Wayside Train Monitoring Systems – an actual overview
Non-railway aficionados will not know them at all, and even frequent rail users may struggle to recognise them: yet today, wayside train monitoring systems (WTMS) are widespread, state-of-the-art installations that do a valuable job. With the increasing automation of rail transport and the associated headcount reductions, WTMS provide at least the same level of safety as the people they replace, if not more. The systems have grown from "laboratory equipment by the tracks" to components of a reliable production system. They not only help prevent accidents, but also permit the early identification of and quick response to situations in which defective trains block routes.

WTMS do not replace any of the obligations of railway undertakings (RUs) – these railway companies themselves rightly retain responsibility for their vehicles. But when used intelligently, WTMS can provide opportunities to optimise the maintenance of both railway vehicles and infrastructure. These days, it is possible to recognise degradation in the condition of rolling stock before a critical point is reached. The data are available, but they are still not used frequently enough!

By no means would I deny that developing ultra-precise measuring systems for prolonged use in a track-side environment is an extremely demanding task. We have to confront this challenge each day. But rather than perfecting individual measuring systems, it’s more beneficial to create an integrated network of all the WTMS available. This facilitates train tracking, trend analyses and diagnostics, and thereby improves safety by way of redundancies and plausibilised measurements. The increase in the availability of train paths, though, has an even greater positive impact on daily operations. From experience, downtimes caused by defective trains can be reduced by a quarter (!) if measurement data are analysed by specialists immediately.

A logical progression from this would seem to be an automated, real-time exchange of data across borders and infrastructures. Only then could imminent problems with cross-border services be eliminated at frontier stations. Full use would be made of the generous space available in almost all cases, of waiting time that is available at changeover points anyway, and of staff, tools and replacement parts. It makes no sense to detect problems with vehicles when they are well within a country when these faults would be identifiable in advance and could be solved at changeover points. Obstacles to cross-border data exchange between different infrastructures would undoubtedly be more of a political nature than a technical one.

Obviously the harmonization of critical values will play a role in this context. From experience, this requires difficult and lengthy discussions, which I would be happy to enter into, but as a second priority. Also worth considering are new methods of transmitting alarm signals to the locomotive cab in conjunction with technologies such as ETCS and GSM-R, as well as the use of WTMS measurement data to optimise traffic flows. This would not just be done on the basis of WTMS alarms, though: train data measured, such as the current overall weight of a freight train, should also be taken into account. All these data are already available for use.

I am delighted that the subject of WTMS has been launched on an European scale, and look forward to an interesting exchange of experiences for the sake of rail travel in Europe and beyond!

(M.Sc. Urs Nietlispach
Head of Wayside Train Monitoring Systems, SBB)

Dear Readers,
Contents

RTR Special – Wayside Train Monitoring Systems | 2011

3
Urs Nietlisbach
Preamble

6
Aleksandar Radosavljević
Života Djordjević
Simo Mirković
Concept for Wayside Train Monitoring at Serbian Railways – pilot project Batajnica

12
Sonja-Lara Bepperling
Andrew Nash
Using the Best Practice Risk (BP-Risk) method to estimate safety requirements for Wayside Train Monitoring Systems

16
Erich Eisenbrand
Hot box detection in European railway networks

26
Ilse Vermeij
Daan Venekamp
Peter Boom
Using Gotcha to obtain real-time data gathered from wayside monitoring systems to optimise the LCC

31
Dietmar Maicz
Johannes Stephanides
Wolfgang Zottl
Argos – Intelligent local measurement stations for continuous monitoring of vehicle condition

39
Joëlle Vouillamoz
Christoph Munter
Profile and antenna detection system at Heustrich

45
Giovanni Bocchetti
Nadia Mazzino
Antonio Lancia
TCCS – Train Conformity Check System

54
Stefan Koller
Hanspeter Schlatter
Fire & chemistry indication

60
Urs Nietlisbach
Martin Frey
Consistently networked WTMS at SBB

65
Roland Stadlbauer
Michael Rumpler
CheckPoints in operations control in Saudi Arabia
Dear Readers,

The ongoing growth of importance to apply wayside train monitoring systems in European railways is given at least by three main drivers. First is the operational safety in terms of remote controlled interlockings and centralization of operation control to compensate the missing human inspection of passing trains at stations. The second argument can be found in the availability of the European freight corridors. Preventive recognition of upcoming fault states allow immediate interaction and thereby increasing quality of transport due to less disturbances of traffic flow. Last but not least the third concept is the usage of measured data for maintenance purposes. This requires a well established information storage and distribution platform to provide reliable data to potential user groups. For all mentioned fields of application wayside train monitoring systems have to meet the customer’s requirements to gain satisfaction in daily operation. Looking on the priorities set by different infrastructure managers all over Europe the first devices always installed were hot box detectors to prevent derailments caused by damaged boxes or faulty breaks. Here the cost benefit ratio can be directly calculated by the loss of property documented in the accident data base of an infrastructure manager. The second priority can be found more the less in monitoring wheel-rail-contact forces to identify at least flat spots, unbalanced cargo or overload. For the purpose of track design improvement more sophisticated solutions were designed which deliver more and also with higher precision reliable data to explain the complex field of wheel-rail interaction under various conditions. Today most implementation strategies end at this point but there are currently arising some promising technologies ready to enter the market soon. Fire recognition (or hot spot indication), chemistry check and clearance profile detection can be found in this third group of devices. The business case for the development and implementation of such devices highly depends on the specific boundary conditions of an infrastructure manager. This special issue of RTR shall give an overview on the variety of wayside train monitoring systems already used in daily operation or on the border to market enter. The technical devices are only a part of an overall implementation strategy which must cover the operational handling in case of alarms and the usage of measured data in maintenance procedures to improve the quality of railway transport.

(Andreas Schöbel)
1 Introduction

An extraordinary event in railway operations implies an event which impedes or makes service impossible, endangers human lives and destroys railway property and goods in transportation. Extraordinary events can be classified according to their causes and consequences: crashes, accidents and natural disasters (Table 1) [1].

By observing the accident database of one infrastructure manager, one can see a high number of small derailments at shunting yards and less on normal track between stations, but with high degree of loss (Table 2, 3).

Automation of wayside train monitoring leads to higher estimation accuracy and minimizes human necessity in railway operation. Consequently, the impact of human factors is becoming less important in case of extraordinary events. Current worldwide tendencies are to minimize the influence of human factors in extraordinary events which would be impossible without the application of modern systems for railway operation control and wayside monitoring equipment [2, 3, 4].

On the other hand, for railway vehicle maintenance it is also very important to act in a timely manner. Furthermore, from the aspect of safety and reliability, the wheel sets are the second most important assembly, just after the braking system. Poor wheel conditions can often lead to derailments, whereas early detection of wheel faults brings numerous benefits to infrastructure owners and also to railway operators.

In order to increase safety, improve rolling stock maintenance and to protect infra-

![Concept for Wayside Train Monitoring at Serbian Railways – pilot project Batajnica](image-url)

This paper concerns the number and composition of extraordinary incidents on the Serbian Railways (ŽS) network over the past few years. Taking into consideration possible measuring modules, the most interesting failure state are derailments. Further, the number of detached cars is given regarding the wheel running surface damages and survey of detached passenger and freight cars in relation to failure type over the past few years. Moreover, suggestions are given for the most appropriate locations for wayside monitoring of rail vehicles on the ŽS network. The last chapter of this paper deals with a preliminary estimation of acquisition and implementation of trackside locations through financial and sensitivity analyses. Based upon demand and market analysis carried out by Serbian Railways, CIP Institute of Transportation and in collaboration with Vienna University of Technology, the first installation for automatic wayside train monitoring on Serbian Railways will be built at Corridor X near Batajnica station on the line from Beograd to Nova Pazova.
structure public enterprise “Serbian Railways” plans to create a system for wayside monitoring. Implementation of wayside monitoring on the Serbian Railways network will decrease the influence of human factors in vehicle inspection and faults will be identified in a timely manner.

The first installation for wayside train monitoring on Serbian Railways will be located near Batajnica station and will be a result of close collaboration with Austrian Federal Railways and the Vienna University of Technology. The installation will have two TK99 measuring groups for hot-box, hot wheel and hot disc detection and dynamic scale G-2000 for wheel set weighing, flat spot detection and detection of uneven loading of wagons. Both devices are developed and assembled by Infrastructure of Austrian Federal Railways (ÖBB-Infrastruktur AG).

2 Survey of car defects

Serbian Railways (ŽS) had 365 detached cars in 2006 (393 in 2009) due to faults on wheel running surfaces (Table 4) [5, 6].

The nature of faults can be of different origin:
- Mechanical wear,
- Faults in wheel material and non-homogeneous material,
- Faults caused by heat stresses and overheating.

Consequently all running surface defects can be divided into seven groups: Flat spots 179 – 49,044, 180 in 2009, Flat spots and stickers 33 – 9,04 %, 49 in 2009, Stickers 66 – 18,82 %, 93 in 2009, Holes and flat spots 42 – 11,5 %, 17 in 2009, Material extraction 29 – 7,94 %, 45 in 2009, Material accumulation 11 – 3,01 %, 5 in 2009, Crease and scaling 5 – 1,36 %, 4 in 2009. Almost half of all defects are running surface flat spots, 179/180 occurrences, and just 5/4 defects are recognized as crease and scaling.

<table>
<thead>
<tr>
<th>Types of Accidents</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collisions</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Overtaking</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Car Derailments</td>
<td>16</td>
<td>26</td>
<td>23</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>Fire and Explosions</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Derailments and Overtaking at Shunting yards</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>66</td>
<td>79</td>
</tr>
<tr>
<td>Collisions, Overtaking and Derailments of Maintenance Vehicles</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Other Accidents</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>21</td>
<td>33</td>
<td>30</td>
<td>93</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 2: Types of accidents

<table>
<thead>
<tr>
<th>Types of Operating Incidents</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collisions Avoided</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Overtaking Avoided</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Signal Passing</td>
<td>15</td>
<td>12</td>
<td>14</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Derailments and Overtaking at Shunting yards</td>
<td>76</td>
<td>83</td>
<td>68</td>
<td>66</td>
<td>72</td>
</tr>
<tr>
<td>Fire and Explosions</td>
<td>25</td>
<td>42</td>
<td>43</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Collisions, Overtaking and of Maintenance Vehicles</td>
<td>–</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Other Operating Incidents</td>
<td>310</td>
<td>300</td>
<td>294</td>
<td>298</td>
<td>262</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>435</td>
<td>447</td>
<td>430</td>
<td>383</td>
<td>349</td>
</tr>
</tbody>
</table>

Table 3: Types of operating incidents

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat spots</td>
<td>18</td>
<td>29</td>
<td>14</td>
<td>22</td>
<td>20</td>
<td>17</td>
<td>7</td>
<td>16</td>
<td>4</td>
<td>9</td>
<td>21</td>
<td>2</td>
<td>179</td>
</tr>
<tr>
<td></td>
<td>10,05</td>
<td>16,2</td>
<td>7,82</td>
<td>12,29</td>
<td>11,17</td>
<td>9,49</td>
<td>3,91</td>
<td>8,93</td>
<td>2,23</td>
<td>5,02</td>
<td>11,73</td>
<td>1,11</td>
<td>100</td>
</tr>
<tr>
<td>Flat spots and stickers</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>0,76</td>
<td>0,17</td>
<td>0,32</td>
<td>0,73</td>
<td>0,36</td>
<td>0,39</td>
<td>0,38</td>
<td>0,38</td>
<td>0,38</td>
<td>0,38</td>
<td>0,38</td>
<td>0,38</td>
<td>33</td>
</tr>
<tr>
<td>Stickers</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>0,91</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>0,67</td>
<td>100</td>
</tr>
<tr>
<td>Holes and flat spots</td>
<td>3</td>
<td>11</td>
<td>0</td>
<td>7</td>
<td>4</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>0,61</td>
<td>3,69</td>
<td>0</td>
<td>1,43</td>
<td>0,29</td>
<td>3,15</td>
<td>0</td>
<td>0,94</td>
<td>0</td>
<td>0,23</td>
<td>0</td>
<td>0</td>
<td>1,02</td>
</tr>
<tr>
<td>Material extraction</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>0,18</td>
<td>3,18</td>
<td>0</td>
<td>1,28</td>
<td>0,26</td>
<td>0,26</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Material accumulation</td>
<td>3,44</td>
<td>31</td>
<td>10,34</td>
<td>20,68</td>
<td>3,44</td>
<td>0</td>
<td>10,34</td>
<td>20,68</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0,57</td>
<td>3,07</td>
<td>0</td>
<td>2,06</td>
<td>0,57</td>
<td>0</td>
<td>2,06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Crease and scaling</td>
<td>9,09</td>
<td>18,18</td>
<td>9,09</td>
<td>9,09</td>
<td>9,09</td>
<td>9,09</td>
<td>0</td>
<td>27,27</td>
<td>9,09</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
</tr>
<tr>
<td></td>
<td>1,51</td>
<td>3,02</td>
<td>1,51</td>
<td>1,51</td>
<td>1,51</td>
<td>1,51</td>
<td>0</td>
<td>4,54</td>
<td>1,51</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,51</td>
</tr>
<tr>
<td>TOTAL</td>
<td>32</td>
<td>61</td>
<td>25</td>
<td>46</td>
<td>41</td>
<td>35</td>
<td>17</td>
<td>43</td>
<td>10</td>
<td>22</td>
<td>25</td>
<td>8</td>
<td>365</td>
</tr>
</tbody>
</table>

Table 4: Running surface faultinesses survey in 2006
Demand analysis for WTMS

Wayside equipment is capable of monitoring the actual state of running gear through temperature monitoring and wheel-rail impact recording.

Because of its characteristics, the wayside monitoring equipment should be placed at track positions where the most critical behavior is expected. On the other hand, from a maintenance point of view, wayside monitoring equipment is only a supplement to ordinary methods of vehicle inspection in depots.

Figs. 1 and 2 show the results of the survey of detached cars in the period 2005–2009 by failure type on the Serbian Railways network. The total number of detached cars was 3910 in 2005, 4123 in 2006, 4632 in 2007, 4680 in 2008 and 3530 in 2009.

3 Selection of the most appropriate locations for installations on the Serbian Railways network

The locations where critical behavior of vehicles is expected should be taken into consideration for installation of wayside monitoring equipment. Also, in case of destruction, wayside train monitoring should be installed before other elements of infrastructure with a high value of reinvestment.

Data obtained from such installations also can give substantial support to stationary diagnostic systems in maintenance depots. The equipment selection for installations in wayside monitoring systems and locations should be done in accordance with the infrastructure owner and its maintenance and service strategy.

In the scope of early defect detection, it is indispensable to have equipment capable for contactless recognition of overheating, flat spots and uneven loading, accurate data processing and transfer to remote places. Identification of freight cars which are loaded out-of-gauge should be left for the final phase of the project since such equipment is still in experimental use on the other railway networks (i.e. BLS, ÖBB) [7]. Equipment for detecting gauge overload should be restricted to locations close to border stations and before tunnels with lower contact wire where lorries are transported by Ro-La-trains [8].

A pilot project at the entrance to Batajnica station (I-1, Fig. 3) close to Belgrade is proposed for installing equipment for derailment, hot box and flat spot detection. The device for flat spot detection would also be used for dynamic weighing of freight cars. This installation would cover all trains arriving to and departing from Belgrade Railway Junction, and will be located on a double track line [1].

The first phase of wayside monitoring equipment implementation on the Serbian Railways network should cover all entering stations to the Belgrade junction. Border stations (Subotica, Šid, Ristovac, Dimitrovgrad, Vršac, and Prijepolje) are planned for the second phase, and all other major junctions (Niš, Novi Sad, Lapovo, Požega) for the third phase. In the fourth phase, only hot box detection equipment will be installed at the remaining chosen locations, because of the high entrance probability of this specific failure mode. As mentioned before, the last and fifth phase should be exclusively related to the installation of out-of-gauge detection equipment at border stations (Subotica, Šid, Dimitrovgrad, Preševo, Prijepolje). Such equipment should be able to monitor all loading gauges and also HC containers and Ro-La trains.

Realization of this approach would lead to an effective coverage of the Serbian Railway network with equipment for dynamic weighing, hot box, and flat spot and out-of-gauge loading detection.

This is only a proposal plan for the implementation of wayside train monitoring on the Serbian Railways network. Future steps will be dependent on an increase in transport, line electrification projects, international agreements on freight transport, improvements in allowed speeds on particular lines and finally on adequate financing. The proposed order of wayside train monitoring introduction and position would also be re-evaluated after the initial feedback from the pilot project. Further, after the first phase of wayside train monitoring implementation on Serbian Railways, it should be possible to overcome the lack of field experience we are currently facing.
4 Preliminary investment estimation for installation acquisition

The estimate carried out by the relevant departments of Serbian Railways for direct costs due to car derailments caused by malfunctioning of car equipment is around 40% of total damage costs and is close to 60,000 EUR. Furthermore, the estimate of service interruptions on main lines is around 50 hours. Currently, there is no cost statement available for this interruption.

The estimate for ŽS direct monthly costs for wheel set replacement and turning wheels is around 19,000 EUR, which leads to an amount of more than 220,000 EUR per year. Further estimates indicate that ŽS has losses of around 170,000 EUR annually due to car detachments caused by failures and load adjustments [9].

Since the calculation of indirect losses is very complex, and on the other hand it is not possible to apply methods used in economically developed countries, it can be assumed that the indirect losses for ŽS are at least 4 times greater than the direct ones. The omnipresent lack of vehicles has a major influence for ŽS on the aforementioned amount of direct losses. On the other hand, the large number of freight cars from a safety and inspection point of view leads to a conclusion that a modern wayside monitoring implementation is necessary.

The investment estimation process for installations of rolling stock wayside monitoring equipment for the Serbian Railways Department of car and technical activities took into consideration only the direct effects of Serbian Railways financial affairs which are easy to follow and quantify through company expenses.

Basic assumptions for efficiency estimates are:

- Investment estimation and its dynamics,
- Defining input elements for calculation of costs and benefits.
- Taking into consideration current equipment costs for wayside monitoring, the estimated investment value for all four phases is around 4,780,000 EUR [1].

The starting point for the efficiency estimate of installations, acquisition and implementation was to assume losses incurred by not investing in such stationary systems and possible future direct costs due to extraordinary events that effect and occasionally impede train services.

Costs incurred by extraordinary events are considered as direct savings and revenue for ŽS after implementation of trackside installations. Savings in transport operational costs are calculated. Savings in train service costs are calculated according to the average estimated time of traffic interruption and savings in service costs per unit of time.

Average annual direct losses of ŽS at the current traffic frequency are 450,000 EUR and 50 hours of service interruption. The savings estimate with the full application of automatic wayside monitoring is around 90% of direct costs. Effects of wayside monitoring are evaluated every year for an economic life cycle of 25 years.

### Table 5: Calibrated risk matrix in Mio. EUR per year

<table>
<thead>
<tr>
<th></th>
<th>A (Weekly)</th>
<th>B (Monthly)</th>
<th>C (Once a quarter)</th>
<th>D (Yearly)</th>
<th>E (Once in ten years)</th>
<th>F (Once in one hundred years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.24</td>
<td>0.06</td>
<td>0.02</td>
<td>0.005</td>
<td>0.0005</td>
<td>0.00005</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>0.6</td>
<td>0.2</td>
<td>0.05</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>24.0</td>
<td>6.0</td>
<td>2.0</td>
<td>0.5</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>240.0</td>
<td>60.0</td>
<td>20.0</td>
<td>5.0</td>
<td>0.5</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**Fig. 3: Proposed locations for installation on Serbian Railways network**
The Internal rate of return, which is inside the profitable zone, leads to the conclusion that the investment is profitable from an economic point of view. The Internal rate of return would be significantly higher if indirect costs could be taken into consideration.

The Sensitivity Analysis (Table 6) has been carried out using the following assumptions:

- Increase of investment by 20%,
- Decrease of investment by 20%,
- Increase of savings 20%,
- Reduction of savings 20%.

<table>
<thead>
<tr>
<th>Test type</th>
<th>Internal rate of return (IRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic case</td>
<td>11.99%</td>
</tr>
<tr>
<td>Increase of investment by 20%</td>
<td>9.64%</td>
</tr>
<tr>
<td>Decrease of investment by 20%</td>
<td>15.32%</td>
</tr>
<tr>
<td>Increase of savings 20%</td>
<td>14.78%</td>
</tr>
<tr>
<td>Reduction of savings 20%</td>
<td>9.26%</td>
</tr>
</tbody>
</table>

Table 6: Sensitivity analysis results

The specific view in the accident data base is given by the aspect whether it is possible to recognize one fault state by some way-side monitoring system. Risk is always defined as a product of probability and severity. The European standard [10] offers the possibility to deal with different risks by using a risk matrix [11]. For operational application the qualitative descriptions of probability and severity are quantified (Table 5). The calibrated matrix covers the range of operational scope. The protection goal for wayside train monitoring at ZS is set up to 500 000 EUR per year. Finally, the protection goal divides the matrix into two areas: one below the protection target and one above the protection target where there is a serious demand to set preventive measures to reduce risk to the infrastructure manager caused by car related fault states which may destroy the infrastructure.

The estimate of installations application is carried out after taking into consideration all costs and benefits by standard dynamic ratability methods.

Results for the investment estimate are:

- Internal rate of return (IRR) = 11.99%,
- Net present value (NPV) = 603.719.

The Internal rate of return, which is inside the profitable zone, leads to the conclusion that the investment is profitable from an economic point of view. The Internal rate of return would be significantly higher if indirect costs could be taken into consideration.

The Sensitivity Analysis (Table 6) has been carried out using the following assumptions:

- Increase of investment by 20%,
- Decrease of investment by 20%,
- Increase of savings 20%,
- Reduction of savings 20%.

5 Location and equipment displacement in future stationary installation at Batajnica

The installation location is going to be km 24+776 (from km 24+734 to km 24+818) on the left side of the double track line No. 5 from Belgrade to Šid - border line Serbia/Croatia. Strain gauges are sensors which are used for measurements in rail deformations caused by vehicle wheels passing over them. Strain gauges are positioned at a distance of 1.2 m directly on the rail neck between sleepers, in total 10 strain gauges on each rail, 20 in all on that one track. A PC inside a cabin (module 1) which is connected to G-2000 (module 4) calculates the axle loading for each wheel set upon rail strain measured between sleepers and wheel flat spots from impulse forces exerted over the rails.

The cabin equipment (module 1) will consist of power supply electronics for TK99 sensors (scanners), 2 PCs for data storage, calculation and transfer, and UPS units for 15 minutes power supply in case of power supply interruption. The cabin will be thermally isolated and will have a base of 2.40 x 2.40 m. All electronic equipment will sit on two movable racks. The distance between the front of the cabin and the center of the track will be 6 m. The power supply will be 5 kW max. power, 230 V/50 Hz, from a catenary transformer. Connections between cabin PCs and train inspectors PC terminals in Batajnica and Nova Pazova stations will be done by modems.

6 Warnings and alarms

In a case of any irregularity detected on trains passing over the installation, pictogram alarms will be shown on each monitor connected to the stationary system network (Fig. 5). Pictograms will be accompanied by exact values represented in data tables. In accordance to procedures, the train will be stopped and the faulty car will be removed from the train.

Displayed values will include train identification number, date and train time, direction,
Even a minor irregularity can cause major trouble. SST Signal & System Technik sets new standards to keep your rail traffic running smoothly – with exacting diagnostic systems, consistent control networks and excellent service for better traffic quality, higher reliability and noted cost reduction.