

## SIMULATION OF RAILWAY OPERATION FOR ESTIMATION OF DEMAND ON RAILWAY INFRASTRUCTURE

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### ABSTRACT

The design of new railway infrastructure is a complex planning process today in most European countries due to several requirements. From an operational point of view new infrastructure basically has to fulfil the requirements defined by the later customers who are the railway undertakings. Hereby passenger traffic is often organised in a periodic timetable with well defined arrival and departure times in the hubs. These time constraints allow to design the graphical timetable which is indicating the minimum design speed. As a rule, the number of required tracks in a section or station can be also taken out of the graphical timetable. A further optimisation can be carried out between available running time reserves or additional infrastructure. Therefore as input data infrastructure layout, rolling stock and timetable are needed. After the simulation the graphical timetable and many other output graphs like speed/distance and energy consumption/distance are delivered to check the proposed infrastructure layout. This paper shows the application of the methodology for the line from Sofia to Dimitrovgrad (SRB).

### 1. Introduction

The design of railway infrastructure is strongly related with the demand of expected traffic which is defined by a timetable. Therefore the timetable is predicting the layout of the infrastructure. Typically the timetable can be displayed in a graphical way which is also used in daily operation. In the graphical timetable all running trains are displayed with their time slots including the blocking time stairway. The time slots are designed by calculation of the technical running times including some supplements. Based upon the graphical timetable it is possible to estimate the demand of infrastructure. So at every location where time slots are crossing each other, there will be the necessity to have at least a second track. Following this

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rule, the number of required tracks is dedicated by the number of crossing time slots in a certain area. Additionally the arrival and departure times can be taken into consideration as a boundary condition which have to be respected especially when an integrated timetable shall be realised. This paper starts with the basic principles of an integrated timetable [1] and shows then how a methodology can be developed to estimate the demand for the infrastructure [2] on the line from Sofia to Dimitrovgrad (SRB).

## 2. The Integrated Timetable

In many European countries an integrated timetable for passenger traffic has been introduced in the last years. The main reason for this implementation is given by the success in passenger transport because passengers are able to easily know the departure and arrival times in the big nodes. Moreover passengers can be sure that there will be a connection train in any destination they are probably interested in. For the design of an integrated timetable it is necessary to define nodes in the network of a railway infrastructure where the frequency of passengers is high. Typically these nodes can be found in larger cities but not only there as also nodes in the railway network where passengers want to exchange between different directions. The infrastructure design of such nodes is shown in figure 1.

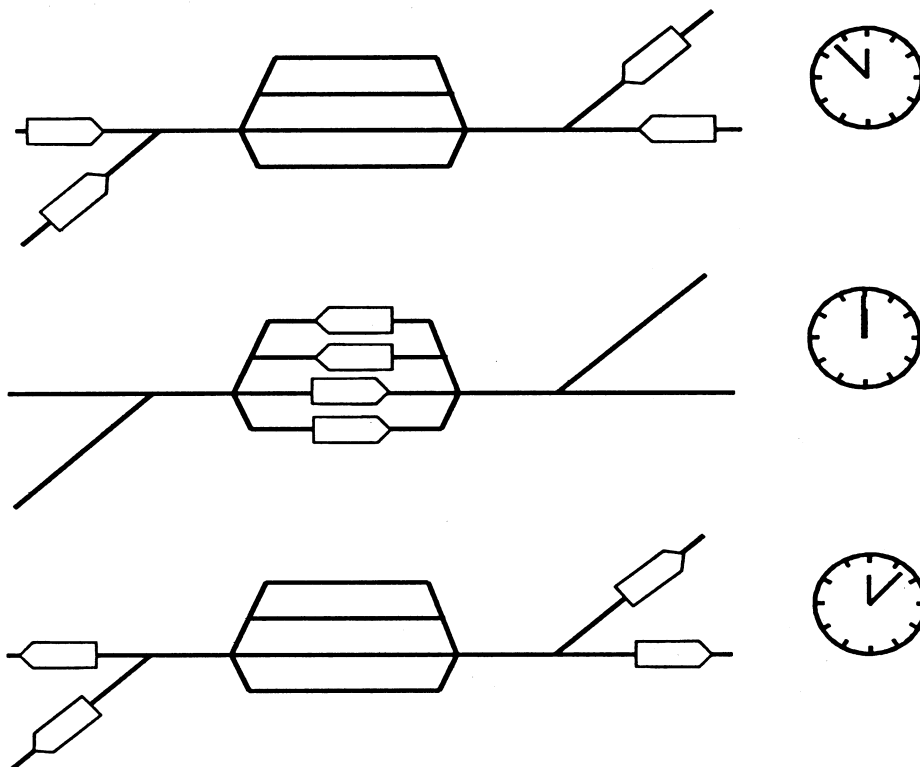


Figure 1. Basic principle of an integrated timetable [1]

Some minutes before the full hour trains from all directions are entering the node. Then there is a certain time for passenger exchange between all the trains. Finally after some minutes all trains leave the node in all available directions. Therefore such nodes have to offer at least so many tracks as trains want to enter. Of course there is the opportunity to share station tracks for even two trains if they just enter the station and then turn back into the direction where they were coming from. Following figure 1 it is simple to understand that four tracks are required when four trains want to enter the node. If they are not passing through the station but only turning back two tracks would be also enough to realise an integrated timetable. If it is required to respect the arrival times, the sections before the node have to be double track sections. Otherwise a short headway time on the entry sections might be enough to cover the boundary conditions.

### 3. Application on methodology for Sofia – Dragoman – Dimitrovgrad (SRB) line

Having once defined the nodes for an integrated timetable in a railway network, the railway lines between the nodes have to be designed in accordance. When having single track lines as a starting point, the demand for crossing opportunities can be simply seen in the graphical timetable.

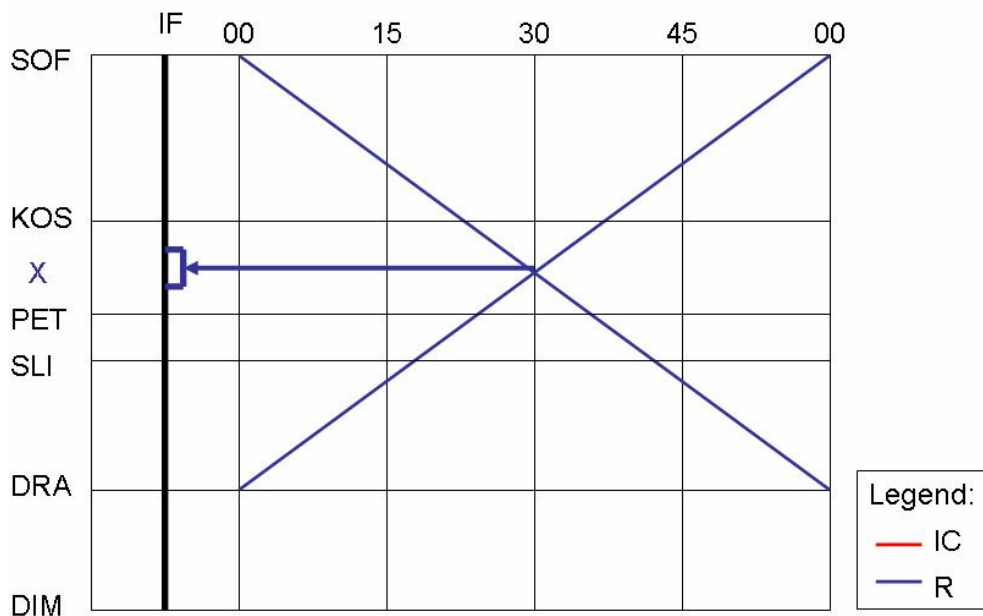
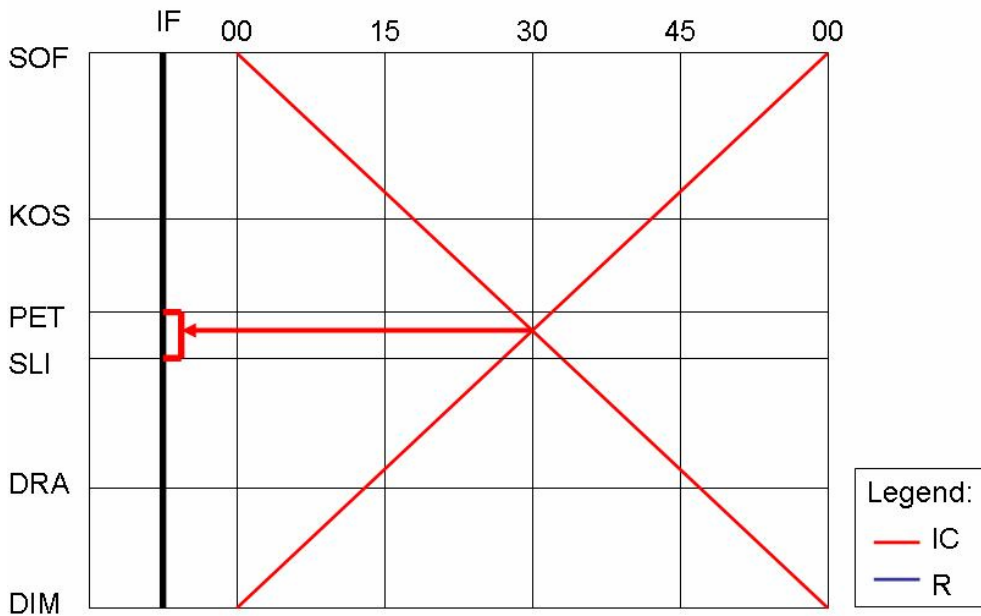


Figure 2. Required minimum infrastructure for regional service

Figure 2 shows the situation when two regional trains with predefined arrival and departure times in the neighbouring nodes (Sofia and Dragoman) want to cross each other on the existing single track line. Taking into consideration the maximum length of the involved trains, the minimum length of the second track can be calculated. Of course, the second track should be available with the track speed to have no restrictions of speed and thereby

additional running time. The crossing opportunity should be located between existing stations of Kostinbrod and Petarc.



**Figure 3.** Required minimum infrastructure for IC service

For an hourly service of the Intercity trains a crossing without any loss of time due to speed restrictions of switches should be enabled between Petarc and Slivnica. As the Intercity trains have less reserve in running time an upgrade of track speed between Petarc and Slivnica would be also required. For the Intercity service it is necessary to shorten the existing running time of 5 minutes to fulfill the integrated timetable. This can be done e.g. by skipping the actual stop at Dragoman or by reducing the running time reserves.

More interesting becomes the situation when in addition to the two trains another two trains at the same time slot have to run on this single track section. This might be the case when two Intercity trains and two local trains have to be operated to have constant intervals both in fast and in slow passenger traffic. If both services have to be operated in the same time slots, a combination of all trains is required to identify the infrastructure layout.

The combination of both services requires an infrastructure which is shown in figure 4. As a generic rule the minimum number of required tracks is defined by the number of time slots in an infrastructure section. Of course this graphical solution has some short comings as train dynamics are not considered in an exact manner but it gives a first impression of the minimum infrastructure layout.

The crossing of Intercity and Regional train should happen close to existing station Petarc without any loss of running time for the Intercity by taking the main track through this double track section. Additionally the Regional service requires a second track from Sofia to Nadezhda to allow parallel entry and leave with the Intercity. For a stable timetable all trains should have at least 5 % in addition to the minimum technical running times. Swiss Railways even prefer higher supplements around 10 % which directly requires more infrastructure

investments. Of course both services should run from early morning till late evening because only then all investments into an upgrade of the infrastructure are economically feasible. The capacity of the trains can be estimated by the potential of inhabitants of all cities covered by each service. Typically more people travel in the near surrounding and only less far.

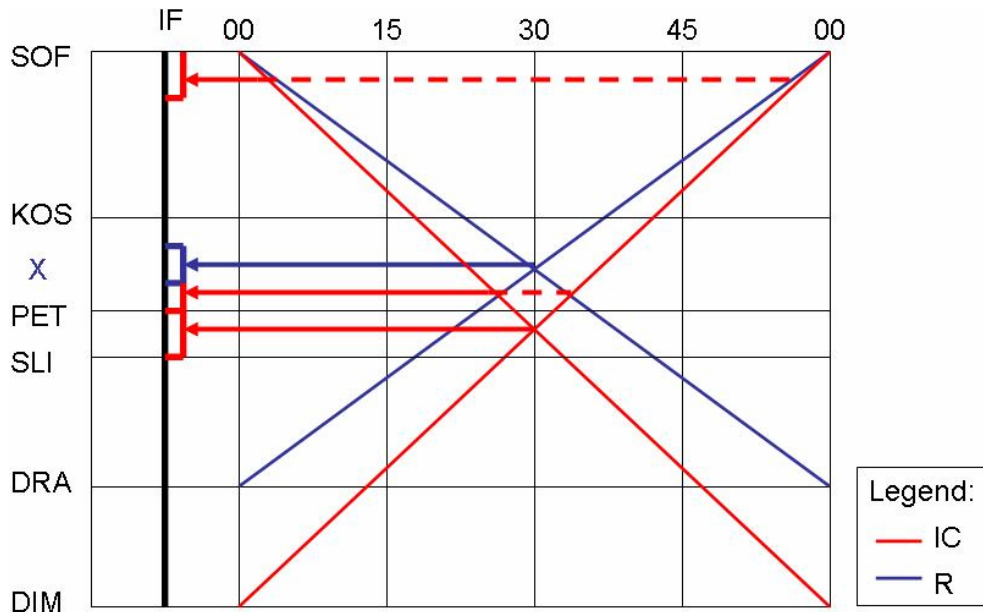


Figure 4. Required minimum infrastructure for IC and regional service

#### 4. Application of simulation of railway operation

To overcome the shortcoming of the proposed graphical solution, any microscopic simulation can be applied to consider train dynamics.

Microscopic simulation models attempt to replicate the actual operation of a railroad over time. They do this by modelling the operation of each individual train during a user-defined time step (often one second) and then repeating the process for the entire simulation period.

Microscopic models consider the impact of trains on each other when they simulate train operations. There are two types of microscopic models: synchronous and asynchronous. Synchronous models simulate all train operations in a single model run while asynchronous models simulate operations in a series of model runs.

In an asynchronous simulation the highest priority trains are modelled in the first run, then this schedule is locked and the second set of trains is modelled; the operation of the second set of trains does not impact the first set of trains, but is impacted by the first set (similarly, the operation of the third set of trains does not impact the first or second sets, and so forth). These types of models are often used for timetable construction since they can replicate ideal operational planning. A good example of this type of program is STRESI developed by RWTH in Aachen.

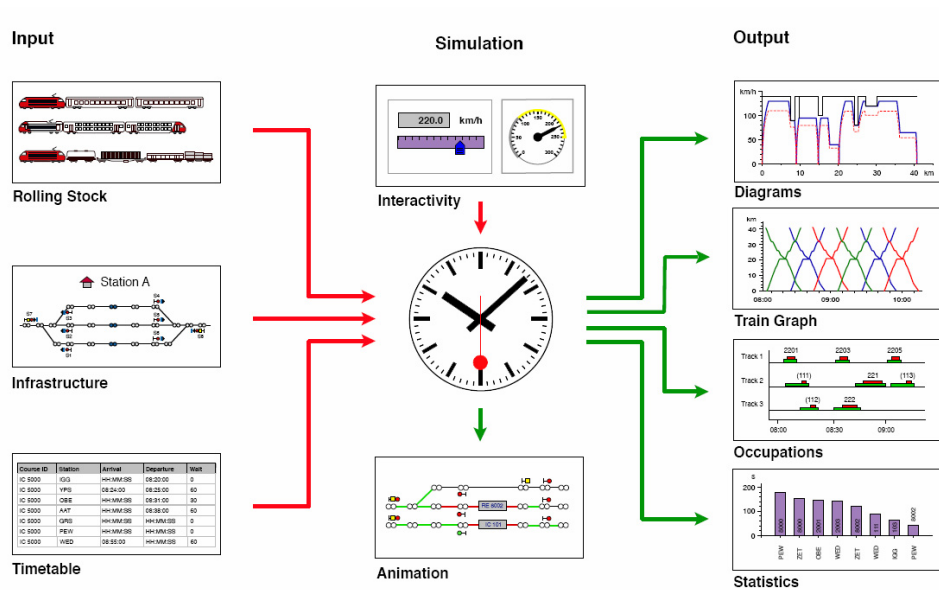


Figure 5. Data flow of an microscopic simulation of railway operation [3]

## 5. Outlook

The described methodology and its application allow an objective discussion of the minimum required infrastructure layout to cover the demand of railway undertakings. Finally the operational required infrastructure layout can be designed from a civil engineering point of view. To meet the requirements of an integrated timetable in terms of arrival and departure times, the design speed of the track layout has to be set. Instead of increasing the speed limits, double track sections might also help to fulfil the timetable requirements. For these tasks the application of simulation of railway operation seems to be a feasible methodology.

## LITERATURE

1. *Pachl J.* Systemtechnik des Schienenverkehrs, Vieweg+Teubner Verlag, 2011, ISBN 978-3-8348-1428-9
2. *Schöbel A., Besau G.* Timetable based design of railway infrastructure, Proceedings of EURO-ZEL 2012, Zilina.
3. *Hürlimann, D.*, Objektorientierte Modellierung von Infrastrukturelementen und Betriebsvorgängen im Eisenbahnwesen, Dissertation at ETH Zürich, 2001.