Journal of Rail Transport Planning & Management xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

Computation of practical capacity in single-track railway lines based on computing the minimum buffer times

A. Jamili

School of Industrial Eng., College of Engineering, University of Tehran, Iran

ARTICLE INFO

Keywords:
Practical capacity
Buffer times
Perturbation
Chance constraint approach
Robust approach

ABSTRACT

Defining the exact amount of capacity in main line railway lines is a key strategic criterion in selection of railway development alternatives. The method of computation of capacity in single-track railway lines is different from double or more track ones. The UIC 406 leaflet defined an invaluable method to compute the capacity on the basis of compressing the actual timetables. In this paper, some new methods are proposed to define the exact amount of practical capacity based on computing the minimum required buffer times during compression process in single-track railway lines. Finally, a bottleneck in Iran mainline railway network is analysed as the case study.

1. Introduction

Determining the capacity of a railway line is a typical study that is performed to analyse the railway lines for defining the strategic decisions on the required developments to manage the passengers and freights traffics. Capacity analysis is to determine the maximum traffic load in railway lines under specific limitations. The effective use of railway lines is one of the main concerns of railway decision makers. Once the capacity of railway lines is estimated, the best alternatives to extend the railway infrastructures could be selected.

Theoretical capacity is defined as the maximum number of trains running safely in a railway line in a specific time period. Moreover, the concept of practical capacity, is based on considering real applications so that the required reliability is achieved. It is worth mentioning that the maximum reliability in railway lines are achieved by minimum, i.e. zero, train delays, that is obtained by considering required buffer times as well as adding necessary supplementary times to the running times and the dwell times. The role of buffer times is to consider some extra times between arrival and departure times of trains specially traveling in opposite directions in single-track railway lines. In general, one can say that the practical capacity specifies a more accurate condition of railway lines. Fig. 1 illustrates the differences between these capacity types. Meanwhile, the used capacity determines the current condition of studied railway line.

As shown in Fig. 1, as the requested reliability increases, the achieved practical capacity reduces. Moreover, this figure shows that, as the desired reliability increases, the practical capacity reduces. Abril et al. (2008) studied the main concepts of railway line capacity and different methods to measure the amount of capacity. They categorized the capacity computation methods in three classes.

- Analytical methods
- Simulation methods

E-mail address: a_jamili@ut.ac.ir.

https://doi.org/10.1016/j.jrtpm.2018.03.002
Received 23 March 2017; Received in revised form 23 February 2018; Accepted 6 March 2018

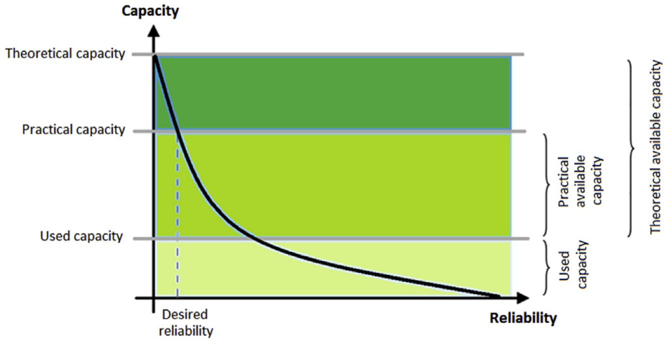

Fig. 1. Different types of capacity.

- Actual timetable based methods

The analytical methods, as well as simulation methods present a good estimate but not an exact amount. The UIC 405 leaflet is an analytical method. On the other hand, using the actual timetable is the newest method that results more accurate amount of capacity, and is used by UIC 406 leaflet, and therefore, this method is studied in this paper.

This paper addresses the single track lines. It is worth mentioning that train movements in single-track railway lines are completely different in comparison with double or more track lines, since in single track ones trains with opposite directions should run in a same track and therefore, all trains with opposite directions are allowed to pass each others only at the stations. Therefore, the train movements in single track lines are completely different in comparison with double or more track line, and should be investigated separately.

Amongst analytical methods to compute the capacity, the most applicable one is 405 UIC leaflet standard. Burdett and Kozan (2006) proposed some methods to compute the theoretical capacity based on some operational conditions including different trains configurations, signals positions, dwell times, train lengths, headways, and train specifications. They illustrated the proposed approaches using a case study. (Siefer and Radtke, 2005) proposed a simulation based method to analyze the railway line capacity. Pouryousef and Lautala (2015) proposed a Hybrid simulation approach for improving railway capacity and train schedules that is used as an input for timetable compression by RailSys to investigate the use of timetable management features to analyze the trade-off between LOS (level of service) parameters and capacity utilization in the U.S. Kort, et al. (de Kort et al., 2003) considered the problem of determining the capacity of a planned railway infrastructure layout under uncertainties, in which the exact demand of service is unknown. They proposed a (max, +) method based on the possibility approach to compute the capacity.

The UIC 406 Leaflet standard proposed a method to compute the theoretical available capacity of railway lines, based on the actual train timetables. . According to UIC, the absolute maximum capacity, or “Theoretical Capacity”, is almost impossible to achieve in practice and it is subject to:

- Absolute train-path harmony (the same parameters for majority of trains)
- Minimum headway (shortest possible spacing between all trains)
- Providing best quality of service (UIC, 2004).

This standard is applied in many recent papers, as well as Landex (2009), Landex et al. (2006), and (Wahlborg, 2004). Abril et al. (2005) proposed a heuristic method to compute the theoretical method in periodic mode, developed in collaboration with the Spanish Railway Infrastructure Manager (ADIF). This technique studies the capacity of every line section considering its adjacent line sections. Lindner (2011) analyzed the applicability of the UIC Code 406 compression method for evaluating line and station capacity. Moreover, a typical timetable situation on a specific infrastructure featuring less station than line capacity is shown, where, node capacity determines the maximum capacity of the whole infrastructure. This demonstrates the importance of evaluating the line capacity outside station areas as well as station infrastructure itself. Based on this aspect Linder explains, why the occupancy rate cannot provide a significant parameter for node station capacity and that UIC Code 406 method cannot be applied for node capacity research. Chu, and Oetting (Chu and Oetting, 2013) proposed a method to identify and quantify the longer occupation times during disruptions and a capacity model considering the characteristics exhibited by disruption programs. They offered a method to identify and quantify these longer times and a capacity model considering the characteristics. Their proposed method can be used to evaluate the feasibility of a disruption program in advance. Goverde, et al. (Goverde et al., 2013) proposed dynamic infrastructure occupation to assess capacity under disturbances, and extended timetable compression method by this method. They used the train dispatching system ROMA that combines the alternative graph formulation of train rescheduling with blocking time modelling of signalling constraints. For the disturbed conditions, four traffic control scenarios are considered: three heuristics and an advanced branch-and-bound algorithm. Moreover, some new researches proposed new methods to generate robust train timetables, e.g. (Shafia et al., 2012a, 2012b) in mainlines, and (Jamili and Pourseyed Aghaee, 2015) in urban railways. Wendler (2007) presented an approach predicting the scheduled waiting time by means of a semi-Markovian queueing model. Weik, et al. (Weik et al., 2016) discussed a stochastic model for the capacity analysis of railway lines relying on single channel queueing systems in Germany.