EURO – ZEL 2012
20th International Symposium
5th – 6th, June 2012, Žilina, SK

TIMETABLE BASED DESIGN OF RAILWAY INFRASTRUCTURE

Andreas Schöbel[1], Gerhard Besau[2]

Summary: 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 designing 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.

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 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 and shows then how a methodology can be developed to estimate the demand for the infrastructure.

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

[1] Vienna University of Technology, Institute of Transportation, Research Centre for Railway Engineering, Karlsplatz 13 / 230-2, +43 1 58801 23211, andreas.schoebel@tuwien.ac.at
[2] ÖBB Infrastructure AG, Praterstern 3, +43 1 93000 35990, gerhard.besau@oebb.at

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. 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.

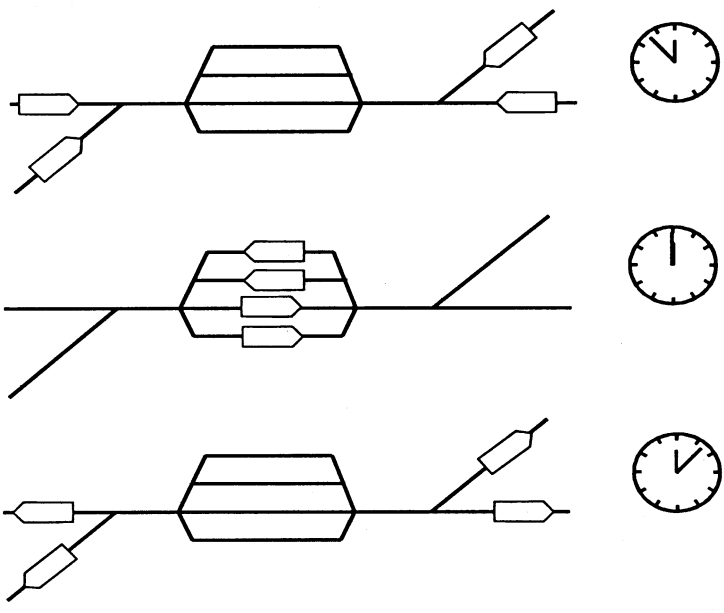

Fig. 1 Basic principle of an integrated timetable [1]

3. Methodology

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 shows the situation when two trains with predefined arrival and departure times in the neighbouring nodes want to cross each other on a 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.

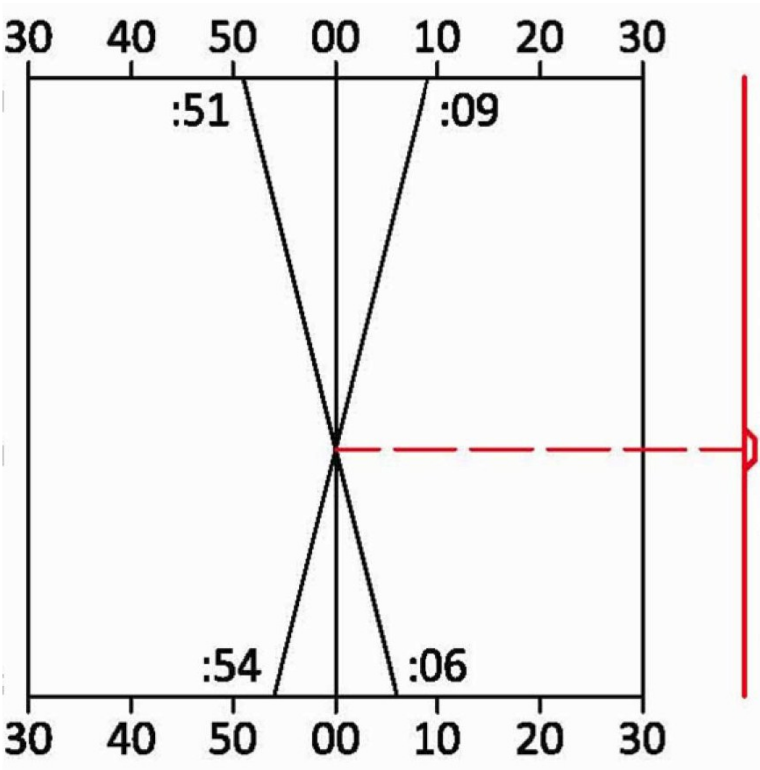

Fig. 2 Graphical timetable and required infrastructure layout

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 fast trains and two local trains have to be operated to have constant intervals both in fast traffic and in slow traffic. For the local trains also another meeting point can be possible defined by different arrival and departure times in the neighbouring nodes. If both services have to be operated in the same time slots, a combination of all trains is required to identify the infrastructure layout.

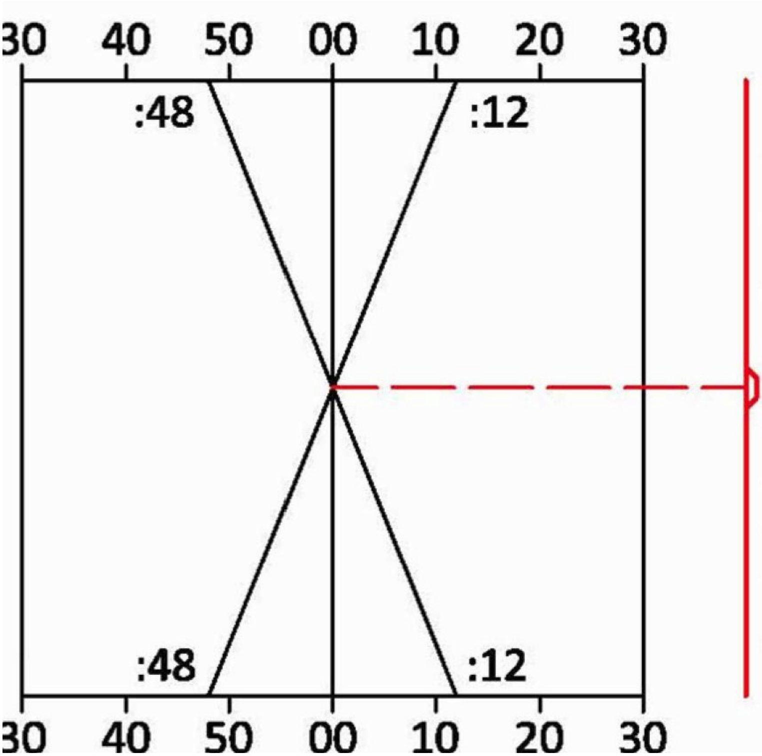

Fig. 3 Graphical timetable for additional trains and their required infrastructure

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.

Fig. 4 Infrastructure layout for combined operation

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.

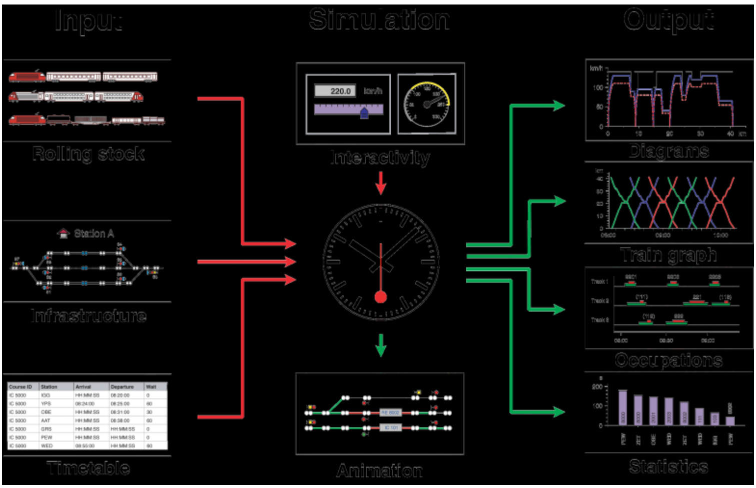

Fig. 5 Data flow of a simulation of railway operation [2]

In contrast, synchronous models simulate all the trains operating in the modelled network at the same time, thus they provide a good way to simulate realistic operating situations (e.g. the impact of train delays on network operations). These models enable users to specify rules that the program uses to make dispatching decisions when there are conflicts between trains. These rules include simple train priorities (e.g. passenger trains before freight trains) as well as more complex rules designed to optimize some particular function (e.g. dynamic overtaking). In essence these models attempt to replicate good dispatching decisions.

5. Results

The application of a microscopic model allows consideration of all relevant items of railway infrastructure as well as rolling stock characteristics. To all train runs a supplement of additional running time can be allocated to compensate the variation of the friction coefficient due to different weather conditions.

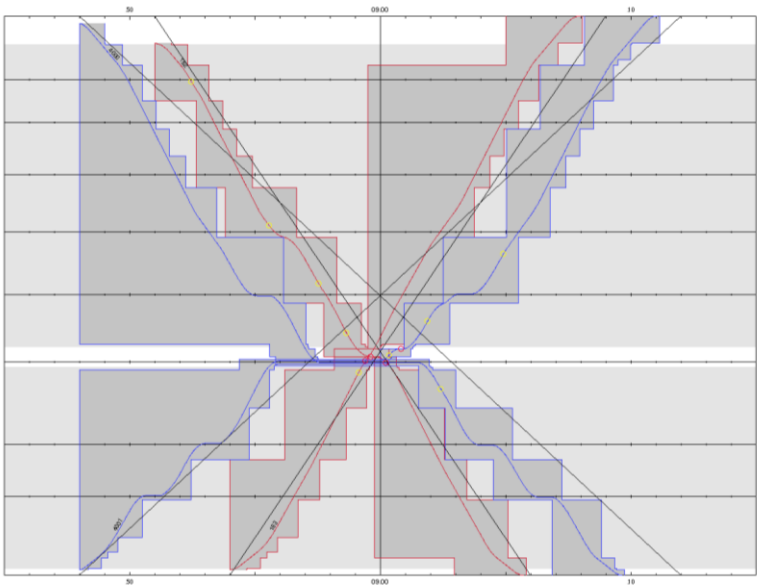

Fig. 6 Graphical timetable from a microscopic simulation

Figure 6 shows the result of a run of the microscopic simulation which is only fulfilling the boundary conditions of arrival and departure times in the neighbouring nodes of the integrated timetable. It has to be noted that some of the stops of the local trains cannot be serviced. On the other hand the required infrastructure layout to run this timetable is quite low. The only challenge is to handle the crossing of four trains in one station area which requires four independent sections for the trains to enter.

Figure 7 gives an indication for the functionality of another infrastructure layout which was previously designed to cover the requirement of having all stops for commuter service. Finally the graphical timetable indicates that this layout is also not fully able to cover all predefined requirements of an integrated timetable. To solve this shortcoming there are as always two opportunities: first is to increase the track speed limit with the existing infrastructure layout, second is to have a double track section in the middle of the section between the both nodes to shorten the running times of the involved trains.

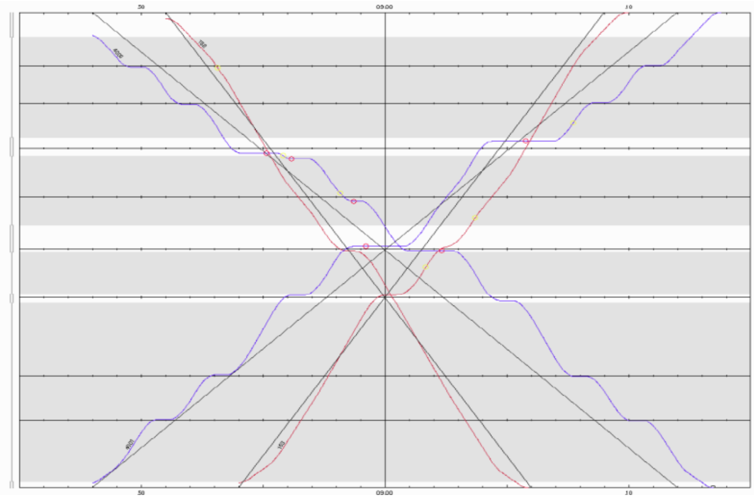

Fig. 7 Graphical timetable for another infrastructure layout

6. Outlook

The results of this paper clearly indicate that it is necessary to run a simulation of railway operation with a microscopic model to cover train dynamics for the estimation of railway infrastructure in accordance to an integrated timetable. The described methodology and its application allow an objective discussion of the infrastructure layout. 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.

References

[1] J. Pachl: Systemtechnik des Schienenverkehrs, Vieweg+Teubner Verlag, 2011, ISBN 978-3-8348- 1428-9

[2] A. Schöbel, D. Semrov: Simulation of Railway Operation under ETCS. ISEP 2012, Ljubljana; in: "Linking people with ITS", CIP, (2012), ISBN: 978-961-6187-50-3.