CETRA[2012]

2nd International Conference on Road and Rail Infrastructure

7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

ORGANISATION

CHAIRMEN

Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering
Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Ronald Blab, Vienna University of Technology, Austria
Prof. Vesna Dragčević, University of Zagreb, Croatia
Prof. Nenad Gucunski, Rutgers University, USA
Prof. Željko Korlaet, University of Zagreb, Croatia
Prof. Zoran Krakutovski, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. Stjepan Lakušić, University of Zagreb, Croatia
Prof. Dirk Lauwers, Ghent University, Belgium
Prof. Giovanni Longo, University of Trieste, Italy
Prof. Janusz Madejski, Silesian University of Technology, Poland
Prof. Jan Mandula, Technical University of Kosice, Slovakia
Prof. Nencho Nenov, University of Transport in Sofia, Bulgaria
Prof. Athanassios Nikolaides, Aristotle University of Thessaloniki, Greece
Prof. Otto Plašek, Brno University of Technology, Czech Republic
Prof. Christos Pyrgidis, Aristotle University of Thessaloniki, Greece
Prof. Carmen Racanel, Technical University of Bucharest, Romania
Prof. Stefano Ricci, University of Rome, Italy
Prof. Tatjana Rukavina, University of Zagreb, Croatia
Prof. Mirjana Tomičić–Torlaković, Univiversity of Belgrade, Serbia
Prof. Brigita Salaiova, Technical University of Kosice, Slovakia
Prof. Peter Veit, Graz University of Technology, Austria
Prof. Marijan Žura, University of Ljubljana, Slovenia

CAPACITY VS. RELIABILITY IN RAILWAYS: A STOCHASTIC MICRO–SIMULATION APPROACH

Giovanni Longo, Giorgio Medeossi
University of Trieste, Dept. of Civil Engineering and Architecture, Italy

Abstract

Railway transport is increasing its strategic role at urban, national and international level both for passenger and freight mobility. In fact, road traffic congestion causes decreasing levels of service and railways can become more and more reliable thanks to recent investments in infrastructures and technology. In recent years, the unexpected economic crisis is forcing planners to find less expensive and easier to build measures, which effectiveness has to be demonstrated before being approved.
As a result, quantitative methods have to be used, which allow a precise capacity estimation, also considering different timetable scenarios, interlocking systems and infrastructure layouts. Moreover, since a high traffic reliability level has to be offered, the effects of increasing traffic on punctuality have to be taken into consideration while estimating capacity.
In this paper a methodology is presented, one which allows a precise estimation of the trade–off between capacity and reliability on railway networks and identifies the system bottlenecks. This methodology is based on stochastic micro–simulation of rail traffic, which has been calibrated using extensive real life data. The successful results obtained using the methodology in important sections of two Pan–European corridors are described and discussed in the second part of the paper. The first case study deals with the network between Trieste and Venice, on the Corridors N.5 and 23; it plays a crucial role at a continental level, since it represents the connection between Italy and all countries of Central and Eastern Europe. The second application focuses on the Croatian part of the x Corridor (Dobova–Zagreb–Tovarnik), which connects Germany and Austria with the Balkan Area.

Keywords: Railway capacity, timetable reliability, stochastic simulation

1 Introduction

An efficient train operation is a primary success factor for all infrastructure managers, since it allows operating a higher number of trains without significant infrastructure investments.
As is known, a trade–off exists between capacity and punctuality, forcing planners to find an equilibrium allowing the highest number of slots to be operated with satisfying punctuality indicators. This is particularly challenging in nodes, where the combination of different stochastic parameters on various lines and for different trains dramatically increases modelling tasks. In the last years, railway simulators have become a very powerful instrument in support of different steps of the planning process: from the layout design to capacity investigations and offer model validations. More recently, the possibility of an automatic import of infrastructure layouts and timetables widened the application spectrum of micro–simulators to large nodes and to more detailed stochastic stability evaluations.
Stochastic micro–simulators can reproduce most processes involved in rail traffic and comprehend not only its deterministic aspects, but also human factors. This is particularly rele-

vant in order to simulate traffic under realistic conditions, considering variability at border, various driving styles and stop times.
In this paper an approach is presented, in which stochastic micro–simulation is used to represent the relationship between robustness, capacity and a number of other important factors, such as traffic variability or running time supplements. The approach can be used to estimate the buffer times, and the running time supplements to obtain a given reliability level. Since the usable capacity is proportional to the buffer times, the approach leads to a very accurate estimation of the number of trains that could be scheduled on a network to obtain given punctuality levels.

2 Methodology

The calibrated model can be used to represent relationship between robustness and capacity, considering running time supplements and buffer times. Such evaluation can be made in some steps.
First, the micro–simulation model should be calibrated and validated by using real life data. Then, a dense timetable is constructed, which is realistic in the train mix and services, but where no buffer time between trains and no running time supplements exist. In this case, every delay leads to a propagation, which ends only when a gap due to different speed or services can be found in the timetable. A regular–interval timetable is obtained repeating the period for a given number of times.
After that, various timetables can be created adding buffer times and/or running time supplements either distributed or concentrated. Buffer times are added by simply increasing the headway and the resulting cycle time. If train performance rates are increased to their realistic levels, distributed running time supplements are automatically created. Concentrated supplements at final station can be added directly in the timetable.
To test the timetable under different conditions, process time variability functions have to be inserted. Train performance variability can be realistically considered as nearly fixed; therefore, the same parameter set of model calibration can be used. Significantly different driving styles can be supposed only in presence of new driving support systems or other measures, whose effects have to be estimated or inserted in a model.
Stop time variability is defined as a normal function, which increases a minimum stop time. The relationship between the delay and stop time has not yet been evaluated, and therefore is not inserted in the simulation. The definition of initial delay distributions for increasing delay scenarios represents another not well solved question, since no literature can be found, where the correlation between delay and the distribution function has been studied. Moreover, different fit results have been obtained, depending on the country and the case study.
The block diagram of the approach is presented in Figure 1.

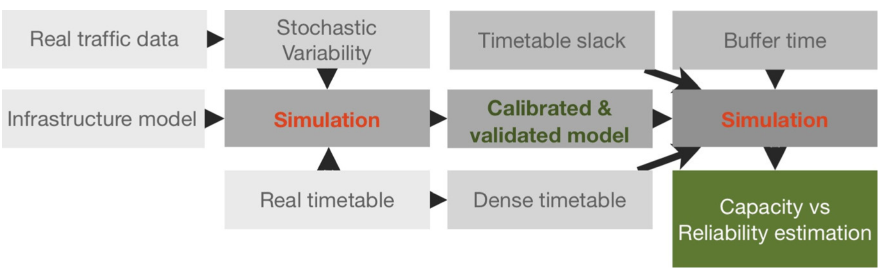

Figure 1 Block diagram of the approach

3 Case Study: Trieste Venice

The methodology has been tested and validated on the railway network between Trieste and Venice. The Trieste–Venice line is part of the European Corridor N. 5 and connects Slovenia to the most important economic regions in Italy, the ports of Trieste and Venice and the hump yard in Cervignano. Some branch lines are mostly used for regional traffic, while the links with Udine allow a fast connection to Austria for both long distance passenger and freight trains. The line between Trieste and Venice is about 130 km long, with a maximum speed of 150 km/h except for some critical points and different interlocking and safety systems. As a result very inhomogeneous block sections are provided, from about 1.3 to more than 5 kilometres. Moreover, the line is used by regional, Intercity and freight services, with different maximum speed, stops, priority and delay variability while entering the considered network.
The model has been tested and validated comparing the real and simulated reliability indicators (punctuality and mean delay) for each train family and line section. The results of the performed simulations allow a precise representation of the infrastructure usage for each section, and the traffic robustness considering each train category, pointing out bottlenecks or other critical points.

3.1 Results

The described methodology has been applied to the considered network, leading to a series of results.
First some more general results are described, which are then applied to the case study to obtain more useful capacity estimations. Capacity is inversely proportional to buffer times between slots, since these linearly increase headway times. But, increasing buffer times reduces delay propagation very significantly if compared to dense timetables and then marginally decreasing. As a result, by choosing very large buffer times, the robustness increase is less than proportional to the subsequent capacity decrease. The trade–off between capacity and punctuality on the Trieste–Venice line is represented in Figure 2(top–left).

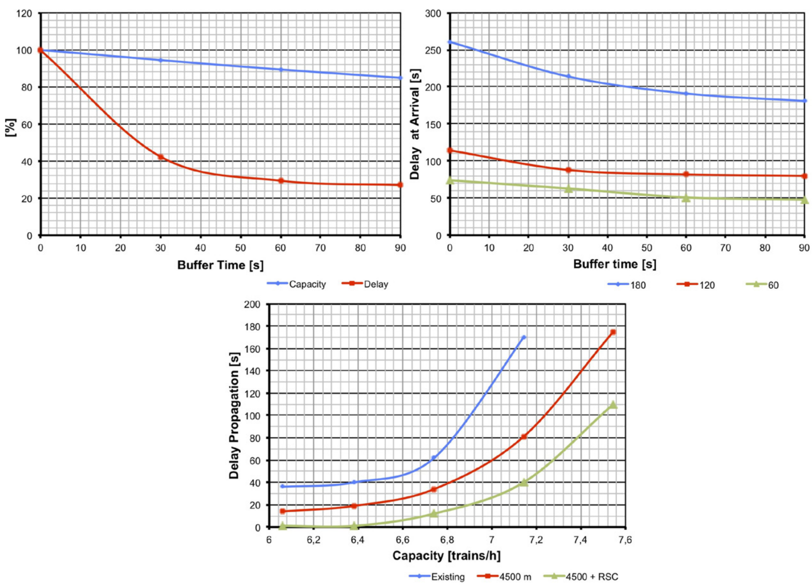

Figure 2 Trade–off between capacity and reliability.

On one side traffic quality is a function of buffer times, on the other buffer times are function of the probability of traffic conflicts (due to train movement variability). In the diagram (Figure 2, top–right) the mean arrival delay as a function of the buffer times and of the mean stochastic delay at train departure are depicted. The diagram clearly shows that the presence of heavy initial delays causes the impossibility to reach high punctuality standards although significant buffer times are inserted. In this case a detailed traffic analysis could point out delay causes and suggest strategies to overcome them. Moreover it can be noticed that a realistic buffer time estimation is impossible without a detailed stochastic phenomena evaluation which could lead to identify variability indicators to be used in the model. These indicators can be considered reliable although new infrastructure layouts or timetables could significantly modify the conditions at the border.

The method has been finally used to assess infrastructure improvement scenarios, obtaining a quantitative evaluation of their impact on both capacity and robustness. In this study the impact of the installation of regular block sections 4500 metres long to supersede the existing variable sections has been evaluated. The simulation shows that this simple interlocking improvement, consisting in the installation of one new block section and on the relocation of other three sections, leads to significant benefits to traffic robustness, allowing an increase of the available capacity (Figure 2, bottom). The reduction of delay propagation due to more regular blocking times allows a more intensive infrastructure usage, although minimal headway times remain nearly unchanged.

4 Case Study: Corridor X Dobova–Zagreb–Tovarnik

The multimodal Pan–European Corridor x will play an important economic and political role for the overall European integration and development as it will link Central and South–East Europe from Salzburg to the port of Thessaloniki.

The Croatian portion of this Pan–European Corridor represents the backbone of railway traffic from east to west on which almost all north–south lines and lines from Bosnia and Herzegovina are connected. Within Croatia, this line connects significant industrial and agricultural areas. As an example, from 1986 to 1990, more than 50% of the total freight traffic passed along this route.

For these reasons, Croatia was considering the modernisation of the Croatian section of Pan–European corridor x that is railway line Savski Marof – Zagreb– Novska – Tovarnik as a priority and therefore has identified it as a possible measure to be financed by pre–accession instruments or structural funds.

The approach for the estimation of capacity and reliability has been applied to the entire line, in order to define a series of punctual improvements that would allow the growing demand for freight slots along the corridor to be met. Differently to the other case study, in this example the reliability level was fixed for all scenarios: therefore, capacity is represented by the maximum number of trains that would reasonably lead to satisfying punctuality when considering realistic departure, running and stop time distributions.

An iterative process was defined, starting from the actual situation and ending with the complete realization of the technical improvements. In particular the following steps were performed at each iteration:

1 Identification through micro–simulation of the system bottlenecks;
2 Selection of set of actions aiming to remove the identified constraints (new scenario) and new identification of the bottlenecks of the modified system;
3 Further selection of set of actions aiming to remove the constraints of the previous scenario (new scenario) and new identification of the bottlenecks of the modified system;
4 This procedure has been cycled until the whole system has been improved to its final configuration.

At each iteration, a dense timetable was first prepared, according to the train mix included within the Master Plan. An increasing amount of buffer times was inserted until the punctuality goal was reached. The critical section was automatically highlighted as that section where the number of trains could not be increased anymore.
The proposed procedure allowed identifying a set of interventions, which are coherent among each other, within the proposed scenario and to the final configuration of the system. The considered interventions may then be considered as a gradual construction of the global design, without money losses. For each scenario the corresponding maximum traffic levels have been estimated and these values have been compared to traffic forecasts in order to predict in which year the scenario would require further improvements.
For example, in the first phase, the critical points are the main station in Zagreb, Dugo S.–Ivanic G. and Lipovljani–Novska sections, on the Dugo Selo–Novska single track line, as well as the Sunja–Novska section on the Sisak–Novska line. To overcome these restrictions the following interventions, leading to a capacity increase of about 30% along the corridor, were proposed:

- New interlocking system in Zagreb Glavni K, including a new layout of the station in order to increase the number of independent movement within the station, thus increasing the capacity for suburban services, with 60 km/h switches. The proposed solution could avoid conflicts between the lines entering the station, producing higher punctuality and timetable stability. The proposed station layout and the new interlocking system are already arranged for the upgrade to a four–track line Savski Marof–Dugo Selo. With the proposed interventions, it is possible to obtain an increase of capacity, a running time reduction (-3 minutes) for all trains thanks to higher line speed and higher timetable robustness.
- Double track on the Dugo Selo–Precec–Ivanic Grad section, which is needed for longer suburban services; Block distance about 1500 m and discrete ETCS Level 1 was adopted.
- Double track on the Novska–Lipovljani section.
- The installation of Interlocking and block system between Novska and Sunja may allow the maximum speed possible on the existing route.
- The realization of a new station in Bliniskj Kut may double the capacity of the Sisak–Sunja section.

Table 1 briefly summarizes the interventions grouped into 4 scenarios, while Table 2 lists the corresponding capacity improvements. The critical sections at each iteration are showed on the simple network layout in Figure 3.

Table 1 Improvement measures proposed in each scenario

SC 1	Zagreb Gl. Double track Dugo Selo–Ivanic Grad Double track Novska–Lipovljani Interlocking Sunja–Novska Station in Bljniskj Kut
SC 2	Double Track Ivanic G–Lipovljani Layout of Dugo Selo Layout of Zagreb Zapadni (60 km/h switches)
SC 3	Four tracks Savski Marof–Dugo Selo
SC 4	Freight Bypass

Table 2 Capacity [trains/day] of each line section and scenario

		0	SC 1	SC 2	SC 3	SC 4
M101	D.G. – Zagreb	240	280	280	400	500
M102	Zagreb G.K. – D.Selo	240	280	280	400	500
M103	D.Selo – Novska	80	110	260	260	260
M105	Novska – Striz./Vrplolje	260	260	260	260	260
M105	Striz./Vrplolje – Vinkovci	260	260	260	260	260
M105	Vinkovci – Tovarnik	96	240	240	240	240
M104	Zagreb G.K. – Sisak	80	96	96	96	96
M104	Sisak – Sunja	40	80	80	80	80
M104	Sunja – Novska	16	48	48	48	48

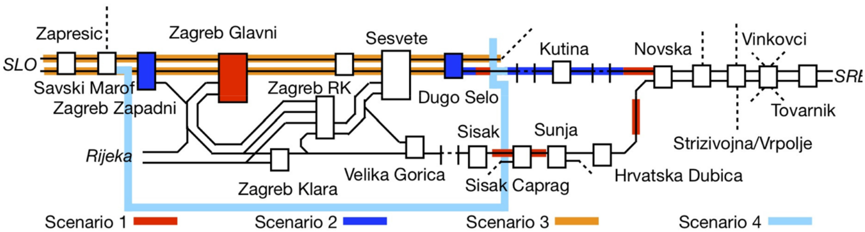

Figure 3 Trade–off between capacity and reliability

5 Conclusions and Outlook

To gain competitiveness in a rapidly changing economic context, railways need efficient and effective improvements, which allow facing strength market conditions. The impact of such improvements has to be precisely evaluated, to allow choosing interventions and combining them in long–term development programs.

The presented methodology and the high detail, possible using micro–simulation models, combined with a precise model calibration, allow a realistic and comprehensive representation of the trade–off between capacity and robustness in order to evaluate timetable or infrastructure scenarios.

The first case study clearly represents the relationship between capacity and reliability, as well as the impact on both of a simple improvement in the block system. The application to the Corridor X demonstrates the applicability of the approach to long–term, gradual improvement studies even on long and complex corridors.

Both the proposed method and its results perfectly correspond to the indications of UIC Leaflet 406 [6]; moreover the method allows a systematic use of its principles, which can lead to more general results. For example, in a given line section UIC capacity is 246 trains/day, while simulation results indicate 260 trains/day as maximal capacity with acceptable delay propagation.

The study will be continued to consider also different interlocking and safety systems; the empirically represented relationships will be fitted in order to obtain their general analytic expression. On the basis of the obtained results new measures will also be proposed, which could better represent the performances of an infrastructure in terms of capacity and reliability and therefore be optimally deployed in multicriteria analysis.

References

[1] de Fabris S., Longo G., Medeossi G. 'Automated analysis of train event recorder data to improve micro-simulation models', In: Allan, J., Hill, R.J., Brebbia, C.A., Sciutto, G., Sone, S. (eds.), Computers in Railways XI, WIT Press, Southampton, 575-583, 2008.

[2] Hansen, I. A., Pachl J. Railway Timetable and Traffic. Eurail press Hamburg, 2008.

[3] Huerlimann, D., 'Object-oriented modelling in railways'; ETH Dissertation Nr. 14281; (in German), 2001

[4] Kaminsky R., Pufferzeiten in Netzen des spurgefuerten Verkehrs in Abhängigkeit von Zugfolge und Infrastruktur. Dissertation, Wissenschaftliche Arbeit Nr 56 des Instituts für Verkehrswesen, Eisenbahnbau und -betrieb der Universität Hannover, Hannover 2001

[5] Medeossi G., 'Capacity and Reliability on railway networks: a simulative approach', PhD Thesis, University of Trieste

[6] UIC leaflet 406 R, Capacity. UIC International Union of Railways, France.

[7] Željezničko Projektno Društvo d.d. (2009) Studija Modernizacije X. Paneuropskog Koridora, HZ Infrastruktura