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The train marshalling by a single shunting engine problem

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A B S T R A C T

We consider the problem of marshalling a train from a number of rail cars that are distributed throughout the classification bowl of a shunting yard. In contrast to most other contributions we do not consider marshalling based on repeated roll-ins, but marshalling by shunting engine. This is also a common process alternative at shunting yards that has not yet received much attention from the scientific community. The goal is to find the optimal route for this shunting engine that respects all constraints applicable to movements in a shunting yard. We propose a Mixed Integer Programme (MIP) under consideration of single-block trains. A block refers to rail cars that share the same destination. Then we conduct a series of numerical experiments and show that the solutions of the MIP improve by 10% on average when compared to those produced by a Real-World-Heuristic that is designed to approximate the current marshalling practice. Finally, we statistically derive relationships between selected problem instance characteristics and the expected marshalling effort that can be useful for practitioners and operators of shunting yards.

1. Introduction

Shunting yards are a central part of the railway infrastructure used for freight transportation. They are located at the nodes of the railway network and serve the purpose of reassembling freight trains based on arrival- and departure-schedules of trains as well as destinations of the respective rail cars. The processes taking place to achieve this transformation are very complex and highly interrelated. Therefore they provide a rich field for optimisation on the strategical, tactical and operational level. The market of single wagon freight transportation in Europe has been declining for the last years and is expected to continue to do so as suggested by figures published by Statistics Austria (2014). This development forces railway operators to utilise their infrastructure as efficiently as possible and even work back existing infrastructure. This trend results in a redesign of the network flows and subsequently a redistribution of workload at the remaining nodes of the railway network with grave implications. In order to improve the ability to investigate and evaluate shunting yards, the simulation tool called *SimShunt* has been developed. It is capable of simulating an entire shunting yard with all its underlying processes and operations especially at its capacity limit. While doing so, it collects a large amount of statistical data that can be used for performance evaluation. *SimShunt* depends on a number of decision making systems in order to work fully automatically. The result of this work serves as such a system.

We now provide a general overview of the infrastructure and the main process. A more detailed description is provided by Boysen et al. (2012). A schematic layout indicating the main functional areas is provided in Fig. 1.

We would like to present the main process by following a rail car through its life cycle in a standard shunting yard. The life cycle of a rail car in a shunting yard begins with the arrival of a train. This train is called inbound train. Every inbound

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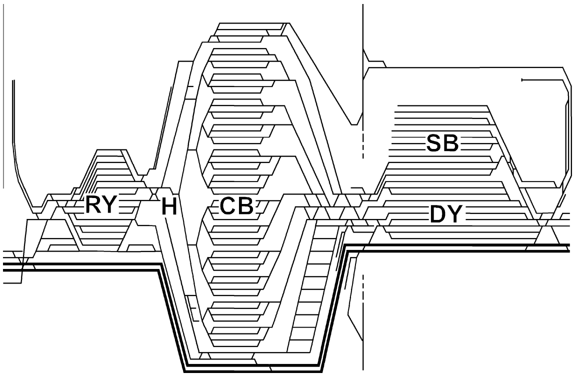

Fig. 1. Schematic layout of a typical shunting yard.

train gets assigned to a suitable track in the receiving yard (RY), where the trains are inspected and their rail cars are decoupled. Decoupling refers to the separation of rail cars that do not share the same destination. Rail cars that appear sequentially on a track and share the same destination are called a block. In most cases those blocks stay together and are processed jointly throughout the process. After the separation is completed, the rail cars are pushed over the hump (H) by a shunting engine. The hump enables the rail cars to enter the classification bowl (CB) without external propulsion by following a downhill system of tracks and automated switches. At this point three important decisions in respect to performance have to be made. Those are the following.

1.1. Roll-in sequence

The hump can only be used for the roll-in of a single inbound train at a time. Since there is no way for a rail car to overtake a preceding rail car on a track, all rail cars that have been rolled-in before other rail cars are standing strictly before them. Therefore the roll-in sequence is very important. In addition, the hump is operated at its capacity limit in order to process as many inbound trains as possible. This results in the need to select the next inbound train to be rolled-in from the already processed trains. This number increases and makes this decision more difficult as the yard approaches its capacity limit.

1.2. Outbound train assignment

Every rail car has to leave the shunting yard with a suitable outbound train. All rail cars have a predefined destination which allows for identification of possible outbound trains serving this destination. Usually rail cars will be assigned to the next eligible outbound train, but other aspects can be taken into account which may lead to different assignments. This decision is driven by the need to reduce the number of rail cars in the classification bowl (fewer outbound trains per destination) and the need to minimise marshalling effort (more outbound trains per destination).

1.3. Classification track assignment

This decision assigns a certain track in the classification bowl to a rail car. With this information the automated guidance system can lead the rail car to that track. This decision is trivial as long as there are more tracks than outbound trains. Unfortunately, this precondition is rarely met in the Real-World. Generally, a classification track stores rail cars for more than one outbound train. The aim is to keep the number of tracks per outbound train as small as possible. This decision is based on characteristics of other outbound trains at a certain track and the location of the tracks already hosting rail cars of a certain outbound train.

The sum of these three decisions determines the position of every rail car in the classification bowl. The classification bowl consists of a number of large, parallel tracks, each of which can be used to store rail cars. The tracks can only be entered by un-propelled rail cars rolling-in via the hump from one end, and by shunting engines from the other end. At some point in time before the scheduled due time of an outbound train, the train has to be prepared and cleared for exit. This preparation consists of four steps: marshalling, coupling, technical inspection and organisational tasks. We focus on the marshalling process. This process refers to collecting rail cars from their respective tracks, called source tracks, and moving them to a common track, called the building track. This building track is dynamically chosen from all suitable tracks in the CB or Departure Yard (DY) for each marshalling problem instance. When all rail cars are on the building track they are joined together and become the outbound train. Outbound trains often consist of one or more blocks. A block refers to rail cars that share the same destination. Most commonly the blocks correspond to the planned stops of the outbound train. This enables the train operator to deliver the rail cars at their respective destination feeder line with minimal effort by just decoupling the last block at each stop.