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Delay management in public transportation: service regularity issues and crew re-scheduling

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Abstract

In this paper, we propose a decision support tool to assist a local public transportation company in tackling service delays and small disruptions. We discuss different ways to assess and improve the regularity of the service, and we propose a simulation based optimization system that can be effectively used in a real-time environment taking into account both vehicle and driver shifts. In particular, we describe a tabu-search procedure for the online vehicle scheduling optimizing the regularity of the service and a column generation approach for the consequential crew re-scheduling minimizing the driver extra-time. As a case study, we analyze the management of urban surface lines of Azienda Trasporti Milanese (ATM) of Milan. In the last part of the paper we report a detailed analysis of the experimental phase showing the effectiveness of the proposed approach.

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1. Introduction

The quality of a local public transport depends on the perceived efficiency and reliability. However, events or disturbances innate in the system, especially in an urban setting, may generate disruptions that negatively influence this perception. Additionally, disruptions usually increase the operating cost, for instance, involving extra allowances for bus drivers, or penalties to be paid to the municipality that commended the service. In this paper we focus on day-to-day situations where the regularity of the service is compromised by delays and small disruptions. Currently, the daily operations of transit companies are monitored "manually" by an operation central office taking advantage of Automated Vehicle Monitoring (AVM) systems and mobile telecommunication devices. Each operator controls the operations of one or more lines, detecting delays that may generate disruptions or collecting information about

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problems on the line such as vehicle breakdowns or accidents. In the presence of a disruption, the operator assists remotely the drivers deciding the actions to be taken in the line. In addition, the operator must inform passengers both onboard and waiting at the stops, of the new solution adopted to tackle the disruption. The basic actions that an operator in the central office can enforce are, for instance, to perform vehicle detours, to delay a vehicle schedule, or to cancel one or more trips. The operator may also decide to use spare resources (drivers or vehicles). However, this is not an option for the ordinary disruption management since, usually, these resources are extremely scarce and are utilized in exceptional cases only.

Methods to cope with disruptions have been introduced initially in the airline industry (see for example Clausen et al. (2010)) and then extended to railways Jespersen-Groth et al. (2009), Cacchiani et al. (2014). The complexity of the constraints emerging in railways, mainly due to the shared infrastructure, often suggested hybrid approaches conjugating optimization techniques with simulation Berger et al. (2011). Only recently this problem has been tackled in local public transport. In this context, peculiar features motivate an ad hoc study of disruption management methods that can take advantage of transit additional flexibility such as trip cancellations, detour or limitations that add significant degrees of freedom and open for different types of approaches. For example Li et al. (2009) cope with the vehicle re-scheduling problem in the presence of a disruption due to the breakdown of a single vehicle and other vehicles must deviate in order to take care of passengers. This kind of problem appears suited for extra urban transportation where the frequency is low, rather then for the urban case. Bartholdi-III and Eisenstein (2012) tackle the problem of equally spacing buses in a urban environment. This paper however does not consider the issues deriving from the modified driver scheduling.

In this paper we present a new simulation based optimization algorithm that can assist the operators to face different types of small delays and disturbances with the ultimate objective of increasing the quality of service, or at least to limit the perception of inconvenience on passengers, using the available resources. After a short analysis of different methods for the evaluation of the regularity of the service (Section 2), we introduce the simulation procedure and we define the *delay managment algorithm* (Section 3). We describe the tabu-search algorithm employed for the real-time re-scheduling of the vehicles (Section 3.1) and the column generation method tackling the crew scheduling re-optimization (Section 3.2). Finally, we report the results obtained by our procedure in real-world scenarios arising in the urban management of surface lines of Azienda Trasporti Milanese (ATM) of Milan (Section 4) and we draw some conclusions depicting future developments (Section 5).

2. Evaluating the regularity of the service

The main challenge in managing disturbances in the regularity of the service is to be able to distinguish events that may have a negative impact on the service from those whose effect will recover in a short time without interventions.

In order to develop an algorithm that proposes a course-of-actions to mitigate the effect of disturbances, we need a precise and formal way to evaluate the regularity of the service along one line. The public transportation lines that we are taking into account provide a *frequency based service*: at each stop a frequency of vehicle passages is specified, instead of the timetable (e.g., a vehicle every 7 minutes). In this case, even if generalized delays are present, the service is not perceived as disrupted by passengers, provided that frequencies are regular and aligned with the planned ones. Note that, in this type of service, even though users perceive the service delivered according to frequencies, resources, namely vehicles and drivers, continue to be managed on a timetable base, hence delays or other events which are not perceived as disruptions by users, may generate disruptions when the resource management must be inevitably adjusted. These disruptions are called endogenous.

There are many ways to estimate the regularity of the service. The most regular service is obviously that reproducing exactly the planned timetable. Thus the regularity measure should consider the adherence of the provided service with the planned one. In the case of timetabled service the measure will consider the planned timetable, while in the frequency based service this measure can be relaxed and only the headways will be accounted for. In the literature many proposals are present (see for example Barabino et al. (2013) for a brief survey). It can be observed that, most of the times, these measures are suitable when computed off line, when all data collected during the day are available. This is particularly true when the average, the standard deviation or other cumulative indicators of the observed value are used. However, this is not always possible when the measure has to be computed in real time to support decisions