SIMULATION STUDY OF TATRA ELECTRIC RAILWAY POSSIBLE RECONSTRUCTION

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Abstract

The future development of tourism in High Tatras area is affected by the development of the transportation infrastructure. The Tatra Electric Railways (TEŽ) are important component of it. This autonomous railway system exists in the current state since 1970. Some modernization measures in this area are needed to satisfy demands of passengers in 21st century. This paper describes several scenarios for traffic and constructional changes of TEŽ and introduces application of Villon simulation tool to validate all aspects of the scenarios.

Keywords: railway transportation simulation, Tatra Electric Railways.

Presenting Author's biography

Peter Márton. Graduated in Operation and Economy of Railway Transport at the University of Žilina, dissertation at University of Žilina in 2004. Since 2002 lecturer at Faculty of Management Science and Informatics, University of Žilina. Specializing in operation of freight railway transport, co-author of simulation tools of transportation terminals operation and several simulation studies on railway transport in Slovakia, Germany, Switzerland and China. Member of International Association of Railway Operations Research and Transport Section of Slovak Scientific and Technological Society.

1 Introduction

The Tatra Electric Railways (Tatranské elektrické železnice - TEŽ) is an electrified (1500 V DC) single track narrow gauge (1000 mm) railway system in the Slovak part of the Tatra mountains. It consists of two parts (Fig. 1):

- Poprad - Starý Smokovec - Štrbské Pleso (29,1 km)
- Starý Smokovec - Tatranská Lomnica (5,9 km)

After the completion of the Košice - Bohumín Railway in 1871 and of Poprad - Kežmarok Railway in 1892, travelling to the High Tatras region became easier. Number of spa visitors and tourists expanded. This increased the demand for accessibility of Tatras resorts and villages.

In the beginning of the 20th century, a private company T.V.V. (Tatrafuredi erdeki villamos vasut) decided to build an electrified, narrow gauge railway from Poprad to Starý Smokovec. Construction started in 1906 and the track was opened in 1908. The section from Starý Smokovec to Tatranská Lomnica was opened in 1911. Finally, the line section from Starý Smokovec to Štrbské Pleso was opened in 1912. At that time, the railway was used for passenger as well as for cargo transport. In 1948, the railway was nationalized. In the second half of the 1960 decade, the railway underwent major reconstruction in the frame of preparations for the FIS Nordic World Ski Championships in 1970 and since 1970 only a passenger service has been provided. At the beginning of the 21st century, the old trains built by ČKD in the end of 1960 decade were replaced by new Stadler GTW railcars (ŽSSK Class 425) [1].

Layout of the TEŽ responds to the standards and requirements of beginning of the 20th century. Railway was built in broken topography without tunnels and long bridges to minimize construction costs. This layout is characterized by a lot of curves. During reconstruction in 1970, only track superstructure was changed, because of the TANAP (Tatras Natural Park) protection rules.

In the last two decades, growing number of tourists use their own cars to arrive to the High Tatras area. One of several reasons is unattractive public transportation system. The TEŽ creates backbone of this system.

Almost 6 years passed since the windstorm calamity in November 2004 that paralyzed all High Tatras transportation system. Besides a lot of negatives a new chance to modify the TEŽ layout was offered. Unfortunately, until today, different proposals how to improve and modify the TEŽ layout were only discussed and not realized. There are different interest groups and different proposals that take part in this discussion. This discussion is realized only on a theoretical level without any relevant arguments and results and without any feasibility study.

Main aim of our research is to prepare relevant expert arguments for a new level on discussion of the future development of the TEŽ that should be started in near future.

2 Scenarios of TEŽ operation re-design

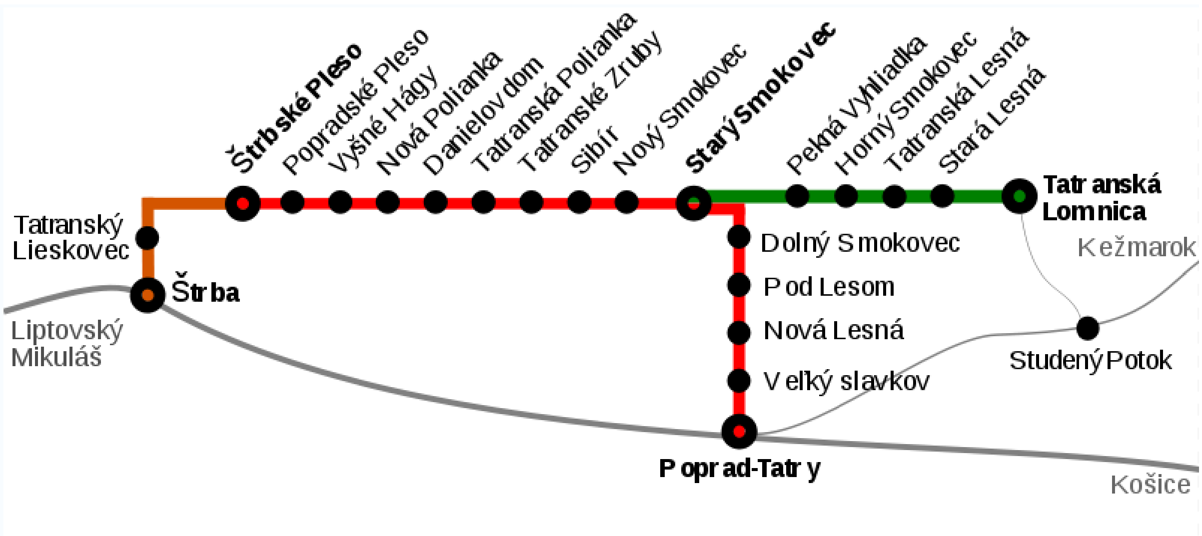
Improvement of operation of any railway system [4] can be achieved through interventions in three main areas:

- operation control,
- construction works,
- signalling and interlocking system.

Trains of TEŽ are slower than passenger vehicles or buses. So the possibility to speed up TEŽ-trains is one of the questions that are often discussed. Possibilities how to achieve faster TEŽ-trains exist.

As we mentioned in the introduction, new electric motor units (EMUs) are in operation. Maximum construction vehicle speed of new EMUs is 80 km/h. But an actual maximum speed permitted by timetable is 60 km/h. Maximum vehicle speed of EMUs is not used in some line segments because of different reasons (e.g. residential area, unprotected railway

Fig. 1 TEŽ network



crossing). This improving measure pertain results to the first scenario of TEŽ operation re-design.

Maximum vehicle speed could be possibly exploited in additional line segments if some of their construction properties were adapted be done. This improving measure pertains to the second scenario.

First and second scenarios have a common attribute - the total length of TEŽ lines remains unchanged compared with the actual situation. In the third scenario we investigate improved TEŽ lines topography. Some line curves were straightened. Valley-side line segments were replaced by bridges in this scenario.

Shortening of travel time is the main impact of all measures tested in the three scenarios. It brings a demand for the modification of actual timetable. We believe that timetable modifications are one of possible measures to improve attractiveness of railway transport for tourists in High Tatras. Another important measure is to put a new centralized traffic control into operation. This measure can bring some travel time savings too. Not negligible effect of this measure are personal costs savings. This measure was reflected is all three scenarios.

3 Nature of modeled system

Operation of TEŽ railway system is simple, compared with standard gauge railway systems. TEŽ railway system is autonomous and independent of standard gauge lines. Both systems meet in stations Poprad and Studený Potok. TEŽ railway system is also independent of the rack railway Štrba - Štrbské Pleso. Independence of TEŽ railway system means that delays of standard gauge trains and rack railway have no negative impact on TEŽ trains running. All passenger trains use the same construction type of EMUs. It means that running times of all trains in specific line segments are equal. Therefore, trains delays occurrence can be neglected in simulation study objective.

Modeled system was understood as deterministic system in this sense. All processes of modeled systems can be described using discrete event-oriented simulation.

4 Tool used for scenarios evaluation

Computer simulation is one of possible instruments that can be used to evaluate the scenarios. We used the simulation model of TEŽ as a laboratory to study and recognize all effects of measures suggested in the three mentioned scenarios.

There are numerous simulation tools that can be used for railway traffic simulation. We decided to use our "own" simulation tool Villon. This simulation tool was developed at the Simcon Ltd. (Slovakia) [2] in cooperation with the University of Žilina (Slovakia).

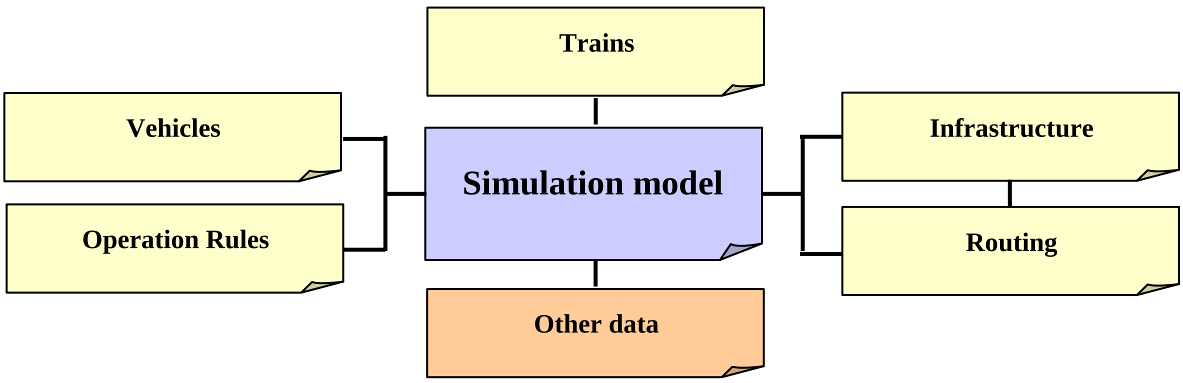
4.1 Villon simulation tool

The simulation tool Villon allows users (professionals in the field of transportation) to create simulation models of transportation terminals, to run prepared scenarios as well as to evaluate results of simulation runs, all without the need to write a single line of program code – utilizing only Villon's interface. The creation of complex simulation models of logistic systems, of course, requires a certain level of experience and knowledge. However, using the Villon simulation tool, even a less experienced user is able to create simulation models of simple logistic systems within a short period of time (few days). Villon provides the user with comfortable user-friendly editors to edit all needed data to run a simulation model, supports customisation of many aspects of simulation runs, offers animated output of modelled activities in 2D or 3D view as well as extensive set of post-run evaluation tools (including statistics, graphical protocols and others) [3].

5 Simulation models of scenarios and its specifications

We created four simulation models in all. The first simulation model was used as a base for evaluation of scenarios measures impact. Other three simulation models were created, each for one scenario.

Fig. 2 Input data structure



Input data had paper and electronic form. Input data for all simulation models gathered information about:

- infrastructure - attributes of line segments between stations, attributes of station tracks and points
- vehicles - attributes of EMUs
- timetable - attributes of trains running

Layout of TEŽ was taken from paper plan of High Tatra region in scale 1:5000. This paper plan was scanned and vectorized. Result of vectorization was a diagram of nodes and edges. Edges represent parts of line segments, station tracks and points. Edges in this diagram have only two attribute - their length and radius. Attributes of diagram nodes were x and y ordinates. Routing of TEŽ in simulation model would not be accurate enough when using only this diagram with the above mentioned attributes of nodes and edges. It was necessary to define additional attributes which are needed for running times calculation - slopes, speed limits, etc. Editing of TEŽ layout took a fifth part of a time of the basic simulation model development. This part of model development was difficult and required a lot of manual definition. So called physical infrastructure of model was completed by after this part of model development.

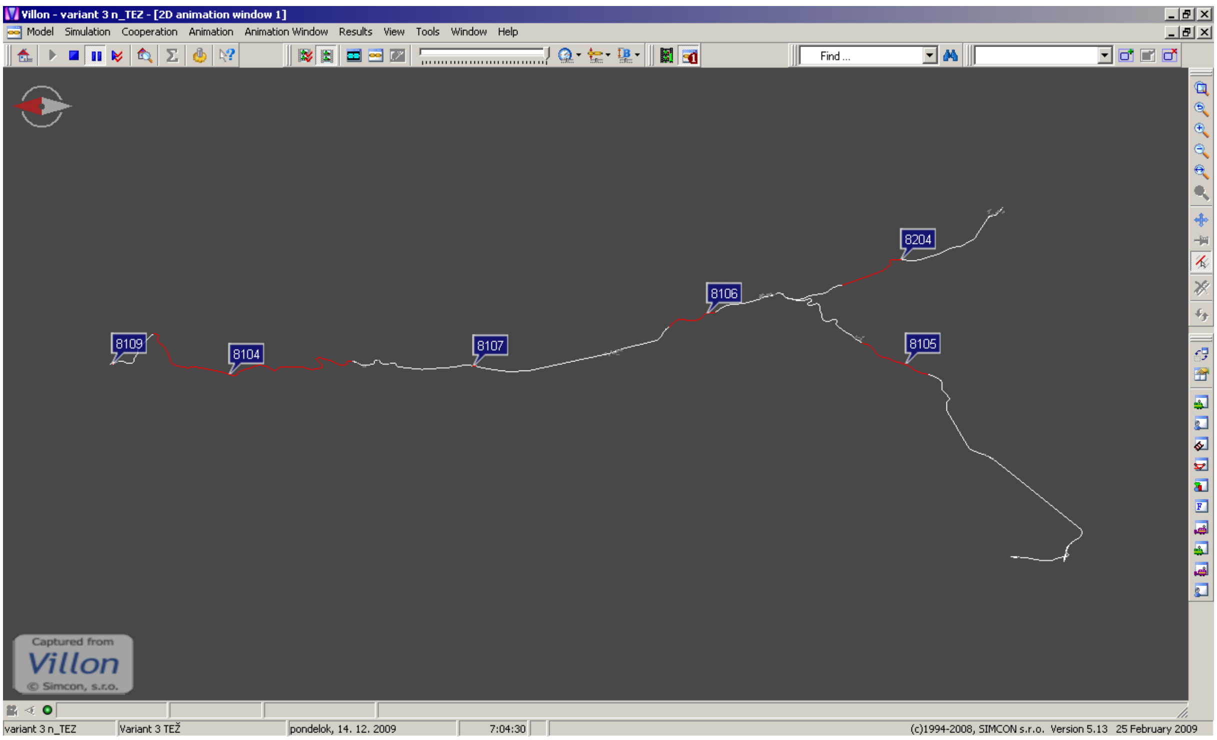
Development of so called logical infrastructure in Villon simulation tool environment is necessary to define trains running in a model. It consists of defining of new attributes of infrastructure diagram edges. These attributes are called "track profession". Track profession is information about diagram edge role in the process of trains running. TEŽ layout consists of many line segments and several small stations with two or three station track. So logical infrastructure development took a fraction of time which was needed for physical infrastructure definition. One of defined and assigned track profession was "line segment" profession. Another profession was "EMUs service center track".

Trains running in railway operation are based on fixed standards. Selection and occupation of line segments and station is not stochastic. It was necessary to define fixed rules for trains running directly in model (e.g. each train arriving to station A from direction B can use only station track XY). Definition of these rules was the last step in TEŽ layout development and closed the definition of the simulation model.

Data about vehicles are important from several points of view. Particularity of TEŽ railway system is that only one vehicle construction type is in operation. Definition of this part of simulation model was than definition of simulation models of standard gauge railway systems. Common information about length, weight and number of axles were used. Traction force diagram was defined as important vehicle attribute to enable calculation of train running times. Data about vehicles were in paper form originally.

Timetable data are last but not least important part of simulation model of TEŽ. Timetable data defined in simulation model are based on EMU's circulation plans and timetable tables. It was necessary to input all this information manually to the model, although the data was available in an electronic form. It was necessary because of Villon tool supports mainly freight trains attributes import mainly. Passenger trains have their specific attributes.

Fig. 3 Animation view of the TEŽ network



Timetable data includes information about EMUs departure from service center in Poprad, time positions in each stop and station during route, number of EMUs used per train, instructions for trains operation. Instructions for train operation are special type of information. These instructions are defined as a flowchart. One flowchart represents activities that should be realized during one train existence in simulation model. Activities are represented by edges of this flowchart, e.g. passenger boarding, train running from station A to station B.

6 Scenarios results

6.1 Evaluated output characteristics

We evaluated and compared following output parameters to find differences, advantages or disadvantages of operation simulated in particular scenarios:

- running time between two train stops - for each running direction,
- carrying capacity of line segments.

6.2 Running times

Changes of train speed in all three scenarios affected positively running times. Impact of possible modernization and line route modification is often discussed in different forums. Some experts overestimate potential time savings.
Simulation results showed that running times in scenarios 1 and 2 are not significantly different from actual running times. Running times for scenario 3 are more interesting. Running times in the actual timetable in minutes are in Tab. 1.

Tab. 1 Actual running times

Line, Direction	Running Time
Poprad - Štrbské Pleso	75
Štrbské Pleso - Poprad	65
Starý Smokovec - Tatranská Lomnica	14
Tatranská Lomnica - Starý Smokovec	14

It is necessary to mention that a speed increase in individual line segments do not decrease significantly the total running time in line. TEŽ railway is a single-track system, as was already mentioned in the introduction. It means that although a train arrives earlier to a station, it can leave this station and continue to the next one only in the case that the next line segment is free. So in simulation we have seen often cases that a train from one direction had to wait in station for train from the opposite direction. So contrary to expectation this fact absorbs positive impact of higher speed of EMUs in some line segments in scenarios 1, 2 and 3.

Resulting saves in running times in minutes for every scenario are in Tab. 2.

Tab. 2 Resulting time saves by scenarios

Scenario	Line, Direction	Time Saved
1	Poprad - Štrbské Pleso	6
2	Poprad - Štrbské Pleso	6,5
3	Poprad - Štrbské Pleso	10,5
1	Štrbské Pleso - Poprad	5
2	Štrbské Pleso - Poprad	5
3	Štrbské Pleso - Poprad	9
1	Tatranská Lomnica - Starý Smokovec	1,5
2	Tatranská Lomnica - Starý Smokovec	1,5
1	Starý Smokovec - Tatranská Lomnica	3
2	Starý Smokovec - Tatranská Lomnica	3

6.3 Carrying capacity of a line segments

Larger carrying capacity could be an important indicator for timetable construction in future. Measures proposed in the frame of scenario 3 have high potential to increase carrying capacity. Greater carrying capacity means chance to increase number of offered trains for passengers. Actual basic space between two trains is one hour in the TEŽ network. Tab. 3 shows percentage increase of carrying capacity of all line segments line in Scenario 3.

Tab. 3 Percentage increase of carrying capacity of a line segments

Line segment	Increase
Poprad - Veľký Slavkov	43,18
Veľký Slavkov - Pod Lesom	5,49
Pod Lesom - Starý Smokovec	7,59
Starý Smokovec - Tatranská Polianka	19,71
Tatranská Polianka - Vyšné Hágy	41,82
Vyšné Hágy - Štrbské Pleso	6,00
Starý Smokovec - Tatranská Lomnica	10,87

Increase of carrying capacity is clear in line segments with proposed topography improvement, curves straightening and replacing of the valley-side line segments by bridges.

Line segments are not autonomous entities and carrying capacity of one segment affects carrying capacity of another one. Again, as was already mentioned by evaluation of shortening of running times, impact to the total carrying capacity is not so clear. Comparison of number of trains in base simulation model (actual timetable) and all scenarios is shown in Tab. 4.

Tab. 4 Number of trains in TEŽ network by base simulation model and all scenarios

Line	Base	S 1	S 2	S 3
Poprad - Štrbské Pleso	49	50	50	53

7 Conclusion

We developed simulation model of TEŽ system to explore possible impacts of the modification of TEŽ lines routing and running times shortening by exploitation of maximum technical speed of EMUs used in TEŽ.

We evaluated the most important output parameters:

- running times on line segments,
- total running time,
- carrying capacity on line segments,
- total carrying capacity.

Results of scenarios showed positive impact of mentioned measures for individual line segments. Despite of it, the total result is not so clear, because of single-track lines of TEŽ system. Gains in running times and capacity cannot be fully utilized because of obligatory waiting for free line segment.

One possible solution of this problem could be proposal of new location of some stations to change time of passing of trains from opposite directions and shorten necessary waiting. We suppose that evaluation of this problem and its solution could be an interesting topic of our next experiments.

8 References

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