https://doi.org/10.26552/com.C.2015.2.49-54

Sanjin Milinkovic - Slavko Veskovic - Biljana Mitrovic - Zivota Dordevic - Peter Marton *

A SITE SELECTION MODEL FOR WAYSIDE TRAIN MONITORING SYSTEMS AT SERBIAN RAILWAYS

To remain competitive in a transport market, railway needs to increase reliability and to reduce the transport costs. Timely detection of a fault or defect can prevent a possible accident and can reduce maintenance costs. This paper presents a model for selection of locations for wayside train monitoring systems that are used to detect faults on the wagons. We present two models: first, based on multi-criteria decision making method is used for selecting a macro location, and second model based on fuzzy logic is used to determine a micro location of a wayside train monitoring system work station on Serbian rail network.

Keywords: *Wayside train monitoring systems, fuzzy logic, multi-criteria decision analysis.*

1. Introduction

Modern railways are complex systems that must perform efficiently while completing demands that include safety [1], ecological, economic and other criterions. One of the most important aspects is maintenance. For the most economical maintenance system, it is very important to use dynamic data or real-time data from the system (data on trains, infrastructure, etc.) to feed an optimization model for maintenance planning. Maintenance planning models can be different optimization methods, but with the similar results that can be used in the process of the maintenance planning in various time span (operational, strategic, etc.).

Modernization of the freight wagons maintenance on Serbian Railways is, with revitalization of the rail infrastructure, a process that could improve a freight transport and increase its efficiency and concurrency on the transport market. To establish the priorities for development and improvement of the freight wagons maintenance it is important to analyze the influence of various parameters on the technical and working condition of the wagons, and on the number of failures and reliability. For the successful and efficient maintenance systems it is important to apply modern technologies for train monitoring and diagnosis. Wayside Train Monitoring Systems (WTMS) are used on many railways to detect technical risks in infrastructure environment before an incident occurs. They use various sensor and surveillance systems in monitoring systems: clearance profile detectors, fire and chemical detectors, wheel load check points, hot axle box and blocked brake detectors, and other natural hazard alarm systems [2 and 3]. The advantages of WTMS make it a safer alternative to human inspection of trains, and can be used to recognize potential fault states that can cause damages to rolling stock or infrastructure, or cause disturbances in traffic. A connected system for train monitoring that uses data storage and analysis with additional models for prediction [4] and interpretation of data, can be used as an essential part of the maintenance system. This concept involves a number of WTMS located through a railway network. Many railways have developed an efficient networks of WTMS located mostly on the freight corridors with high number of trains. In Serbian Railways (SR) the pilot project of a WTMS is constructed near the station Batajnica. First results suggest that this concept has been able to recognize faults states, but for the more efficient results there is a need for wayside monitoring systems that are positioned on several locations on the network [5 and 6]. We propose two models for ranking the alternatives for locations of the wayside train monitoring systems on Serbian Railways. First model uses multi-criteria analysis to rank the alternatives for macro location of the WTMS on the network. Second model based on a fuzzy logic [7] is used for the selected macro locations to determine micro location of the WTMS on the railway line. Main use of the models could be as decision support tools in the process of strategic planning of the investments for train monitoring systems. This paper is structured as follows: in the next section we define common causes for failures on the wagons of Serbian Railways and a need for an increase in technical inspection of wagons; in Chapter 3 we define

* **[1]Sanjin Milinkovic, [1]Slavko Veskovic, [1]Biljana Mitrovic, [2]Zivota Dordevic, [3]Peter Marton**
[1]Faculty of Transport and Traffic Engineering, University of Belgrade, Serbia
[2] Serbian Railways, Serbia
[3]University of Zilina, Faculty of Management Science and Informatics, Slovakia
E-mail: s.milinkovic@sf.bg.ac.rs

a model for a macro location, and in Chapter 4 a model for micro location of the WTMS station. Finally, we present the results and conclusion.

2. Analysis of the common reasons of incidents on Serbian railways

Railway vehicle is a complex structure created for the transport of passengers and goods. During the operation of wagons it is expected to have some problems with corrosion, wear, stress, aging, overload, unfavorable conditions of use, and poor handling of the equipment or vehicles. Significant decrease in state of the vehicles can be the result of the damages generated in incidents.

Defects on wagons can jeopardize safety of the railway traffic. However, based on experience, studies, and analysis on Serbian railways, the highest percentage of incidents is caused by the faulty bogies and brakes and the number of incidents was not rising in the past years (Figs. 1 and 2). In this paper we will analyze the locations of the train systems for monitoring and

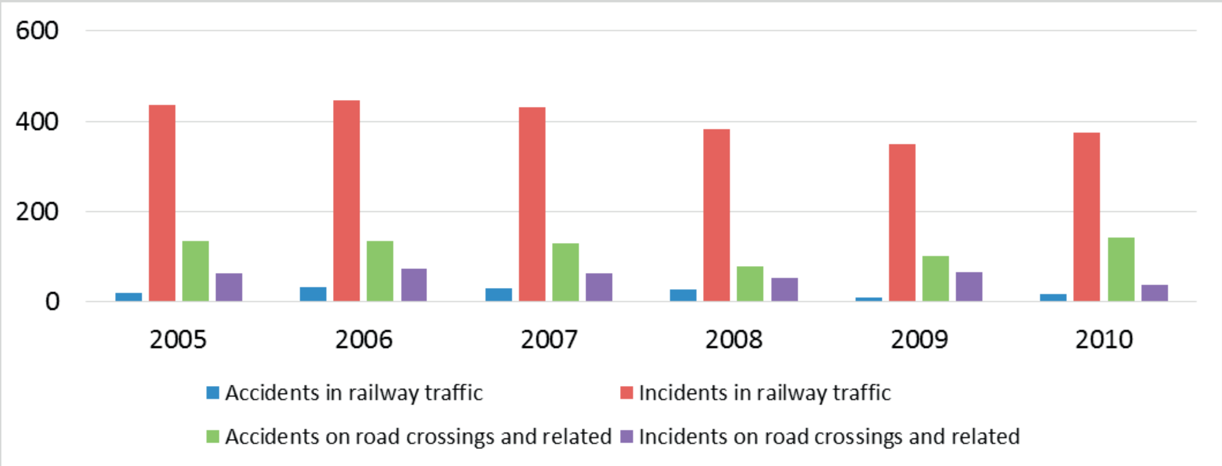

Fig. 1 Structure of the incidents by year on Serbian railways

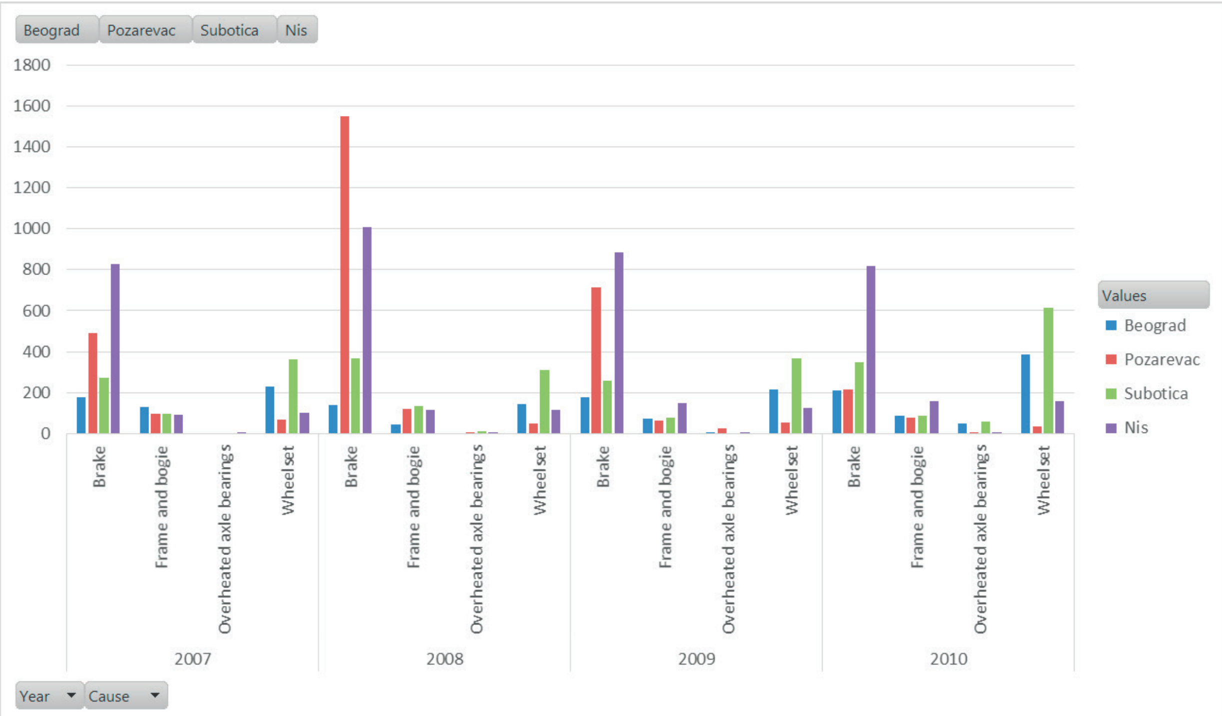

Fig. 2 Structure of the incidents on Serbian railways by causes

detection in order to timely react to detected defects and thus reduce the costs and improve the efficiency of the system.

In SR, first measuring workstation provides detection of the overheated bearings, flat spots on the wheel, and axle overload. The workstation has a combination of detection systems installed on the track. The workstation measures the data during the train movement. The workstation was built near Batajnica, as it is a line with a lot of freight transport from North to South (Subotica - Beograd - Dimitrovgrad/Tabanovce). Specific conditions required are met on this location as it has a 2km straight section of a double track line, with a constant speed of 80k/m/h. The workstation has two subsystems: TK99 for detection of hot-boxes and blocked brakes, and equipment for dynamic weighting of train weights and detection of flat spots G-2000 (Fig. 3).

The system has a database where a computer connected to the system for records, loads the newly measured data obtained when the train passes the workstation and then calculates flat spots, and loading on each wheel.

Fig. 3 First measuring workstation near Batajnica in Serbian Railways

3. Model for macro location of WTMS workstation

The model for macro location of WTMS (MacLoc WTMS) workstation is based on the multi-criteria analysis that analyzes sections of the SR network as alternatives by predefined criterions in order to give a ranking of the best alternatives. The criterions for the ranking of the best macro locations for workstations are:

- Number of wagons with defects that was not allowed in traffic after the inspection due to specific faults.
- The volume of transported goods by sections.
- Influence of the section. This input was calculated as a value on the scale as it consists of several factors: length of the lines on the section, category of the rail line, percentage of lines with international (transit) freight trains, etc.

The sections of the Serbian Railways networks with corresponding input data are presented in Table 1.

Input data for analysis of macro location Table 1

Sections		Number of wagons with defects	Transport of goods	Influence of the section
a_1	Beograd	2057	37172	4
a_2	Pozarevac	3572	120082	1
a_3	Zrenjanin	1689	57195	2
a_4	Subotica	3357	85906	4
a_5	Novi Sad	687	126956	1
a_6	Ruma	901	76987	1
a_7	Zajecar	811	147960	1
a_8	Nis	4567	79689	4
a_9	Lapovo	570	100439	2
a_{10}	Kraljevo	269	110698	1
a_{11}	Pozega	1200	79689	1

We made a survey involved to find the ratio of influence for each of three input data. Experts were tested by Delphi method, and the results are normalized weight coefficients for the criterions: criterion 1 - Number of wagons with defects is the most influential (0.4) while other two criterions are equal to 0.3.

We used a PROMETHEE II method where input data are defined as 11 alternatives and 3 criterions with maximization function and defined preference functions (Fig. 4).

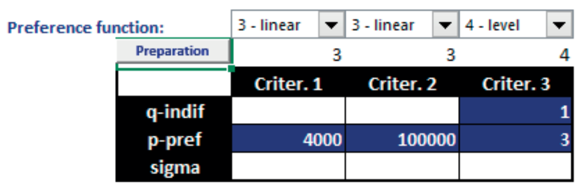

Fig. 4 Preference function for input data

The results of the model are ranking of the sections or list of the best alternatives in a following sequence: $a_8 > a_4 > a_2 > a_7 > a_1 > a_5 > a_{10} > a_{11} > a_9 > a_3 > a_6$, also presented in a Net flows graph (Fig. 5). The best three sections for positioning WTMS are Nis, Subotica, and Pozarevac. The results were expected as these sections are on the main rail corridors and with the highest number of trains. The section Nis has the highest score, so we select this section for the next phase, determining a micro location.

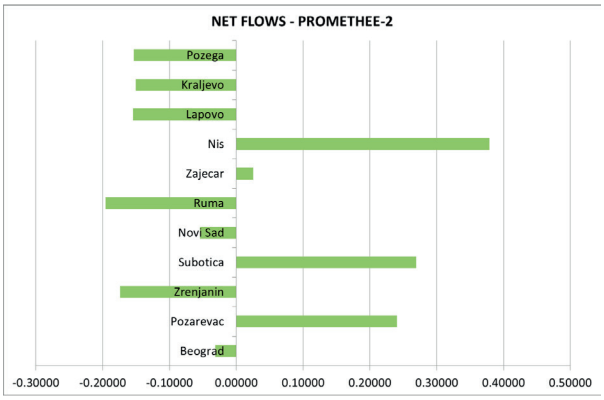

Fig. 5 Results from PROMETHE II method

4. Model for micro location of WTMS workstation

After the selection of the section, the next step is to find a good micro location. In this phase we propose a model that uses techniques of Computer Intelligence, i.e. fuzzy logic system that uses fuzzy system with approximate reasoning (Fuzzy Interface System - FIS) [7]. Fuzzy inference system is defined by three input variables and one output variable [8 and 9].

The input parameters are defined in combination of *trimf* and *tramf* preference functions (Fig. 6):

1. Evaluation of the line section by technical aspect, with three descriptive marks (fuzzy sets) "bad", "satisfactory", and "good".
2. Number of freight trains on the line section. The range is defined for three fuzzy sets: "small", "medium" and "large" number of trains.
3. Distance from the existing WTMS workstation. Defined with two fuzzy sets: "small" and "large".

The output variable as a result of FIS gives a micro location of the workstation. The output value is defuzzified on the scale 1-15 from three fuzzy sets.

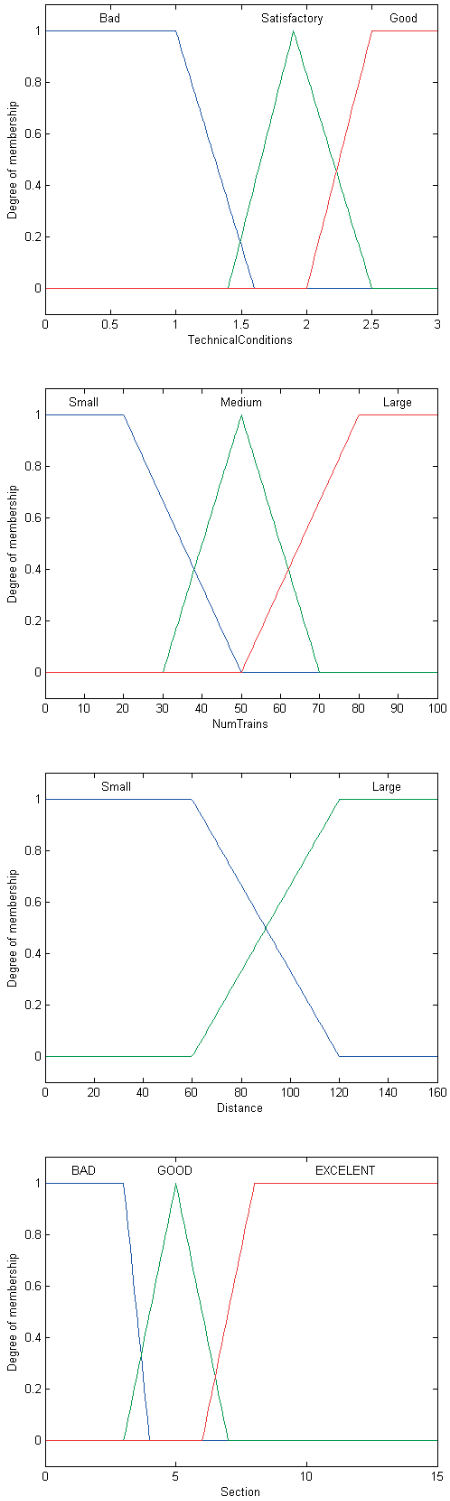

Fig. 6 Input variables and output variable for FIS model

Fuzzy inference system is set by 18 "If-Then" rules mapping from an input to an output using fuzzy logic (Fig. 7). The process of fuzzy inference also involves membership functions, logical operations. Fuzzy inference process comprises five parts: fuzzification of the input variables, application of the fuzzy operator (AND or OR) in the antecedent, implication from the antecedent to the consequent, aggregation of the consequents across the rules, and defuzzification.

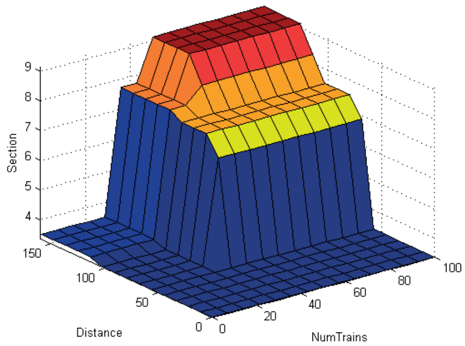

Fig. 7 Surface view of relation between input and output variables

The section Nis, as a selected section, is analyzed by 4 railway lines. Each line is divided by station sections – sections between two adjacent stations (Table 2). Values for the input variables are set according to the obtained data for year 2012. Final results show that micro location with the highest value is the section of line between *Nis* and *Nozrino stajaliste* on the line Nis - Stalac.

5. Conclusion

Based on the structure and number of the wagons with defects, number of trains and goods transported, and characteristics of lines on the sections of Serbian Railways network, we have awarded the section Nis the highest priority in locating new workstations for train monitoring. Further, all the rail lines and all station sections were included in the fuzzy logic model for micro location, and two adjacent station section on the Nis - Stalac line emerged for consideration on investing a train monitoring workstation. The final results give a list of preferable station sections, but it must be further analyzed whether this

FIS model results for micro location of the workstation — Table 2

Railway lines / Station sections	INPUT VARIABLES			FINAL RESULT / Output
	Technical conditions	Number of trains	Distance	
NIS - DIMITROVGRAD LINE				
NIS - Niska Banja	1.4	50	103.9	3.41
Prosek staj. - Radov Dol staj.	1.5	50	89.2	7.51
Dolac - Bela Palanka	1.6	50	82.2	6.38
Crkvica staj. - Pirot	1.5	50	55.4	3.27
Bozurat staj. -Dimitrovgrad	2	50	27	3.01
NIS-PRESEVO LINE				
NIS – Doljevac	2 2	30	157	5
Kocane staj. - Pecenjevce	3	30	137.3	5
Zivkovo staj. - Leskovac	2	30	122.5	5
Dordevo - Seline staj.	1.6	30	104.7	3.59
Vladicin Han - Vranje	1.6	30	70.9	3.27
Nerapovac staj. - Presevo	1.8	30	38.60	3.12
NIS - KOSANICKA RACA LINE				
NIS – Doljevac	1.6	20	87.5	3.27
DOLJEVAC - Zitorađa	1.8	20	66.27	3.28
Recica staj. – Prokuplje	1.6	20	56.9	3.29
Toplicka Mala Plana tov. i staj. - Plocnik tov. i staj.	1.6	20	47.9	3.3
Barlovo tov. i sta. - Kursumlija	1.6	20	23	3.31
Rasputnica Kastrat - Kosanicka raca	1.6	20	11.4	3.32
NIS-STALAC LINE				
NIS - Supovacki Most staj.	2	90	121.7	9.67
Grejac St. - Nozrina staj.	2	90	132.2	9.67
Aleksinac – Sunis	2.4	90	151.5	9.64

location will be technically suitable for the WTMS, as this system requires specific conditions on the track. If the selected micro location is not suitable due to other technical conditions (track without curves, etc.), the model must be run again with new input parameters. Models could be additionally calibrated using the data and experience gathered from the train monitoring systems. In Serbian Railways inspection and train monitoring is done by train personnel in stations. Further implementation of WTMS technology will reduce the costs and improve the safety. Application of the proposed models will be interesting in the research and development phase to help decision makers in planning the investments in WTMS workstations.

Acknowledgement

This paper is supported by The Ministry of Education and Science of the Republic of Serbia, within the research projects No. 36012 and No. 680-00-140/2012-09/10.

References

[1] RASTOCNY, K., ZAHRADNIK, J., JANOTA, A.: An Object Oriented Model of a Railway Safety-Related Control System. *Communications - Scientific Letters of the University of Zilina*, 2002, 4, ISSN 1335-4205.

[2] SCHOBEL, A., SVALOV, D.: Hazard Alert Systems. G. THEEG, E. ANDERS AND S.V. VLASENKO eds. *Railway Signalling & Interlocking: International Compendium.* Eurailpress, 2009, ISBN 9783777103945.

[3] SCHOBEL, A., STADLBAUER, R., PISEK, M., MALY, T.: *Wayside Dynamic Weighing and Flat Spot Detection at Austrian Railways. Proc. of the INFOTRANS*, Pardubice, 2007, pp. 257-262.

[4] VESKOVIC, S., TEPIC, J., IVIC, M., STOJIC, G., MILINKOVIC, S.: Model for Predicting the Frequency of Broken Rails. *Metalurgija*, 2012, 51(2), 221, ISSN 0543-5846.

[5] RADOSAVLJEVIC, A., DORDEVIC, Z., MIRKOVIC, S.: Concept for Wayside Train Monitoring at Serbian Railways - Pilot project Batajnica. In A. SCHOBEL ed. *RTR Special: Wayside Train Monitoring Systems.* Eurailpress, 2011, p. 6-12 ISBN 978-3-7771-0426-3.

[6] VESKOVIC, S., DORDEVIC, Z., STOJIC, G., TEPIC, J., TANACKOV, I.: Necessity and Effects of Dynamic Systems for Railway Wheel Defect Detection. *Metalurgija*, 2012, 51(3), 333-336, ISSN 0543-5846.

[7] LIESKOVSKY, A., MYSLIVEC, I.: Fuzzy Logic in Railway Vehicle Control - a Necessity or a Mode? *Communications - Scientific Letters of the University of Zilina,* 2001, No. 2-3, ISSN 1335-4205.

[8] MITROVIC, B.: *Location Model of WTMS System Workstations in Serbian Railways Network (in Serbian)*, Master Thesis, University of Belgrade, 2013.

[9] MITROVIC, B., MILINKOVIC, S., VESKOVIC, S., BRANOVIC, I., DORDEVIC, Z.: *Location Model of WTMS System Workstations in Serbian Railways Network,* M. Ivkovic, YU INFO 2014, Kopaonik, 2014.