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Hybrid simulation approach for improving railway capacity and train schedules

Hamed Pouryousef [a, *], Pasi Lautala [b]

[a] Civil and Environmental Engineering Department, Michigan Tech. University, 1400 Townsend Drive, Houghton, MI 49931, USA
[b] Michigan Tech Transportation Institute (MTTI), Michigan Tech. University, 1400 Townsend Drive, Houghton, MI 49931, USA

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A B S T R A C T

Timetable management is one of the operational methodologies commonly applied in the highly structured European rail system to improve the capacity utilization while maintaining acceptable level of service (LOS) parameters; but their potential benefits to the less structured U.S. system have received little attention. The objective of this study was to investigate the use of timetable management features to analyze the trade-off between LOS parameters and capacity utilization in the U.S. The research applies a hybrid simulation approach, where output from RTC, a simulation tool developed in the U.S., was used as an input for timetable compression by RailSys, a simulation tool developed in Europe. 28 scenarios were developed in RailSys to identify a preferred scenario with reasonable LOS parameters while maintaining the capacity utilization under the recommended threshold, and the selected scenario of RailSys was then validated in RTC. The results of the study revealed that 10-min maximum allowed dwell time provided the best corridor capacity utilization. Also, the LOS parameters were significantly improved for total number of stops (55% reduction), total dwell times (80% reduction) and average dwell time (65% reduction); while the timetable duration was increased (capacity utilization was degraded) by 18% compared to the initial schedule.

1. Introduction

The majority of passenger rail services in the United States (U.S.) operate on shared-use corridors with substantial freight rail services. Passenger/freight traffic may each operate on dedicated tracks, but in most cases, all trains share the same track infrastructure. The European passenger rail services also operate on shared-use corridors, but the infrastructure conditions and the operating priorities and patterns are different, typically favoring passenger operations (FRA, 2009; Cambridge Systematics and Inc., 2007). Recently, the increasing demand for train traffic (passenger and freight) is creating pressure to add capacity in the U.S. either through the construction of new tracks and lines, or through improved operational strategies.

Capacity analysis, at the network, main line/corridor, or terminal/yard level is one of the tools used to evaluate the benefits and costs of capacity improvement alternatives. Although the concept of capacity and the objective to achieve a high

* Corresponding author.
E-mail addresses: hpouryou@mtu.edu (H. Pouryousef), ptlautal@mtu.edu (P. Lautala).

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utilization while maintaining sufficient level of service (LOS)[1] for trains is global, the configuration differences between the European and the U.S. rail systems (such as the infrastructure ownership and the operating philosophy) leads to the use of different methodologies, techniques, and tools for capacity evaluation. More information on these differences and how they affect the capacity studies is provided in Pouryousef et al., 2013 (Pouryousef et al., 2013).

This paper focuses on rail line/corridor level analysis. It provides a brief synopsis of methods and tools to evaluate main line capacity and the LOS parameters, but the main objective of the study was to investigate the use of timetable management features common in European rail environment to analyze the trade-off between LOS parameters and capacity utilization in the U.S. rail environment. The methodology included development of a "Hybrid Simulation Approach". This differs from traditional analysis, as it takes advantage of the complementary features of non-timetable and timetable based simulation software and uses output from one software as input in another. A single-track case study is used to demonstrate the approach, the outcomes and the challenges.

2. Capacity analysis

There is no standard definition for railway capacity, but one definition that is used is the number of trains that can safely pass over a given segment of the line within a selected time period (UIC, June 2004). Various definitions, metrics, methodologies and tools are applied for evaluating the capacity in Europe and North America, due to the differences of rail network characteristics between the two continents (Pouryousef et al., 2013). Three critical differences between Europe and the U.S. are the ownership of infrastructure, the predominant traffic type (freight vs. passenger), and operating philosophies. In the U.S. more than 90% of the infrastructure is owned and managed by private freight railroads (Thomas, 2005), while in Europe infrastructure is almost completely owned and managed by governments or public agencies. The U.S. operations are predominantly for freight transportation and the prevailing operating philosophy for the majority of freight trains and even some passenger and commuter services is based on the improvised pattern that has no repeatable dispatching plan on over extended time period. In Europe, passenger trains dominate the corridors and almost all trains (freight and passenger) follow structured operations with a regular schedule that is developed months in advance (Thomas, 2005). The reasons noted above, combined with variations in other characteristics, such as rolling stock and signaling systems, all affect capacity, as well as tools and techniques used for capacity analysis.

The literature mainly divides capacity analysis approaches into analytical and simulation methods (Pachl, 2002; Abril et al., 2007; Murali et al., 2009; Khadem Sameni et al., 2011; Sogin and Barkan, 2012; Lai and Barkan, 2009). A combined analytical-simulation approach that takes advantage of both analytical and simulation methods has also been used (Schlechte et al, 2011; Cambridge Systematics and Inc., 2006). The simulation methods typically utilize either general simulation tools or commercial railway simulation software that has been specifically designed for rail transportation (Abril et al., 2007; Khadem Sameni et al., 2011). The commercial railway simulation software can be divided into two major categories: Non-timetable based and Timetable based software. Both incorporate two components: "Train movement simulation" to calculate the train speed along the track, and "Train dispatching simulation" to emulate the actions of the actual dispatcher as closely as possible (Thomas, 2005). The non-timetable based simulations are typically used in railways which are operated based on unstructured operation pattern without initial timetable, such as the majority of the U.S. rail network. The primary objective of this type of simulation tools is to automatically resolve the train conflicts. The Rail Traffic Controller (RTC), developed by "Berkeley Simulation Software, LLC" is the most common software in this category and is used extensively by the U.S. rail industry (Thomas, 2005; Khadem Sameni et al., 2011). The simulation procedure of timetable based software, commonly found in Europe, is based on the initial timetable of trains (often a conflict-free timetable is required). The software can identify the train conflicts, but in most cases have limited capabilities to resolve all conflicts without user intervention. The software typically include features to automatically adjust/improve the initial timetable and are equipped with other timetable management features, such as timetable compression technique. RailSys, developed by Rail Management Consultants GmbH in Germany, is one example of a timetable-based simulation package, and details of the different simulation tools has been provided by Pouryousef et al., 2015 (Pouryousef et al., 2015).

Table 1 provides a sample of recently published capacity studies in the U.S. and Europe, and shows the difference between tools commonly used for analysis. RTC has been the software of choice for all U.S. studies while several timetable-based packages have been used in Europe.

In addition to the software packages highlighted in the Table 1, there are other simulation tools used in the U.S., by rail transit and commuter services (e.g. MultiRail, RailSim), and in Europe (e.g. OpenTrack, Viriato, SLS, RAILCAP, CMS). A review of Table 1 indicates that train delay analysis is a common performance metric for capacity evaluation in the U.S. and one that is recommended by the Federal Railroad Administration (Tolliver, 2010). Europeans have a variety of different methodologies to evaluate the railway performance, but most of them utilize timetable management techniques. For instance, timetable compression technique used in this research, was developed by International Union of Railways (UIC) to improve the capacity utilization or LOS by adjusting operational characteristics, such as dwell times, stop patterns, train departure times and/or the

[1] Level of service (LOS) may include various parameters to evaluate the desire level of rail customer/clients' satisfaction. In the U.S., common parameters used are various types of train delays, but in this research, the LOS parameters are taken into account from the timetable and scheduling standpoint. Common parameters include number of stops (unplanned or meet-pass stops), average dwell time, maximum allowed dwell time and total dwell time.