HOLDING FOR TRANSFERS

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1 Introduction

In trunk and feeder systems an important fraction of passengers need to transfer between lines in order to reach their destinations. For example, in Transantiago system in Santiago of Chile, nearly a 47% of the more than 4 million trips per day in the system have to transfer one or more time during their trips [1]. Transfers have the advantage to reduce the operational cost but highly increase the discomfort to users who have to wait for another service, many times without any information regarding the arriving of the next vehicle.

In high frequency transit systems that lack coordinated transfers, groups of passengers could benefit from faster connections if selected departing vehicles were held for short periods. The problem of transfer coordination has been studied in the literature in the context of schedule base system where timetables are develop in order to increase the probability of transfer synchronization between services and allow all the connecting passengers to board the next service [2, 3, 4]. However, little work has been done in order to improve transfers in high frequency system.

To solve this problem, we propose a real-time mathematical programming model for transfers coordination. The decision is whether or not to hold a departing vehicle at the transfer station in order to allow a certain fraction (maybe not all of them) of the transferring passengers on an arriving vehicle to board this one.

2 Transit System Model

2.1 System Characteristics

The system underlying the model has two lines A and B crossing at a common station T where passengers can transfer as shown in Figure 1.

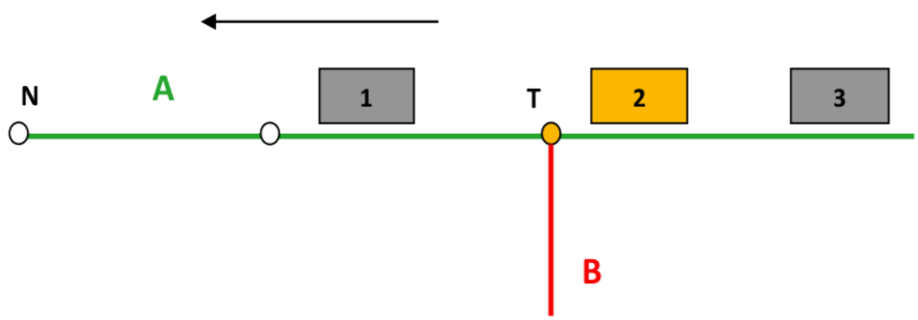

Figure 1: Transfer configuration

Consider the passengers reaching T from line B and transferring into the line heading towards A. Consider that while these passengers are alighting their transit vehicle, Transit vehicle 2 arrives to station T. If this transit vehicle is not hold, many passengers will have to wait for Transit vehicle 3. So, the problem to address is whether or not to hold transit vehicle 2 at T in order to allow a certain fraction (maybe not all of them) of the transferring passengers to board this transit vehicle. Holding Transit vehicle 2 delays those passengers already in this vehicle. It also changes the headways with transit vehicles 1 and 3 which will be perceived across all subsequent stations visited by these transit vehicles. If the headway with Transit vehicle 1 is shorter than the headway with Transit vehicle 3, then holding Transit vehicle 2 may even have a positive impact improving regularity reducing waiting times in stations downstream.

3 Problem Formulation

We formulate a deterministic mathematical programming problem whose objective is to minimize the waiting time (in stations and vehicles) of all those passengers affected by the holding decision. The different groups affected are:

1. Passengers aboard transit vehicle 2 before it departures from T. These passengers are delayed for as long as the transit vehicle is hold.

2. Passengers connecting from line B to A. Two different groups are detected: i) those who successfully connect to transit vehicle 2 and ii) those who cannot connect to transit vehicle 2 and have to wait transit vehicle 3.

3. Passengers waiting at stations downstream on line A.

We assume that at any instant in time, real-time information on the position and number of passengers aboard each transit vehicle as well as the number of passengers waiting at the various stations is available.

Transfer rates from line B to line A are modeled by a trapezoidal distribution as shown in Figure 2. In this figure, the minimum time to transfer to line A is set by t_{min}. After this time, the flow of passengers arriving at line A from B start to increase until it reaches a saturation flow of s at t_2. This flow stays constant until t_3, where it starts to decrease until t_{max}, time at which every passenger have arrive to line A.

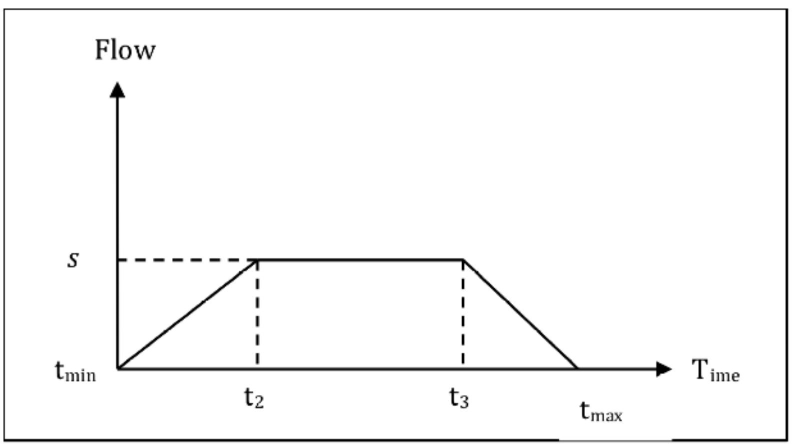

Figure 2: Passenger transfer distribution

The area under the trapezoid represents the total number of passengers connecting from line B to line A at the transfer point T.

4 Preliminary Results and Final Comments

The proposed model is now applied on a single instance of the transfer problem. The initial positions of all transit vehicles are shown in Figure 3. The Figure is just schematic, where the station are evenly spaced, station 5 being the transfer point.

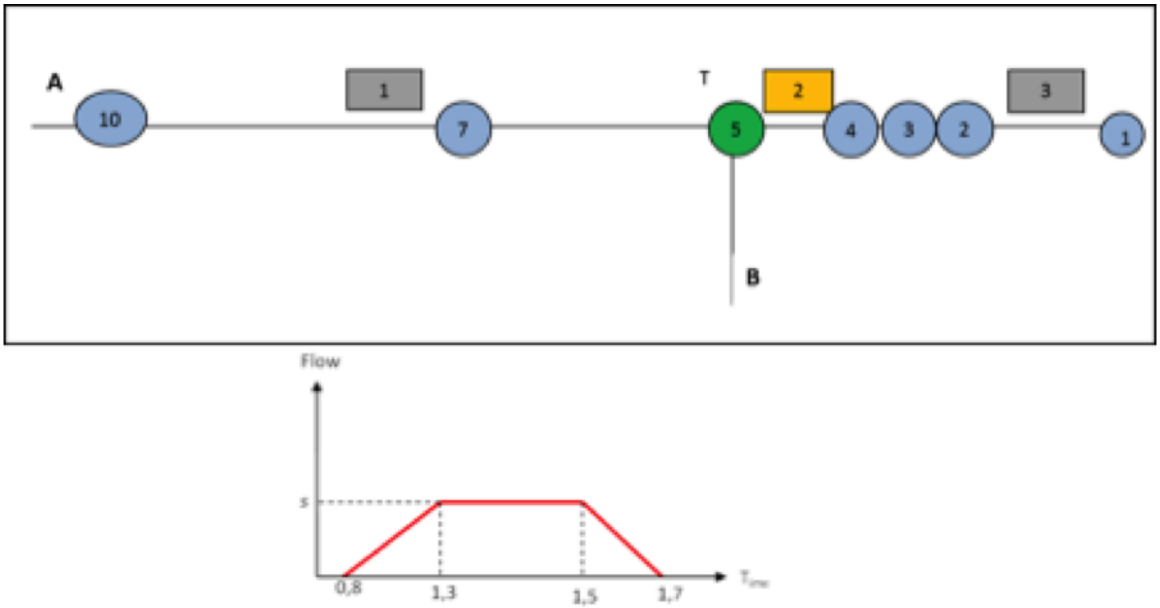

Figure 3: Stations and initial transit vehicle position in the model

Four different cases are considered in order to obtain the number of passengers that successfully board transit vehicle 2 at T coming from line B, as shown in Figure 4.

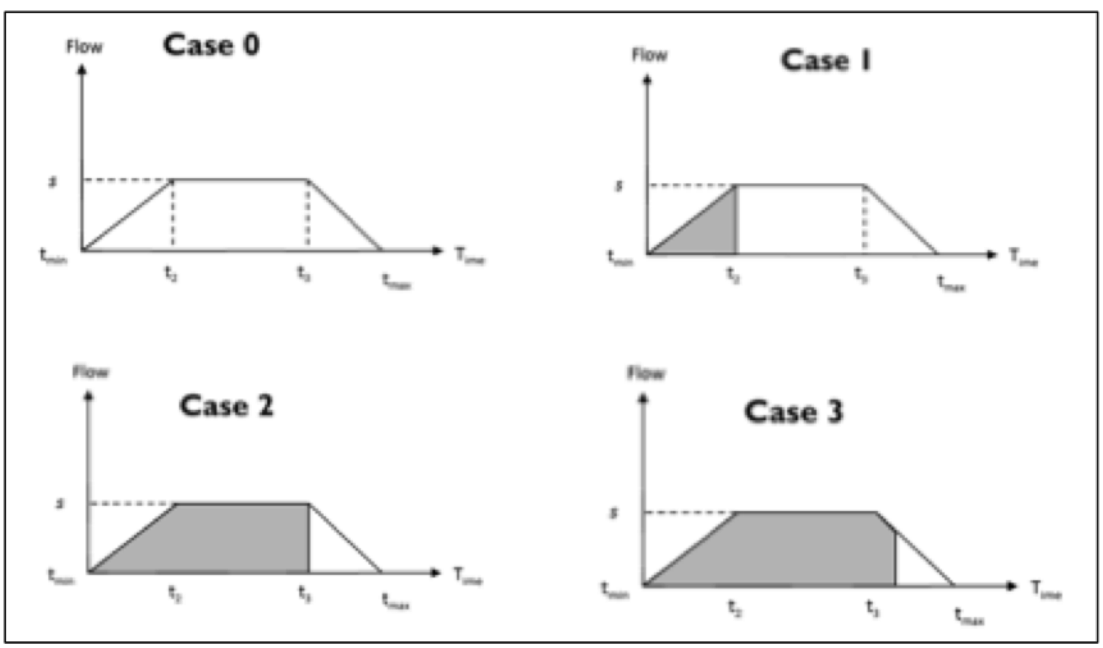

Figure 4: Transfer cases

The results for the case study are shown in Table 1. In red is highlight the optimal value for this instance, which belongs to Case3.

Case 0: No Transfer				Case 1: With Transfer				Case 2: With Transfer				Case 3: With Transfer			
OF	holding	#pax transfer		OF	holding	#pax transfer		OF	holding	#pax transfer		OF	holding	#pax transfer	
		train2	train3			train2	train3			train2	train3			train2	train3
1632.48	0	0	120	1572.16	0.75	54.55	65.45	1485.44	0.93	98.18	21.18	1473.19	1.00	111.30	8.70

Table 1: Results for case study

For Cases 1 and 2 the solution obtain indicates that we must transfer as much passenger as we can. This gives as the idea that for this specific instance the best solution will be Case 3. In this case, we can see that the solution indicates that the optimal number of passengers that will transfer to transit vehicle 2 is in between the time boundaries t_3 and t_{max}.

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