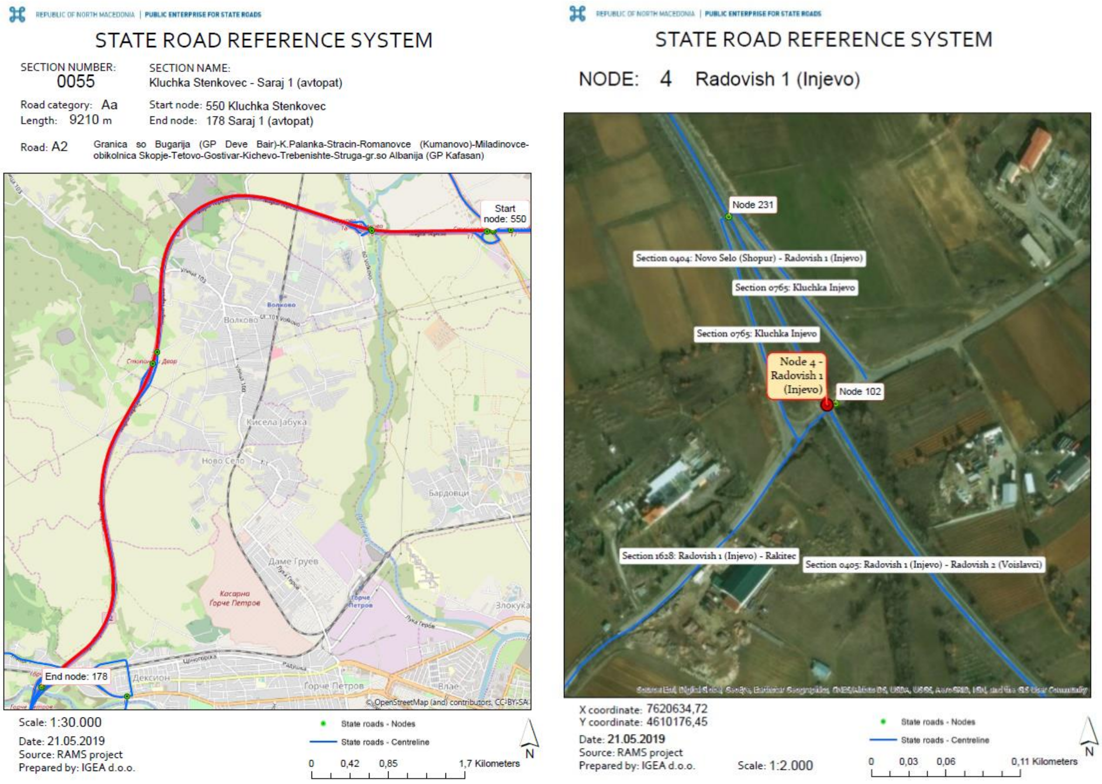

Fig. 1: Visualization of new RRS – PDFs were created for all road sections and nodes

Established RRS requests regular maintenance while new roads are constructed and changes in existing network happens. For this purpose, ESRI ArcGIS Desktop software [3] with some additional procedures is used. Regularly updated Sentinel satellite imagery [4] is used in addition to topographic maps and orthophoto data to provide users most accurate backroad information what is especially important in process of road data collection for roads that are still in construction phase.

3. RAMS SOFTWARE

The established RAMS software consists of the more independent components (RAMS Portal, RDB, WEB GIS) that are integrated in common IT solution where HDM-4 Software [5] is used for road data analysing and for programming purposes.

RAMS software is based on standard technologies and application tools and the system is open and flexible, so that can be adjusted to PESR specific needs and integrated with other PESR IT systems. RDB and GIS system are designed not to serve exclusively for RAMS needs but to serve other PESR units as well; in WEB GIS is already integrated digital archive project documentation and environmental data resulted from other PESR projects.

3.1 RAMS Portal

Established RAMS portal (Fig. 2) served as single entry point to all RAMS components (RDB, WEB GIS, metadata catalogue) and is integrated with PESR Active Directory single sign on system where user rights are managed by PESR IT team. RAMS portal supports the use of RAMS software and provide users news about RAMS, new or updated data, FAQ, metadata, and provide link to RAMS user and technical documentation.

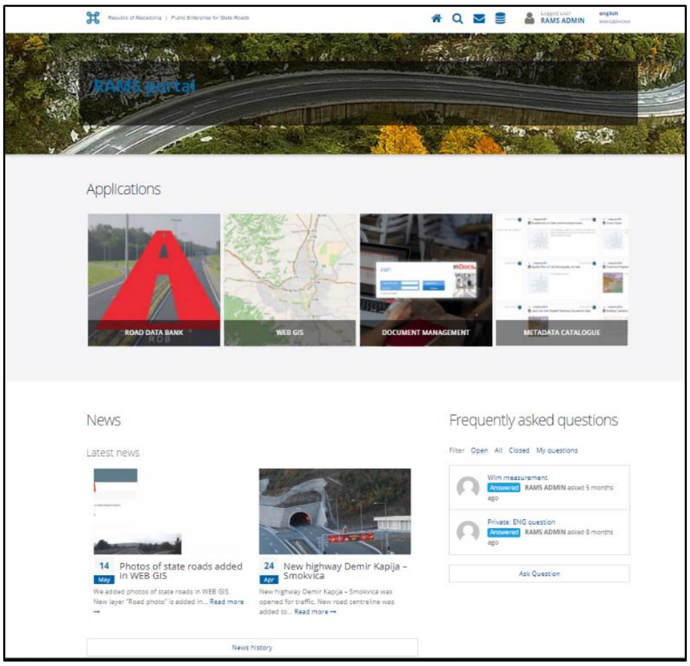

Fig. 2: RAMS Portal interface with links to RAMS applications, news and FAQ

Also, metadata system was implemented as part of the RAMS Portal. Metadata module was developed with GeoNetwork, WEB based open source solution. Metadata structure is compatible with the INSPIRE standards. Metadata description for all data included in RDB and WEB GIS was prepared during the project.

3.2 Road Data Bank

RDB presents, together with new RRS, core of the RAMS IT system. RDB consisting of:

- RDB database implemented as central geodatabase inside of MS SQL Server Spatial [6] environment (open standard relational database with additional option for storing spatial objects),
- RDB application as WEB solution to enable use of the RDB as many users as possible and as client/server solution with more advanced functionality for advanced users (Fig. 3),
- HDM data handling module for data preparation for HDM-4 software road network analyses.

RDB is designed for road data management, data collection, data analysis. In process of implementation RDB standardized environment was adapted to some specific PESR needs regarding the data structure. Current database structure consists of:

- reference system data tables,
- road geometric/design elements data tables,

- road cross-section profile data tables,
- pavement structure data tables,
- road condition data tables,
- traffic data tables,
- traffic accidents data tables,
- HDM Data handling support data tables,
- road works management data tables (road works, road data collection works),
- WIM (weight in motion) data tables,
- iRAP data tables.

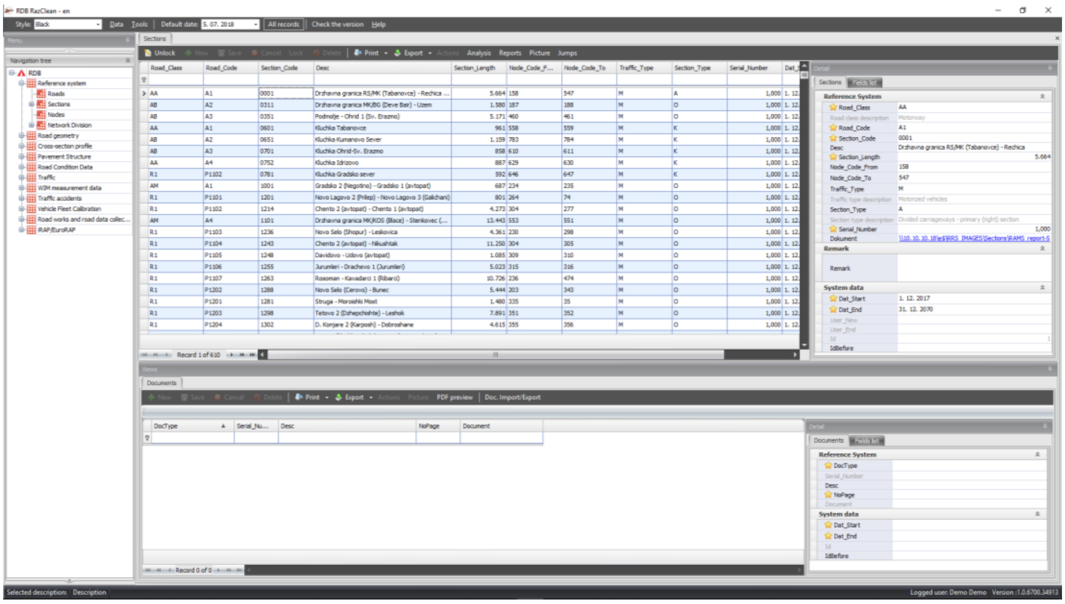

Fig. 3: RDB Client/Server application

RDB database is designed as strongly integrated relational and GIS database that stores all the roads data in standardized relational database, according to RRS (road section and chainage) and geometry (coordinates) simultaneously – solution that has many beneficiaries in data use and care for proper data location and data history.

RDB database was filed with road reference data, all existing road data and road data measured – GPR road structure data and WIM measured traffic structure data. All existing available data from different sources (XLS data, maps, Official leaflet, Dynatest measurement data, photos, video, traffic data, etc.) was first analysed regarding the structure, completeness and location referencing. All data, when possible, were modified to requested RDB structure and transformed new RRS; mostly transformation of mileage between referencing from roads to road sections was needed.

Important functionality of RDB is customized Data handling module that is used for road data analyses, defining homogenous sections and importing prepared data to HDM-4 software. Based on the collected and processed data, different homogenous sections (links) for different HDM-4 analyses can be provided. In addition, the average characteristics of a matrix of road classes can be computed and exported to HDM-4 to be able to perform an HDM-4 network strategic analysis. Data can be exported the road network data per km, per homogenous road sections or for a matrix of road classes to MS Excel for further analysis.

3.3 WEB GIS

Huge amount of road data collected in RDB can be effectively presented only through the visualization of this data on road network. WEB GIS (Fig. 4) serves as central point and basic tool for each PESR employee, where anybody can find all data about roads, not only data regarding RAMS. The WEB GIS covers also the presentation of results of data analyses made by RDB data handling module and results of HDM-4 prepared programs of road maintenance works. WEB GIS is also entering point for access to other road documentation, pictures, etc.

WEB GIS with modern 3 level WEB architecture, is independent but integrated with other RAMS software, where data are stored in MS SQL Server Spatial Database, application server is implemented on open GIS standard GeoServer [7] environment with WMS and WFS services and light user interface supported by any standard WEB browsers and developed in compliance with OpenGIS® and OGC standards [8], PESR gets efficient WEB GIS solution tailored to PESR needs.

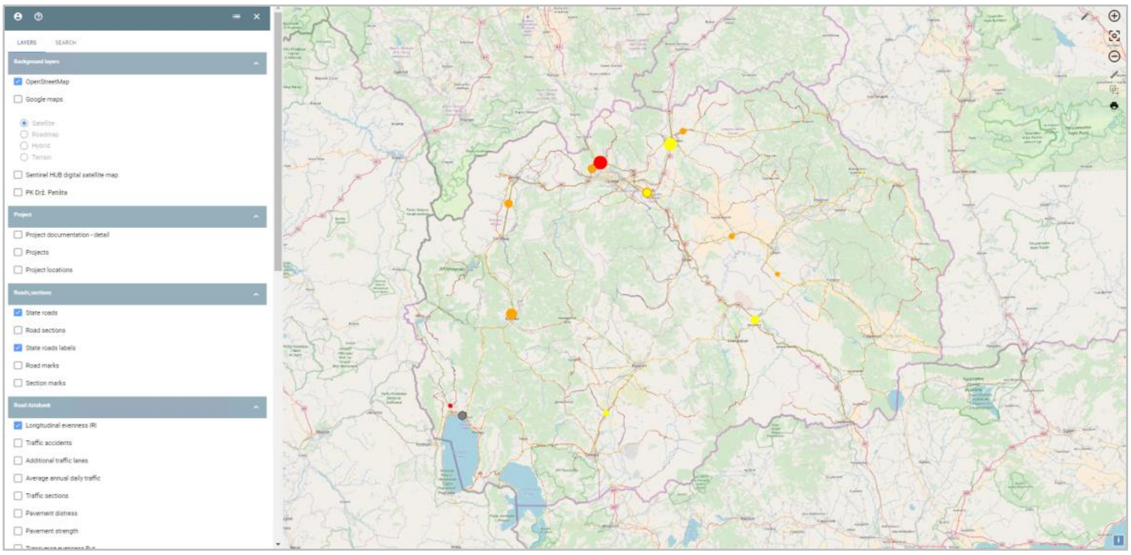

Fig. 4: WEB GIS interface

Important task was also collecting of cartographic and other data (orthophoto, topographic maps, satellite imagery, registers, land and building cadastre) used for background information to display road data. Currently for background data 2 main sources are used:

- Open source data (Open Street Map, HUB Sentinel Satellite data, Google maps data),
- Data from Agency for Real Estate Cadastre, North Macedonia, based on agreement WMS services were integrated for some of their data (land cadastre, buildings, state border, municipalities, cadastre borders).

4. GROUND PENETRATING RADAR MEASUREMENTS

Goal of the ground penetrating radar (GPR) measurement was to determine pavement structures (material type and thickness of pavement structure layers) of state roads with flexible pavement in Macedonia for planning and programming of maintenance treatments in RAMS. The GPR roads survey was made by Road Doctor Survey Van (RDSV) [9] in September 2017 for all state road network – totalling 4350 km of measurements. The RDSV system (**Error! Reference source not found.**) includes ground penetrating radar (GPR), two video, laser scanner, accelerometer and positioning system (GPS with IMU). The equipment was GSSI SIR-30 central unit with two 2GHz horn antennas. The horn antennas were setup in so-called Coreless-GPR method, where the accuracy of layer thickness interpretation is high even without drill cores.

Data was collected for driving lane on motorways and for right lane (in the direction of chainage) on other state roads. All the data was processed and edited with Road Doctor 3 - software (Fig. 5).

The data was collected with 10 cm intervals (10 scans per meter). After processing, bottom of the bound layers and bottom of the unbound layer were interpreted with support from video. Layer interpretations were homogenized for 10m sections to be exported to a database, combined with information from road reference system. Homogenous sections were divided in groups based on layer thicknesses. Also gravel sections and brick roads were marked.

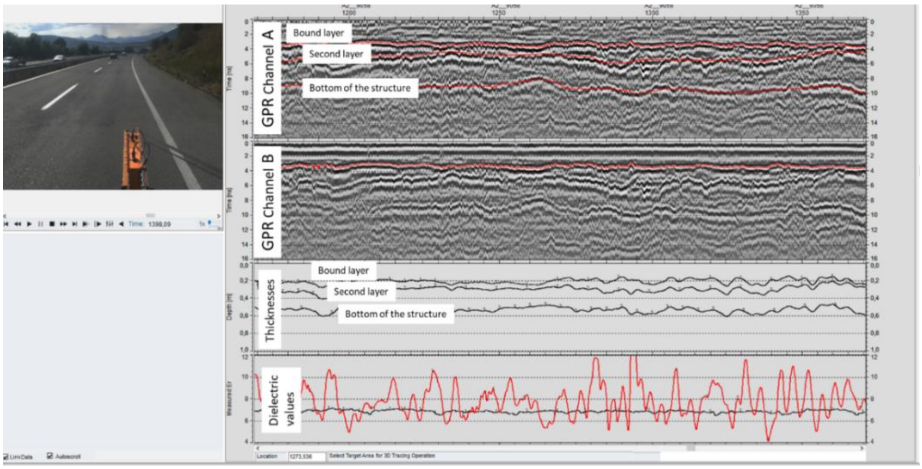

Fig. 5: GPR interpretations in Road Doctor view showing interpreted layers as red lines in two top windows. Third window shows interpreted layers with depth calculation and fourth window shows dielectric values of the pavement.

Important results of this measurements are also road pictures now integrated in WEB GIS - total of 69.000 images were produced with image interval of 50m along the roads. Also, source measurement data were delivered including video of road. Data can be viewed with Road Doctor Viewer or Road Doctor 3 software.

5. WEIGHING OF COMMERCIAL VEHICLES IN MOTION

Weighing of commercial vehicles in motion was done as a part of the RAMS project. The goal was to figure out the structure of heavy vehicles and equivalency factor on Macedonian roads and to get right information to help supporting decision makers on managing and planning roads in Macedonia. Data collection on 20 typical most trafficked road sections were done in the fall of 2017.

For all 20 measurements SiWIM high speed Bridge Weigh in Motion system [10] was used. All 20 sites were equipped with WIM systems, and on some location additionally with Camera to capture all vehicles exceeding 3,5 tonnes GVW. Each site was acquiring data for 14 days.

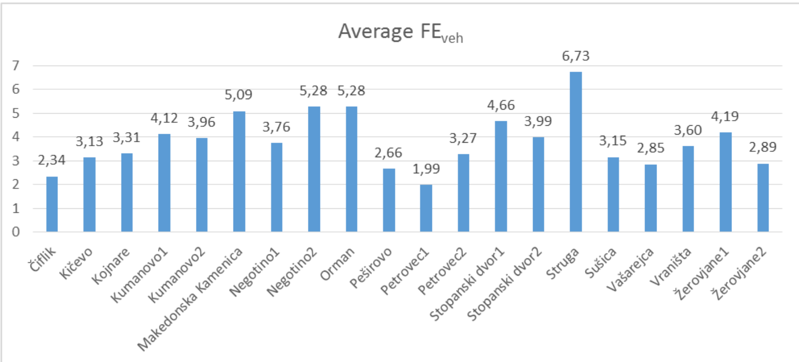

Fig. 6: Average FE_{veh} per site

After data collection data were analysed and database for use in RDB and final report prepared. In Final report was presented ESALs for every class as requested in RFP by the World Bank. In addition, Report includes some extraordinary events collected during the project and recommendations how collected data can be used and suggestions on how to work with WIM data and systems in the future.

Main results include data on speed, number of axles, axle loads, axle distances, total mass and Equivalency Factor of every vehicle over 3,5 tons of total mass. Equivalency Factor of a vehicle (Fig. 6) calculated by the OECD method with 80kN reference axle load and given formula (written in the RFP). Classification of every vehicle from Class 5 to Class (according to the European Union EEC 1180/70 Directive).

6. HDM-4 ROAD NETWORK EVALUATION

The main objective was to use collected road network data stored in RDB for network evaluation and to perform strategic and program level analyses of long and mid-term road maintenance needs, respectively, using the HDM-4 tool for preparation of a 3-year road reconstruction, rehabilitation and maintenance plan.

In order to perform road network evaluation using the HDM-4, the following tasks were performed:

- The assessment of available road network inventory, condition and traffic data
- Preparation of road network data for strategic level analysis (i.e. development of matrices) and program level analysis with the help of developed HDM-4 Data Handling Tool from RDB data
- HDM-4 calibration for local conditions
- Strategic level analysis to obtain maintenance budget needs
- Development of a 3-year program of maintenance works for Macedonian road network.

The main conclusions of the road network evaluation using the HDM-4 are summarized below:

- The overall network condition is relatively good based on available data. The IRI is lower than 5.0 m/km for substantial part of the network, including all functional classes. For most of the network rutting is very low, below 5 mm. However, these data should be taken with caution, and new network survey is necessary with previously calibrated equipment.
- The AADT on most of sections is below 6000 veh/day. There are just a few expressways and R1 regional road sections with AADT up to 10000 veh/day. On motorways traffic is below 7500 veh/day per carriageway. Traffic is relatively similar between different functional classes.
- Relatively low NPV/CAP ratios were obtained for most of the projects as a result of relatively low traffic loading and high cost of treatments. For some of projects, and particularly for sections in poor and very poor condition, the NPV/CAP ratio is lower than 5.
- Annual budget of 30 Mill Euros for periodic maintenance is needed to keep the current network condition under the condition that routine maintenance is also improved. Lower annual spending on periodic maintenance lead to increased network deterioration. Fig. 7 presents the estimated change in roughness over the analysis period.
- The prioritized road works programs for annual budgets of 10 Mill. Euros and 30 Mill. Euros are developed. The focus is on sections in fair condition and on AC overlay projects. Programs also include reconstructions of some highly trafficked sections that are in very poor condition.
- Limited number of motorway and expressway sections is included in the program, due to their relatively good overall condition, type of the treatments used, pavement width and similar traffic to other functional classes. A separate analysis needs to be performed for motorways and expressways, and for lower functional classes. However, the budget split needs to be defined for such analysis.

This analysis was based on existing and available condition and traffic data. There is a need for more recent and accurate data, and the analysis should be updated once new data becomes available. Some sections that were rehabilitated/reconstructed in the last three years, after the roughness survey for which data were provided, may show up in the program. However, these sections should be excluded and program updated, when information becomes available.

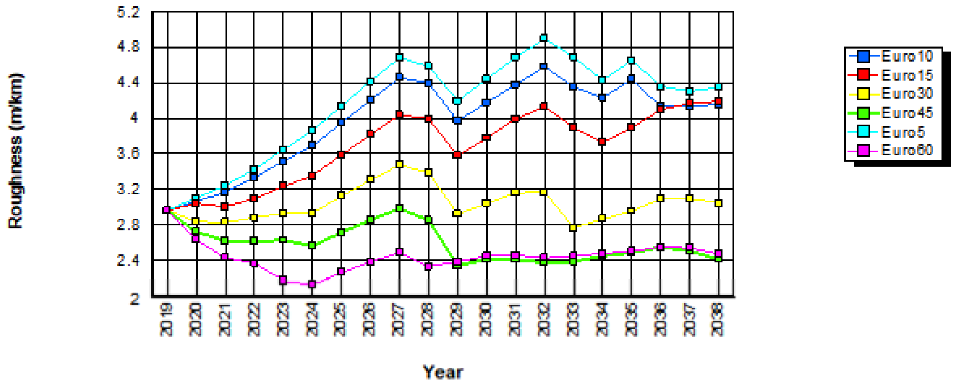

Fig. 7: The change in longitudinal roughness for different budget levels (Annual budget in M €/year)

7. CONCLUSIONS

A comprehensive system was designed, which, with appropriate usage of trained professional users, enables PESR to have efficient data management of public roads under PESR jurisdiction. New established RRS, dividing roads in shorter road sections, brings stable skeleton for road data collection and storage. RDB enables storing road data in standardized form in open MS SQL Server Spatial geodatabase and management of these data through the C/S and WEB applications. Implemented WEB GIS allows users easy visualization of all road data and part of the information is also available for public. RAMS Portal with news, metadata and links to applications give unique view on the whole RAMS system. All RAMS subsystems are open to upgrade with other road asset data, such as bridging objects, traffic signs and horizontal markings, roadside equipment, etc. and on long term gives PESR opportunity to standardize management of all road connected data inside of established system.

System requires regular data update, both in regard to reference system changes and in regard to regular (scheduled annually, bi-annually or other interval) or on-request (after road works, requested by inspectorate, Police, PESR, ...) field measurements. The frequency of surveys for monitoring road, bridge, or traffic conditions has an important bearing on the cost of surveys and sustainability of data collection. Data should be collected only as frequently as is required to ensure proper management of the road network. The frequency can vary depending upon the data of interest.

Road inventory data should be updated when changes are made on a road network, like construction of new sections or changes to the existing sections, as well as when road rehabilitation / reconstruction works have been performed on existing sections, which should include at least year when the works were performed, type of works performed, and pavement condition following the works. Road inventory data should be verified every five years.

Regarding pavement condition data, it is important to note that some survey equipment is available in house, like Dynatest profiler that can be used for survey of longitudinal and transverse unevenness, as well as for acquiring videos/photos that can be later processed to obtain visual condition data. In addition, PESR owns a KUAB Falling Weight Deflectometer that can be used for pavement structural condition survey.

Table 1 presents the proposed frequency for survey of road functional and structural condition. The proposed frequency depends on road class.

Table 1: The proposed road survey frequency

Road sub Network	Functional condition survey (Longitudinal roughness, rutting, distresses)	FWD structural condition survey
Motorways & Expressways	2-year cycle – 50% of the network to be surveyed each year	4-year cycle – 25% of network to be surveyed each year 200 m interval between data points in the driving lane
Main and Regional R1 roads	4-year cycle – 25% of the network to be surveyed each year	Evaluation of pavement bearing capacity at project level before and after rehabilitation/reconstruction.
Regional R2 and R29 roads	5-year cycle / based on needs	

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