Estimating investment value in railway lines reconstruction process

A prognostic model for estimating investment value of reconstruction of railway lines using artificial neural networks is presented in the paper. The aim of the model is to improve the efficiency and effectiveness of decision making as related to investment in rail infrastructure projects. The model development process is presented and illustrated with an appropriate example, which points to the possibility of using the model for making a rough and rapid assessment of the investment value of railway-lines reconstruction, with a reliability of 80-85% when some input parameters are unknown.

Key words: railway infrastructure, investment value, reconstruction, artificial neural networks

Authors:

Assist.Prof. Ljiljana Milić Marković, PhD. CE
University of Banja Luka
Faculty of Architectural and Civil Engineering and Geodesy
ljmarkovic@open.telekom.rs

Prof. Ljubo Marković, PhD. CE
Faculty of Technical Sciences
Kosovska Mitrovica
ljubo.markovic@pr.ac.rs

Prof. Goran Ćirović, PhD. CE
High School for Building and Geodesy
Belgrade
cirovic@sezampro.rs

Prof. Dragan Mihajlović, PhD. CE
University of Banja Luka
Faculty of Architectural, Civil and Geodesy Eng.
 dram200954@gmail.com

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Estimating investment value in railway lines reconstruction process

Ljiljana Milić Marković, Ljubo Marković, Goran Ćirović, Dragan Mihajlović

Procjena investicijske vrijednosti u procesu rekonstrukcije željezničkih pruga

U radu je prikazan prognostički model za procjenu investicijskih vrijednosti rekonstrukcije željezničkih pruga izrađen primjenom umjetnih neuronskih mreža. Cilj izrade modela je poboljšanje efikasnosti i efektivnosti donošenja odluka o ulaganju u projekte željezničke infrastrukture. Prikazan je proces izrade modela i dan je odgovarajući primjer kojim se upućuje na mogućnost primjene modela za eventualne grube i brze procjene investicijskih vrijednosti za rekonstrukciju željezničkih pruga s pouzdanošću od 80 do 85 % kada nisu poznati svi ulazni parametri.

Ključne riječi: željeznička infrastruktura, investicijska vrijednost, rekonstrukcija, umjetne neuronske mreže

Übersichtsarbeit

Ljiljana Milić Marković, Ljubo Marković, Goran Ćirović, Dragan Mihajlović

Einschätzung des Investitionswerts bei der Rekonstruktion von Eisenbahnstrecken

In der Arbeit wird das Prognosemodell für die Bewertung des Investitionswerts der Rekonstruktion von Eisenbahnstrecken dargestellt, entwickelt anhand eines künstlichen neuronalen Netzerwerks. Ziel der Modellentwicklung ist die Steigerung der Effizienz und Effektivität der Entscheidungen über Investitionen in Eisenbahninfrastrukturprojekte. Das Verfahren der Modellentwicklung wird näher dargestellt. Anhand eines Beispiels wird auf die Einsatzmöglichkeiten des Modells bei einer groben und schnellen Bewertung des Investitionswerts für die Rekonstruktion von Eisenbahnstrecken hingewiesen, mit einer Zuverlässigkeit von 80 bis 85 % wenn nicht alle Eingangsparameter bekannt sind.

Schlüsselwörter: Eisenbahninfrastruktur, Investitionswert, Rekonstruktion, künstliche neuronale Netzwerke
1. Introduction

In accordance with the global strategy for rational redistribution of traffic, and in line with the plans presented by neighbouring countries and Europe as a whole, the Republic of Serbia has signed the following international agreements:
- European Agreement on Main International Railway Lines [1],
- European Agreement on Important International Combined Transport Lines and Related Installations, [2],
- Agreement on the Establishment of a High Performance Railway Network in South East Europe [3].

The principal aim of signing these agreements was to achieve, through adequate measures and in a reasonable time period, such an advanced level of infrastructure in the Serbian rail network that will enable, assisted by modernisation of rail vehicles, achievement of high technical interoperability standards [4], so that Serbian network can accommodate other operators and enable competition. In addition, Serbian Railways plc will increasingly attract passengers and goods through such high level of services, in line with its public and commercial functions. The existing railway network in Serbia was built mainly in the second half of the 19th century and during the 20th century, with track elements fulfilling the requirements of the time. Over the past 30 years, not enough has been invested in this network, which is principally due to general economic sluggishness, poor organization, and the lack of funding even for basic maintenance and repair of railway lines. Thus, no more than approximately 36 km of track lines are repaired annually (instead of the necessary 190 km). Over the past decade, and even since 2002, an average annual investment in railway infrastructure amounted to 16.5 million euros, mainly from loans (e.g. in the Republic of Croatia, the annual investment for the same period amounted to 113 million euros) [5]. As a result, we are currently faced with the situation in which speeds in excess of 100 km/h are allowed on 3.2 % of track lines only, while a maximum speed limit of 60 km/h is applied on the majority of the network (about 50 %). On some lines, there are sections where the speed is limited to 20 km/h or less. The European standard for the maximum permissible load capacity of 225 kN/axle is met by 44 % of the lines. Out of the total rail network length (3,809 km), there are 1,247 km of electrified track lines (32.7 %), and 276 km (7 %) of double track lines [6]. Today, Serbia is ranked 110 out of 132 countries for the quality of its railway infrastructure [5].

2. Assessment of railway lines reconstruction investments using neural networks

Making decisions related to reconstruction work on railway lines is a very complex process. Decisions on work needed are based on the information from various sources, which objectively defines the condition of the railway line in the light of requirements regarding its wider and narrow area of influence. Based on the available and collected information on the existing condition of the railway, appropriate analyses are made in order to:
- identify and assess the existing condition of the rail network,
- make an assessment of future changes,
- identify current and future demands on the rail network,
- predict impact of planned works on the current and/or future condition,
- determine funding needed to fulfil current requirements,
- determine funding needed to implement the planned reconstruction program.

The quality of the above analyses directly depends on the information on rail lines as stored in the rail network database, which is a basic and indispensable link for successful problem solving. Development of artificial intelligence, as a means of support to the decision-making process in railway reconstruction works, has also resulted in generation of methods based on various expert system techniques. An expert system is an intelligent computer program that uses knowledge and inference procedures for solving problems. Expert systems simulate human expertise and can solve problems that do not have algorithmic solutions [7].
One such system is ECOTRACK. It is a compilation of most of the existing systems and, as such, it contains the highest quality solutions from these systems. What makes ECOTRACK special is its very detailed set of rules for making decisions regarding the need for maintenance and reconstruction. These rules are based on decay parameter models. Many prominent experts from most European rail administrations took part in the definition of these rules. The ECOTRACK system is flexible and open for new experience, i.e. it allows addition, change and elimination of rules, but at the discretion of railway administrations [7]. The functional architecture of ECOTRACK is made of five levels. Each level represents a planning activity that includes several detailed functions [7]:

- Level 1: Initial diagnostic – the system uses a database and knowledge base to carry out a preliminary diagnosis of each permanent-way section (geometry, permanent way structure, ballast, and infrastructure). Basic works are defined for each section (geometry, rails, sleepers) and additional information is collected in connection with the state of the track and stored in the database.
- Level 2: Detailed diagnostic – the information collected is used, and decision-making rules for level 2 are applied in order to define the basic works. The user can check and the decisions made by the system.
- Level 3: Harmonisation – a set of rules is used to ensure automatic harmonisation of works, based on the list of basic works. The harmonisation can be: spatial (between two railway sections) and time-related (basic works can be combined over a time period).
- Level 4: Optimization of resources – individual prices of works are entered into the plan and total costs are analysed. The maintenance and repair plans can be changed so as to optimize them at an economic level (cost reduction).
- Level 5: Overall network management – support to the overall network maintenance by means of: statistical analysis, assessment of effects of individual permanent way components and assessment of work methods, simulation of various maintenance policies ("what if"), and simulation of limited availability of resources.

In addition to traditional methods for determining funding needed to implement a reconstruction program [8], the development of the programming concept known as soft computing has enabled the use of artificial intelligence that simulates natural processes – artificial neural networks [9].

2.1. Artificial neural networks

Artificial neural networks are defined as physical cellular systems that can learn, memorize and use experimental knowledge [10]. They are based on an analogy with the nervous system of a living being. The analogy is based on two aspects [11]:

- Knowledge that enters the neural network from the surrounding environment is used for training the neural network,
- The connections between neurons, known as synapses, are used for accumulating knowledge.

In his study, H. Adeli [12] placed emphasis on the possibility of using artificial neural networks for estimating the investment value of construction works. To improve the efficiency and effectiveness of decision-making related to investment in rail infrastructure projects, a prognostic model for estimating the value of investment in the reconstruction of railways, based on artificial neural networks, is presented below.

2.1.1. Prognostic model

Nineteen completed rail reconstruction projects were used as a basis for making a prognostic model aimed at estimating investment value for reconstruction of railway lines using neural networks [13]. For data confidentiality reasons, the names of these projects (rail sections) are indicated numerically. The basic information about the lines on which reconstruction works were carried out was collected from previous projects (length of tracks, track structures, etc.) and using infrastructure condition databases formed at the level of rail infrastructure management companies. The databases were formed from data gained by monitoring and measurement (EM-80 L track recording car, Plasser & Theurer [14]). Based on these data, which were transformed into parameters for condition measurements and grouped into quality indexes, a technical analysis was carried out to determine the existing characteristics of the track (geometric condition, condition of permanent way - tracks, sleepers, etc., ballast and infrastructure) and specific railways and/or rail sections were chosen as appropriate for reconstruction works. A list of basic works was also made. The total costs of reconstruction work on each rail section were calculated on the basis of the reconstruction work planned, while the prices were defined by the user. The condition of train station and the extent of work required were estimated, in form of fit-for-investment rating, using the existing condition assessment model. The condition / investment requirement was categorised as follows:

- 1*: comprehensive interventions (intervention on structural elements of the building, moisture treatment, complete replacement of interior installations, renovation of public and sanitary facilities, replacement of roof covering, replacement of exterior and interior woodwork),
- 2*: medium-scale interventions (repair and replacement of waterproofing, roof covering repair and replacement, replacement of exterior and interior woodwork, partial replacement of interior installations, interior improvement work),
- 3*: small-scale interventions (roof cover replacement, façade and interior wall painting, repair of sanitary facilities),
- 4*: excellent condition (intervention not necessary),
- R – demolition (when the cost of interventions needed to return the existing structure to its initial condition is close, equal to or greater than the cost of building a new structure).

The total train station reconstruction cost was calculated on the basis of the amount of work planned for the reconstruction project, while the prices were defined by the user.
Control parameters for assessing railway condition after completion of reconstruction work were measured using a track recording car. The data obtained were analysed and compared with the corresponding criteria and tolerance thresholds as specified in the reconstruction project. Based on the results of these measurements and their analysis according to behaviour and decay models, decisions were made on necessary maintenance measures and on the time of their implementation. Financial indicators relating to initially agreed prices were obtained from the corresponding contracts and annexes to such contracts, while the final cost of reconstruction work was obtained from payment certificates and the final calculation of cost incurred.

The structure of the data collected and analysed for one of the railway lines planned for reconstruction (Line 7) is provided in Tables 1, 2, 3, and 4.

Table 1. Data on basic elements of the track – track section

<table>
<thead>
<tr>
<th>Railway line no. 7</th>
<th>Length of the rail section</th>
<th>220,49 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the rail section passing through a station</td>
<td>26,90 km</td>
<td></td>
</tr>
<tr>
<td>Length of the rail section being reconstructed</td>
<td>110,10 km</td>
<td></td>
</tr>
<tr>
<td>Length of the newly constructed rail section</td>
<td>110,09 km</td>
<td></td>
</tr>
<tr>
<td>State of the electrical power infrastructure in the corridor</td>
<td>UNSATISFACTORY in terms of reliability, availability, maintainability and safety</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Data relating to the type and length of structures on the track – track section

<table>
<thead>
<tr>
<th>Structures on railway line no. 7</th>
<th>Construction cost (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete bridges, L = 1704 m</td>
<td>15,050,900</td>
</tr>
<tr>
<td>Steel bridges, L = 2136 m</td>
<td>61,147,000</td>
</tr>
<tr>
<td>Viaducts, L = 970 m</td>
<td>22,657,520</td>
</tr>
<tr>
<td>Galleries, L = 120 m</td>
<td>1,544,000</td>
</tr>
<tr>
<td>Underpasses, L = 157 m</td>
<td>3,274,400</td>
</tr>
<tr>
<td>Overpasses, L = 5385 m</td>
<td>69,388,800</td>
</tr>
<tr>
<td>Double-track tunnels, L = 10230 m</td>
<td>127,147,350</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>300,209,970</td>
</tr>
</tbody>
</table>

Table 3. Evaluation of the state of existing architectural structures at stations

<table>
<thead>
<tr>
<th>Structures at stations on railway line no. 7</th>
<th>Investment rating</th>
<th>Cost of intervention on the given structures (EUR)</th>
<th>TOTAL (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train station no. 1</td>
<td>2*</td>
<td>961,900</td>
<td></td>
</tr>
<tr>
<td>Train station no. 2</td>
<td>2*</td>
<td>875,040</td>
<td></td>
</tr>
<tr>
<td>Train station no. 3</td>
<td>2*</td>
<td>759,970</td>
<td></td>
</tr>
<tr>
<td>Train station no. 4</td>
<td>1*</td>
<td>1,726,200</td>
<td></td>
</tr>
<tr>
<td>Train station no. 5</td>
<td>1*</td>
<td>2,936,720</td>
<td></td>
</tr>
<tr>
<td>Train station no. 6</td>
<td>2*</td>
<td>449,490</td>
<td></td>
</tr>
<tr>
<td>Train station no. 7</td>
<td>2*</td>
<td>564,550</td>
<td></td>
</tr>
<tr>
<td>Train station no. 8</td>
<td>2*</td>
<td>470,090</td>
<td></td>
</tr>
<tr>
<td>Train station no. 9</td>
<td>1*</td>
<td>6,097,530</td>
<td>19,784,500</td>
</tr>
<tr>
<td>Train station no. 10</td>
<td>2*</td>
<td>445,120</td>
<td></td>
</tr>
<tr>
<td>Train station no. 11</td>
<td>2*</td>
<td>391,920</td>
<td></td>
</tr>
<tr>
<td>Train station no. 12</td>
<td>3*</td>
<td>179,560</td>
<td></td>
</tr>
<tr>
<td>Train station no. 13</td>
<td>2*</td>
<td>1,411,360</td>
<td></td>
</tr>
<tr>
<td>Train station no. 14</td>
<td>3*</td>
<td>189,560</td>
<td></td>
</tr>
<tr>
<td>Train station no. 15</td>
<td>2*</td>
<td>360,440</td>
<td></td>
</tr>
<tr>
<td>Train station no. 16</td>
<td>3*</td>
<td>184,560</td>
<td></td>
</tr>
<tr>
<td>Train station no. 17</td>
<td>2*</td>
<td>358,270</td>
<td></td>
</tr>
<tr>
<td>Train station no. 18</td>
<td>2*</td>
<td>1,422,220</td>
<td></td>
</tr>
</tbody>
</table>

Because of a large number of input parameters, the prognostic model development process was divided into two parts. In the first part of the process, the input parameters were based on the data related to the number of tracks on the railway, the length of the railway/rail section passing through a station, the length of the newly constructed rail section, the length of the...
### Table 5. Input data for the first part of the process

<table>
<thead>
<tr>
<th>Number of railway/rail section</th>
<th>Length of railway/rail section [km]</th>
<th>Single-track/double-track railway/rail section</th>
<th>Length of railway/rail section [%] which passes through a station</th>
<th>Newly constructed</th>
<th>Being reconstructed</th>
<th>Length of railway/rail section [%] which passes through geologically favourable terrain</th>
<th>Conditionally favourable terrain</th>
<th>Conditionally unfavourable terrain</th>
<th>State of the electric power plants (score*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4.6</td>
<td>1</td>
<td>6.30</td>
<td>0</td>
<td>100</td>
<td>78.26</td>
<td>21.74</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>20.75</td>
<td>1</td>
<td>0.0</td>
<td>100</td>
<td>0</td>
<td>49.88</td>
<td>50.12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>21.97</td>
<td>1</td>
<td>0.0</td>
<td>100</td>
<td>0</td>
<td>47.11</td>
<td>52.89</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10.22</td>
<td>2</td>
<td>0.0</td>
<td>100</td>
<td>0</td>
<td>8.90</td>
<td>88.45</td>
<td>3.62</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>6.8</td>
<td>2</td>
<td>14.27</td>
<td>33.24</td>
<td>65.44</td>
<td>13.24</td>
<td>86.77</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>94</td>
<td>2</td>
<td>14.23</td>
<td>76.17</td>
<td>23.83</td>
<td>69.15</td>
<td>24.47</td>
<td>6.38</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>220.49</td>
<td>2</td>
<td>12.20</td>
<td>49.93</td>
<td>49.93</td>
<td>64.29</td>
<td>35.17</td>
<td>0.54</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>155.56</td>
<td>1</td>
<td>12.75</td>
<td>0</td>
<td>100</td>
<td>71.33</td>
<td>27.39</td>
<td>1.31</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>2</td>
<td>0.0</td>
<td>100</td>
<td>0</td>
<td>13.67</td>
<td>86.33</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>41.55</td>
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<td>10.76</td>
<td>38.63</td>
<td>61.37</td>
<td>66.55</td>
<td>33.45</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>169.16</td>
<td>2</td>
<td>16.51</td>
<td>71.27</td>
<td>28.73</td>
<td>55.82</td>
<td>41.43</td>
<td>2.75</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>32.55</td>
<td>1</td>
<td>5.6</td>
<td>0</td>
<td>100</td>
<td>61.91</td>
<td>38.10</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>148.47</td>
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<td>17.0</td>
<td>20.0</td>
<td>100</td>
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<td>70.0</td>
<td>6.0</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
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<td>50.0</td>
<td>14.75</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>17.38</td>
<td>1</td>
<td>7.54</td>
<td>0</td>
<td>100</td>
<td>31.0</td>
<td>70.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>76.07</td>
<td>2</td>
<td>12.0</td>
<td>50.0</td>
<td>50.0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

*(0 - rail not electrified, 1 - satisfactory, 2 - partly satisfactory, 3 - unsatisfactory in terms of reliability, availability, maintainability and safety)*

### Table 6. Data on the length of structures along the railway (rail section) route

<table>
<thead>
<tr>
<th>Number of railway/rail section</th>
<th>Length of concrete bridges [%]</th>
<th>Length of steel bridges [%]</th>
<th>Length of underpasses [%]</th>
<th>Length of overpasses [%]</th>
<th>Length of galleries/retaining walls [%]</th>
<th>Length of viaducts [%]</th>
<th>Length of single-track tunnel [%]</th>
<th>Number of structures with investment rating *</th>
<th>Number of structures with investment rating **</th>
<th>Number of structures with investment rating ***</th>
<th>Number of structures with investment rating ****</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>3.16</td>
<td>0.41</td>
<td>0.70</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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</tr>
<tr>
<td>6</td>
<td>1.70</td>
<td>0.14</td>
<td>1.72</td>
<td>0</td>
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<td>2.47</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0.77</td>
<td>0.97</td>
<td>2.44</td>
<td>5.40</td>
<td>0.44</td>
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<td>4.64</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0.26</td>
<td>0.80</td>
<td>0.11</td>
<td>3.18</td>
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<td>12</td>
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<td>2</td>
</tr>
<tr>
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rail section under reconstruction, the engineering and geological
characteristics of the terrain through which the railway passes,
and the condition of the electric power infrastructure in the
railway corridor (Table 5). In the second part, the input parameters
used were the data related to the length of structures along the
railway/rail section and the number of architectural structures
in stations with their investment value (Table 6).
Output parameters are the investment value for groups of
works and the total investment cost for reconstruction of the
railway/railway section.

2.1.2. Establishment of network architecture

In the process of forming the neural network architecture, it was
concluded based on experience and available literature that the
best results are offered by networks with a back propagation
algorithm [15, 16]. The type of network was not varied since
it has been shown that these networks have an optimum
performance for prediction problems [17-19].
The process of finding an optimum neural network structure
is based on the testing of different structures using the same
data set. The testing involves varying the number of layers and
number of neurons in the network. The process of determining
the quality of the network structure, after the network training
process, is based on determining the size of error in output
results. The Levenberg-Marquardt algorithm [20] was used
in the phase of finding an optimum neural network structure.
It was established that, due to a small number of samples, a
network of 3 layers (1 hidden) offers the best results for the
given combination of input data. Choosing a network with one
hidden layer reduces the possibility of over-fitting. An optimal
number of 15 neurons was determined for the middle layer by
varying the number of neurons, on the basis of the smallest error
at the output. The hyperbolic tangent sigmoid transfer function
was used for this network within the hidden layers, except for
neurons in the output layers, where the linear transfer function
was used. When solving the problem of prediction, input
variables were grouped based on experience, without losing the
quality of the input information. Because of the small sample
size, no analysis of key components was carried out (PCA) so as
to determine linear dependence between input parameters. The
architecture of the prognostic model is shown in Figure 1.

2.1.3. Discussion of results

A database of nineteen completed projects was formed while
researching the applicability of artificial neural networks for
predicting investment value of railway line reconstruction. The
database contains information on the works planned for the
reconstruction project: technical information (obtained from
previous projects and analyses of the existing characteristics
of tracks – based on measurement and monitoring results) and
the data on the planned investment value of works for each
section of the line being reconstructed.
Neural networks were applied to the given problem using the
Matlab R2007b software package. Sixteen projects were used
for training the network, and the remaining three projects were
used to check prognostic models. The input mostly included
condition-related parameters obtained from analysis of the
existing characteristics of the lines, while investment values
(total and for groups of works) were used as the output. A three-
layered neural network with back-propagation was selected for
training. At the beginning of the training process, there was a big
difference between the prognostic value and the planned project
value. In cases where large differences
occurred, the weight coefficients were
adjusted based on recommendations
from other published research [21]. After
completion of the training, the results
generated by the network were more
accurate. Finally, to check the quality and
accuracy of the network, a control of the
prognostic model was carried out.
Control of the prognostic model was
performed on the set that was not used
for training (railway/rail sections A, B,
and C). The deviation (error) between the
planned and prognostic values was used
for the analysis of results. Deviations of
predicted investment values, obtained
using the prognostic model of investment
values for the reconstruction project, are
shown in Table 7. Lines 1 - 12 (Table
7) show deviation of the investment
value per groups of works according to
the prognostic model, as related to the

Figure 1. Network architecture of prognostic model
investment value per groups of works according to the project, expressed as a percentage. Line 13 shows deviation of the total investment value for the reconstruction and modernization of railways/rail sections according to the prognostic model, as compared to the total investment value for the project as a percentage.

Negative values in the table indicate that the projected investment value of the works was less than the actual investment value of the project.

By analysing the data presented in Table 7, it was concluded that the deviation of the prognostic model from the values obtained in the project for the total investment in reconstruction and modernization of railways ranges from -2.20 % (project C) to 1.38 % (project A). The average value of deviation of the prognostic model from the investment value given in the project is -0.43 %.

A large deviation of the prognostic model from the values obtained in the project appeared in the section for preliminary works (54.21 %) for project A. This is due to the fact that the data used for training anticipated significant costs for preliminary works (clearing the terrain), while in fact the reconstruction works for project A were carried out on the already prepared railway land.

Other large deviations of the prognostic model (15.56 %) from the actual project values were noted for hydrotechnical works in project C. In this case, significant deviations occurred as there are no complex climatic, hydrological and hydrographical conditions in the project C corridor.

For project C significant deviations of the prognostic model from the investment values obtained in the project also occurred for groups of works for roads along the railway route, road crossings and station squares (14.33 %) and other works (17.87 %).
based on decay parameter models and are a compilation of rules that are applied at different railways in Europe. In addition to the above mentioned systems, various modern operation research methods can also be used for estimating the investment value. The development of the programming and computation concept called "soft computing" has enabled the use of artificial neural networks. Therefore, a research on the use of artificial neural networks for estimating investment values related to railway reconstruction was conducted in this paper. The analysis and establishment of an optimum network for prediction of reconstruction activities, based on the database containing information from nineteen already realised reconstruction projects, is also presented. It was concluded that, for the database under study, the best investment prediction results are offered by a network featuring back error propagation with three layers, as combined with the Levenberg – Marquardt training algorithm. This prognostic model shows that neural networks can be used for estimating investment value of railway line reconstruction projects. The model can be applied for rough and rapid investment value estimations, with a reliability of 80 – 85 % for cases in which some input parameters are unknown. More accurate investment value estimations can be made by including a greater number of input parameters describing the requirements, and by expanding the database of completed rail infrastructure projects.

The application of this model greatly contributes to formulation of a new approach to solving the problem of estimating investment value of railway line reconstruction activities, with the goal of making efficient decisions on investment in rail infrastructure projects.

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