Simulations of railway junction operation

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Introduction

Nowadays there is paid an essential attention to modernisation and reorganisation of railway companies in the field of freight and passenger traffic with the goal to assure the high level of effectiveness. The railway junctions play very important role within the mentioned process of railway modernisation. There is usually needed to invest into the new technical equipment, to rationalise the work of service resource, to modify railway processes, to react to the changed flows of incoming trains etc. Hence, in order to adopt the essential decisions connected with reengineering of railway junctions it is necessary to study the consequences in advance within the frame of suitable virtual environment. Computer simulation represents an appropriate modelling technique, which enables to study many different variants of the complex system operation.

Railway junctions

Railway junctions are parts of the railway network equipped with expensive technical devices where complex technological processes take place. We can distinguish the following kinds of junctions:

- Marshalling yards
- Stations for passenger transport
- Industrial sidings
- Container terminals
- Port terminals

In order to meet the exacting demands of such systems, a highly efficient management and top-quality administration and coordination decisions are required. Hence, an optimum configuration of infrastructure, maximum exploitation of technical and human resources as well as the use of efficient technological processes are of vital importance.

Simulations as a support for the management

A railway junction is to be managed so that high system performance and process quality on the one hand and minimum infrastructure and operating costs on the other are ensured. This can be achieved in different ways, e.g. by adapting the infrastructure, incorporating new infrastructure elements, using other types of resources, improving resource planning,
changing processing techniques, modifying decision strategies or completely reengineering the system. Of course, all these points are also applied to the configuring of new junctions. The question is now what can be done by the management to take decisions as objectively as possible and to prevent wrong decisions from being made. Owing to the already mentioned complexity of such transportation system and their stochastic behaviour, the application of exact mathematical solutions is very restricted. Classical expert studies do not comprise sufficient objective elements, which would make many decisions easier for the management and could avoid the frequently observed indecision or even aversion to whatever decision. The application of an objective tool, which might also contain elements of exact solutions to sub problems, is the obvious choice as a solution to this situation. Its response and results must be so understandable and convincing that both the specialist-consultant and the management can consider them an objective aid to decision-making processes and an argumentative basis.

Such a tool is the simulation model of a railway junction, which replaces an existing railway junction or one to be in a design stage by a computer model. This model is used to graphically reproduce and animate the system to be modelled and its processes true to reality. The findings of such a model may provide the basis for many decisions using output statistical data as well as animated operational processes and events. The consequences of such decisions can be traced and evaluated.

The simulation of systems is a research method supporting the analysis, design and optimisation of real systems in the following three steps:

- Replacement of the real system by a simulation model.
- Experimentation with the simulation model with the aim to determine its properties, behaviour and reactivity to changed conditions.
- Application of the results obtained to the real system (existing or to be configured).

The simulation model must be as true to reality as possible in order that the findings of the experiments can be transferred to the real system. On the other hand, there is a limit to the truth to reality of the model, which should not be exceeded. Simulation must be considered an approximate (not exact) method. The simulation model is situated in an experimental environment and simulation is an experimental method.

As a railway junction is a highly complex system, the application of simulation techniques seems to be the only possible solution.
Simulation run with animation

Simulation tool VirtuOS

This tool was developed in order to enable to build a simulation model, which reflects the whole complex system of a railway junction i.e. marshalling yard [2,3], passenger station, private sidings etc. The essential motivation was based on the need to be able to realise simulation experiments, the results of which could be applied to the junction and help to:

- design a suitable layout of tracks infrastructure within the junction,
- propose the needed amount and composition of mobile service resources,
- create efficient train service technologies and
- verify convenient control and decision making strategies.

However, VirtuOS itself does not provide automatic solutions of the problems, which occur within the junction. It represents an experimental environment (a laboratory) within the frame of which it is possible to study many variants of a studied junction operation, topology of tracks etc. Principally it is possible to say that using VirtuOS the user-experimenter can answer the questions: “What will happen if...?” Therefore it is expected that VirtuOS is handled by the well-trained railway technologist who, in addition, co-operates with the management of an investigated junction.

The work with VirtuOS can be divided into three basic stages:

- Input data collection from a real junction (or prognostic data definition for a new designed
junction) and the building of its model.

- Iterative process of simulation experiments (the runs) on the model.
- Recommendations for the junction operation and infrastructure layout based on the results of simulation experiments and their analysis.

In order to build up the above-mentioned model it has to be collected the data about:

- **Infrastructure** (tracks) - there is scanned and vectorised the paper documentation of a junction (physical infrastructure) and then the function of each of track is defined (logical infrastructure).
- **Mobile service resources** (personnel and shunting locomotives) - there are defined the numbers, professions and working shifts for all these resources.
- **Trains** - the information about train flows (incoming and outgoing) has to be defined and it is also needed to get the statistics about incoming trains composition.
- **Technological processes** - there are defined the train service technologies (in the form of network graphs) after train arrival and before train departure, train sorting and train forming processes (simultaneous train formation, primary and secondary humping, sorting using a hump or flat humping etc.).
- **Control** and **decision making strategies** - there are set up the managements of service resources, the decisions of changes of simultaneous train formation schema etc.

**Editor of track infrastructure**

When the building of a model is finished, there is made its verification and validation. After that it is possible to start process of making simulation experiments which investigate the
junction operations under the required different conditions. The simulation run can produce the different kinds of outputs. During the simulation run it is possible to see on the screen the animation of all movements of trains and service resources and also on-line statistics about utilisation of service resources are on the shelf. On the other hand the post-simulation outputs can be used. The simulation run reports its evolution into the simulation protocol (file on the disk). Afterwards, using the specialised tool, it is possible to obtain from the mentioned protocol any required statistics and the graphical protocols (using time scale) of the realised work of any service resource, any track occupation etc. In addition, it is possible to offer the customers the software called VirtuOs-Viewer. That software enables to have a look at the whole simulation run using animation outputs.

The results of simulation experiments are analysed and studied by the local technologists. Then there are made the concrete proposals of the real junction operation changes or the results show the need of additional experiments. It is possible to say that the adduced working procedure requires an iterative approach, which usually leads to the solution of some specific problem.

**Problem solving using VirtuOS**

VirtuOS is a universally suitable simulation tool, which supports the creation of simulation models used for the solution of many local problems of railway junctions. It is also suitable for the solution of problems arising from changes in the surrounding railway network. In the following, some typical problems from these fields will be described.

1. **Changes in flows of incoming trains**

   Using a simulation model, a junction operation can be determined and evaluated before the flows of incoming trains have actually been changed. Changes in the flows of incoming trains usually result from modifications to the railway network, which can be described as follows:

   - Reduction, increase or structural changes in the flows of incoming trains due to customer interests.
   - Changes in the network technology by the introduction of a new timetable. A typical task for a simulation model in this context is the modelling and examination of operational conditions in a junction before introducing a new timetable.
   - Changes in the network infrastructure (e.g. decisions on the discontinuation or restriction of work in another junction) can also result in changes in the flows of incoming trains and make necessary the examination of the operational processes in a junction.

2. **Cost savings by optimum use of resources**

   The allocation of staff and shunting engines can be optimised using VirtuOS. Not only capacity utilisation can be improved considerably, the amount of resources can be reduced as well.

3. **Rationalisation of technological processes**

   One possibility of a junction operation optimisation without the need for expensive infrastructural measures is the introduction of new technological procedures, e.g. the simultaneous formation of outgoing trains, parallel humping, concentration of humping
activities in a shorter time interval as well as the performance of more process operations in parallel.
Using the VirtuOS-based simulation model, the effectiveness of these procedures can be investigated before their implementation in reality.

Train service technology

4. Planning of infrastructure maintenance

VirtuOS is suitable for preparing necessary operational modifications during the maintenance of a junction and scheduling maintenance work.

5. Reconstruction and configuring of junction infrastructure

The reconstruction of infrastructure is a very complicated and expensive intervention in the operation of a junction. Reconstruction activities may comprise a reduction, exchange or amplification of tracks, brakes or safety equipment. Today, it is hardly conceivable that the management takes a decision on infrastructural adaptations without investigating the resulting consequences using a simulation model. VirtuOS is an effective and tried-and-tested tool for an objective verification of decisions. If the decision on a reconstruction has already been taken, the individual stages can be planned and the operational processes affected by the infrastructural measures within a phase can be examined through VirtuOS. Of course, the above said also applies to the configuring and installation of a new junction.

6. Verification and improvement of operation control strategies

An important feature of VirtuOS is its capability to co-operate with the user during a simulation run. The user (in this case e.g. the dispatcher) can define problems he wants to solve on his own during the simulation of operation in advance. The simulation model permits him to trace and evaluate the consequences of his decisions. By doing so, the dispatcher is able to examine the suitability of different operations control strategies. This co-operation feature of VirtuOS also proves to be very advantageous in the training of managing staff.
7. Management of crisis situations

The railway network and its junctions may also be exposed to different critical social situations (crises), not ascribable to certain management decisions but to the failure of human or technical factors or an Act of God. The following crisis situations are conceivable:

- Acts of God (e.g. floods, earthquakes, epidemics, etc.).
- Technical events (collision of trains, power failure, etc.)
- Social events (strike, military conflicts, etc.)

Graphical output protocol

Such crisis situations may affect a part of or an entire railway junction and result in considerable changes in the flows of incoming trains or affect the infrastructure, reduce the availability of resources or impose changes in the operations control of the junction (e.g. by changing priorities).

A typical property of the above-mentioned crisis situations is that they can only be dealt with after their occurrence and the financial damages are high. VirtuOS is an ideal means for the simulation of such "scenarios" for determining an operation control strategy for the individual exceptional situations to be expected.

Examples of real applications

Let us mention now the examples of recent (realised at the end of 90s) and current simulation projects focused on the economisation of big junctions:
1. Recent projects

- Project *Marshalling yard of Linz* (Linz Vbf) – simulation study focused on the studying the consequences of the substantial yard extension. The co-operation of the Austrian Federal Railways (GD ÖBB Wien), Austria.
- Project *Hamburg Alte Süderelbe* - simulation study for investigation of track infrastructure capacity in the station Alte Süderelbe (City of Hamburg area), in connection with anticipated increase of incoming train flow rate, outlook to the year 2010. The project was realised in co-operation with company Haas Consult and City of Hamburg (Germany).
- Project *Mainz Bischofsheim* – customisation of software product VirtuOS for the special needs of DB Cargo (German Cargo Railways). There was modelled marshalling yard Mainz Bischofsheim. On this project we co-operated with Siemens Braunschweig and DB Cargo Mainz (Germany).

2. Current projects

- Project *Central marshalling yard of Vienna* (Wien ZVBf, Austria) – in the co-operation with the Austrian Federal Railways (GD ÖBB Wien), Austria.
- Project *Marshalling yard Mudanjiang* (China) – in the co-operation with Chinese Railways, China.
- Project *Volkswagen Factory Transportation System* (Bratislava, Slovakia) – in the co-operation with Volkswagen Slovakia.

Conclusions

The substantial decisions in the field of transport, respecting the contemporary level of information technologies and simulation methodologies, should not be adopted without the modelling of their consequences. Hence, it is essential also for planning connected with railway junctions (track infrastructure layout, resource dimensioning and rostering, service technologies, decision-making strategies, reactions on the networks changes etc.) to apply the modelling techniques in order to investigate the proposed measures and solutions. The complex and in practice verified simulation tool VirtuOS enables not only to investigate the consequences of adopted decisions but also by means of the reasonable sequence of experiments to choose the best solution and to save the financial resources.

References

