Chapter 18

Disruption Management in Urban Rail Transit System: A Simulation Based Optimization Approach

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ABSTRACT

The process of disruption management in rail transit systems faces challenging issues such as the unpredictable occurrence time, the consequences and the uncertain duration of disturbance or recovery time. The objective of this chapter is to adopt a discrete-event object-oriented simulation system, which applies the optimization algorithms in order to compensate the system performance after disruption. A line blockage disruption is investigated. The uncertainty associated with blockage recovery time is considered with several probabilistic scenarios. The disruption management model presented here combines short-turning and station-skipping control strategies with the objective to decrease the average passengers’ waiting time. A variable neighborhood search (VNS) algorithm is proposed to minimize the average waiting time. The computational experiments on real instances derived from Tehran Metropolitan Railway are applied in the proposed model and the advantages of the implementing the optimized single and combined short-turning and stop-skipping strategies are listed.

INTRODUCTION

The optimization of railway traffic in public transportation systems is facing a growing attention both between practitioners and scholars. Dealing with such real practical problems necessitates the adoption of efficient modeling framework that can be used in different normal and disruption traffic situations.

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In this regard, Disruption Management (DM) is defined as the process of selecting an appropriate set of strategies and corrective actions after the occurrence of a disorder or deviation from initial plan. It is a critical task in rail systems particularly within congested metropolitan areas. The objective of disruption management is to return the disrupted status to its planned operation status while minimizing all the negative impacts caused by disruptions and recovery costs (Yu & Qi, 2004). The DM concept has a great and growing body of literature on supply chain management and air transportation system. An increasing number of published scientific papers of disruption management in the railway transportation context indicate the importance of effective handling of disruptions. An urban metro system is characterized by its relatively short headway and non-periodic schedules. Major causes of disruptions in metro systems are: peak-hour congestion, unexpected demand increase, train malfunction, signaling failure and line blockage. The unexpected long waiting time, overload and delay severely impact the reliability of transit service. Disruption management has turned into a challenging problem in the operations and planning of urban rail transit systems due to the stochastic variations in passenger demand. In metro systems, a number of strategies are available to manage disturbances: temporary holding of trains, deadheading, short-turning, cancellation of a service, termination of a train, skipping stations, diverting trains, change the order of trains, using a stand-by or back-up train set, and exchanging stop patterns. Carrel, Mishalani, Wilson, Attanucci, and Rahbee (2010) proposed a comprehensive framework for investigating the decision factors and major considerations in service control on high-frequency metro lines. Pender, Currie, Delbosc, and Shiwakoti (2013) presented an international survey of practices in rail disruption management and categorized all responses of passenger rail transit organizations to unexpected disruptions according to the important disruption characteristics: the source, occurrence time, duration, and location.

The operational and passenger costs can be decreased by the means of scheduling strategies customized to the demand profile. The operational efficiency of the public transit services can be improved through demand pattern information over the route. Stop-skipping services are important operation control strategies which are capable of reducing the operating costs and consequently passenger traveling time. It is a well-known service pattern applied in both rail and bus transit systems during the both normal and disrupted situations. Short-turn services are another type of operation control strategies applied where there is a low passenger demand across the part of the route. The application of short-turning services is a tactical control policy that is beneficial in the case that high demand zones need to be supplied. Redirecting the flow of trains in the subway lines is an infrequent control strategy because of its difficulties and complexities. Moreover, short-turn services can help reduce the overcrowding after disruption.

Operational flexibility is an important issue that ensures that there is sufficient capacity to accommodate all the passengers after disruptive events. Immediate response to sudden changes in demand is needed by optimizing the stop-skipping services and by altering the service to redirect trains to congested areas. It should be noted that, usually a combination of transit operating strategies contribute to keep passenger loads and the passenger waiting times in balance (Chen & Niu, 2009).

Although sufficient literature exists on the optimization of control strategies in public transportation networks, not enough studies are conducted on optimization of train schedules under demand and operation uncertainties. The effectiveness of the control strategies relies upon a holistic approach of the whole system. The real-time process of testing and evaluating the disrupted situations is extremely difficult for human dispatchers even with the assistance of advanced information systems such as automatic vehicle location (AVL). Also, to make efficient decisions, computer based decision support systems are needed to help dispatchers to optimize the real-time control decisions. The objectives of this chapter are the simulation based analysis of primary delay and the secondary demand disruption caused by line blockade,