SIMSHUNT – A FAST SIMULATION TOOL FOR CAPACITY ANALYSIS OF SHUNTING YARDS

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ABSTRACT
For capacity analysis of shunting yards a tool for fast and solid evaluation of changes in car flow characteristics and rail infrastructure is needed. Current available simulation tools do not allow a strategic network wide view, due to their highly detailed data requirements. This paper introduces SimShunt, whose goal is to develop a new simulation tool for shunting yards that is fairly easy to handle and possible to use for different yards with short set up times. A combined simulation and optimization approach is used.

Keywords: shunting, simulation, optimization

1. INTRODUCTION

Freight transportation is seen as an eco-friendly and in many cases efficient part of a supply chain. The planning of its infrastructure is possible through computer based simulation tools and can be put on a fundamentally and mathematically sound basis with such methods. As companies tend to use single wagons for transporting their goods, these wagons have to be part of different trains until they reach their final destinations. Shunting yards are needed to reassign the wagons for this type of transport. Different types of shunting yards exist, where complex actions of shunting can be performed. Commercial software tools for analyzing shunting yards are available (Adamko and Klima 2008), but they only allow a very detailed simulation, coming along with fairly long set up times. This results in long processing times for practical applications. Mid- and long term decisions are made on forecasts, which are cyclically updated. Therefore, long set up times tend to generate results based on obsolete data.

A strategic network wide view is not possible with the available tools. Nevertheless, an aggregated consideration is a much more important and relevant question for railway infrastructure projects. Higher potential is seen in an optimization of the whole transport system for single wagons, for which a strategic view of the whole network is needed. Currently, there is no known tool that allows the planning of shunting yards on an allocated, but relevant level.

2. PROBLEM DESCRIPTION

With SimShunt we develop a new simulation approach for shunting yards. The developing partner is the Austrian Federal Railways (ÖBB) who currently uses a simulation tool called NEMO. It is focused on the arcs of the rail network and therefore does not allow capacity analysis of shunting yards. Furthermore, the software tool RailSys allows simulation of planned and delayed rail schedules, which is also in use at ÖBB. It is possible to automatically reschedule trains with it to compare and validate decisions that are made in reality. Kettner, Sewcyk and Eickmann (2003) describe RailSys in combination with NEMO and the required data for the model. Depending on the size of a case different set up times are needed, but in any case several months of work are required. Slovakia based Simcon developed a software tool called VILLON for simulating logistic nodes, like plants, ports, railway stations, shunting yards and others. Its usage requires sufficient data set up (see e.g. Kavicka et al. 1999, Adamko and Klima 2008).

The analysis of shunting yards gains more and more focus in scientific literature. Kroon, Lentink and Schrijver (2008) developed a model for track allocation. Riezebos and van Wezel (2009) present a new method that was developed for the shunting yard Zwolle (Netherlands). Prioritized and blocked tracks are possible for certain trains in their survey, respectively. He, Song and Chaudhry (2003) developed a mathematical model for shunting to minimize times of train throughput and delays. Dahlhaus et al. (2003) present a mathematical model for reallocation of wagons during shunting and point out relevant parameters for the shunting problem. Dessouky et al. (2006) introduced a branch-and-bound based method, which optimizes the track dispatching, whereas the focus of Lübbecke and Zimmerman (2003) is set on optimizing sequence planning and dispatching of locomotives.

The above mentioned methods and models result either in a very specific problem of parts of a shunting yard or in very detailed requirements for a simulation. This results in the fact that a strategic network wide view is not possible with these tools, but the developing partner ÖBB requires a view of shunting problems on an aggregated level.

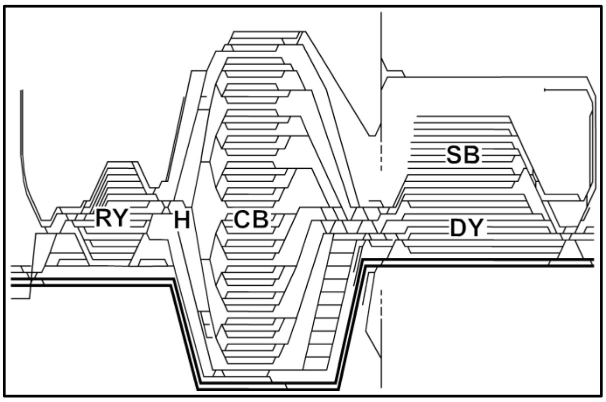

Figure 1: Shunting yard with receiving yard (RY), hump (H), classification bowl (CB), sorting bowl (SB), and departure yard (DY).

The shunting yard that is used for this case consists of different parts, where each of them has a certain number of tracks. They are called receiving yard, hump, classification bowl, sorting bowl and departure yard. A schematic diagram of the used yard layout is displayed in Figure 1.

An optimization of the carriage of single wagons seems to show great potential, but therefore a strategic network wide view including its nodes is necessary. This strategic view is used as a basis to be able to design an operative infrastructure development. The goal of this research is to develop a new simulation approach that is capable to perform capacity analysis of shunting yards with as few input parameter as possible. They should be fairly simple to determine and available for various yards. This would result in short processing times for the simulation. Additionally, various strategies ranging from current best practice to optimization based ones are developed and used for scenario analysis.

3. METHODS

The software tool SimShunt, which is used as a proper tool for capacity analysis of shunting yards, is designed as a hybrid model. It combines elements of discrete event simulation with mathematical optimization. For calculation of effects of different changes in dimensioning infrastructure and resource allocation a generic simulation model is developed. With its help, impacts on various configurations, dimensioning and scenarios can be calculated. The tool is designed with different modules (Figure 2) that contain the following:

- Shunting yard configuration,
- Simulation,
- Optimization and
- Report generator.

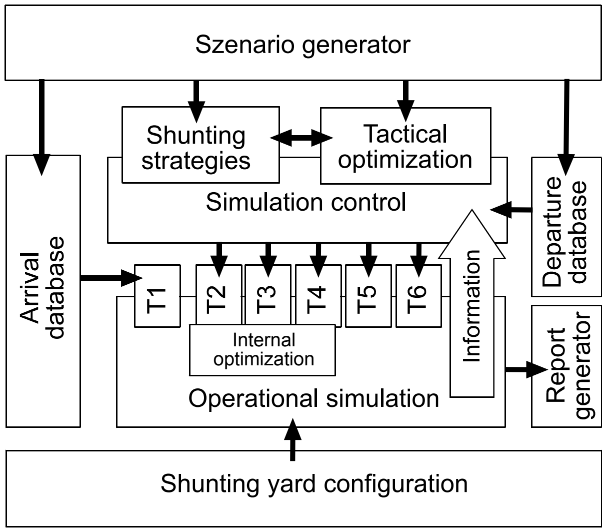

Figure 2: Simulation model design.

The model is designed as a synchronous simulation. Thereby a detailed schedule of movements is not needed. Trains are inserted according to the arrival database by execution of the arrival task (T1). Further different tasks (i.e. T2-T6) exist to simulate defined actions of the whole manipulation process until train departure. Their sequential execution is initialised by the simulation control logic according to different strategies and tactical optimization methods. On the operational simulation level simplified rules like dynamic route reservation are necessary to fulfil requirements on task sequence, conflict free dispatching and avoiding deadlocks, which is a serious problem in synchronous railway simulation caused by real time dispatching (Pachl 2007). Information has to be provided in order to ensure that simulation control has consistent data available.

3.1. Shunting yard configuration

First the tool is initialized with shunting yard relevant data that contain yard layout (tracks, signals) and available resources (shunting engines). This is done within the shunting yard configuration package. The generation of necessary incoming and outgoing trains for the simulation is done from arrival and departure database that consists of real data from the considered shunting yard. Out of this it is possible to generate various scenarios to run cases with different amounts of incoming and outgoing trains and their characteristics by data modification. These scenarios are used to find the capacity limitations of such a yard according to defined conditions.

3.2. Simulation

A discrete event simulation model is developed, using the Java based simulation software AnyLogic. The model is designed on a modular basis to ensure a fast implementation not only for various shunting yards, but also for in- and outgoing train flows. All movements on a yard can be simulated, displayed and followed through a graphical animation. The direction of incoming trains to the yard varies, because it is possible to enter the yard from different incoming tracks. The routing of trains, shunting engines and wagons through the yard is possible from a start to an end signal. Its path is calculated automatically through a k-shortest paths algorithm (see Riezebos and van Wezel 2009; Yen 1971), whose weighted graph consists of signals as nodes and specified connected track sections between the signals as arcs. Note, that a signal can be placed at any position on a track, not necessarily at start- and endpoint of it, to ensure correct track capacities and shunting movements as well as meeting safety restrictions on an accurate level. The use of k-shortest paths allows various alternatives for the routing in case one route is used by other resources or blocked for safety reasons. The simulation model is validated for test cases with real data. Validation can be performed by comparing the collected existing shunting performance indicators with the obtained ones of the rebuilt scenarios of the simulation's report generator.

3.3. Optimization

Optimization based methods – both exact and heuristic ones – need to be integrated to provide rules for shunting yard relevant decisions and are embedded within the simulation. These are decisions for track allocation of the receiving yard and the classification bowl. The former is relevant since the yard that is used in this paper has two parallel hump tracks, which are not directly connected to all receiving yard tracks. When using more than one shunting engine in the receiving yard these tracks are used alternately. Therefore, the track allocation of the receiving yard has influence on the humping sequence. Track allocation is also important for the classification bowl, since the tracks have different capacity restrictions and it influences the complexity of needed shunting movements during the sorting process and the assembling of outgoing trains. Intelligent track allocation can help improving efficiency of the sorting process in the sorting bowl. Various strategies for decision support are implemented and used for predefined scenarios. Therefore, mixed integer programming models can be developed to describe the relevant decision problems (see e.g. He, Song and Chaudhry, 2003). Depending on the size of the problem to be solved, either the model itself is used for determining solutions or a heuristic procedure is developed. Also the currently used heuristic methods are implemented for comparison and used to quantify the impact of potential improvements.

3.4. Report generator and animation

An animated view is generated to get a visual insight of the simulation. Reports with the relevant input parameters and output results can be generated. Benchmarks to validate the yard's capacity are calculated. The most relevant ones are the percentage of wagons of incoming trains reaching the defined outgoing train and of delayed departures. As the hump is a major bottleneck of the shunting process, its utilisation is determined as the major performance indicator. The software tool SimShunt allows to test the impact on changes of traffic volume and characteristic on yard performance as well as to show the efficiency of different strategies and optimisation techniques.

REFERENCES

Adamko, N., Klima, V., 2008. Optimization of railway terminal design and operations using Villon generic simulation model. *Transport*, 23 (4), 335-341.

Dahlhaus, E., Horak, P., Miller, M., Ryan, J.F., 2003. The train marshalling problem. *Discrete Applied Mathematics*, 103, 41-54.

Dessouky, M.M., Lu, Q., Zhao, J., Leachman, R., 2006. An Exact Solution Procedure for Determining the Optimal Dispatching Times for Complex Rail Networks. *IIE Transactions*, 38, 141-152.

He, S., Song, R., Chaudhry, S., 2003. An integrated dispatching model for rail yards operations. *Computers & Operations Research*, 30, 939-966.

Kavicka, A., Klima, V., Niederkofler, A., Zatko, M., 1999. Simulation model of marshalling yard Linz VBF (Austria). *Proceedings of the international workshop on Harbour, Maritime & Logistics Modelling and Simulation*, pp. 317-320, Genoa (Genoa, Italy).

Kettner, M., Sewcyk, B., Eickmann C, 2003. Integrating microscopic and macroscopic models for railway network evaluation. *Proceedings of the European Transport Conference*.

Kroon, L.G., Lentink, R.M., Schrijver, A., 2008. Shunting Passenger Train Units: An Integrated Approach. *Transportation Science*, 436-449.

Lübbecke, M.E., Zimmermann, U.T., 2003. Engine Routing and Scheduling at Industrial In-Plant Railroads. *Transportation Science*, 37 (2), 183-197.

Pachl, J., 2007. Avoiding Deadlocks in Synchronous Railway Simulations. *Proceedings of the 2nd International Seminar on Railway Operations Modelling and Analysis*, Hannover, Germany.

Railsys www.rmcon.de

Riezebos, J., van Wezel, W.M.C., 2009. k-Shortest routing of trains on shunting yards. *OR Spectrum*, 31 (4), 745-758.

Yen, J.Y., 1971. Finding the k Shortest Loopless Paths in a Network. *Management Science*, 17 (11), 712-716.