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An investigation of timed transfer coordination using event-based multi agent simulation

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ABSTRACT

While transfers extend transit service coverage by omnidirectional connections, poorly coordinated transfers significantly increase passenger waiting time, especially in case of missed connections. This paper proposes a simulation approach to investigate the feasibilities of different timed transfer strategies in both schedule planning and operational control. In particular, an Event-Based Multi-Agent Simulation (EMAS) model is proposed, that captures the interactions between the transit vehicles, its passengers and the (urban) environment by considering the transit vehicles and passengers as separate classes of agents which interact in a dynamic system. The model is validated by using observed Automatic Vehicle Location (AVL) and Automatic Fare Collection (AFC) data from two routes with transfers in South East Queensland, Australia. EMAS is then used to evaluate different timed transfer strategies for both schedule planning and operational control. The analysis on timed transfers in schedule planning provides valuable insights on the probability of missing a transfer and extra waiting time for transfer. Six different strategies for timed transfers in operational control are thoroughly tested, including an elaborate sensitivity analysis of the effectiveness of the strategies for different levels of transferring demand and schedule headways. This paper assists transit operators to exploit observed AVL and AFC data to augment the transfer coordination quality.

1. Introduction

In large metropolitan cities, the transit demand is usually wide-spread over space and time. It is not feasible and cost-effective to provide door-to-door transit services for every origin-destination (OD) pair. The transit system is therefore usually designed by a network of intersecting lines and modes, requiring one or more transfers within a multimodal transit network to complete a journey. While transfer extends transit service coverage by omnidirectional connections of routes and reduces fleet requirements, poorly coordinated transfer significantly increases passenger waiting time; especially at missed connection. Hadas and Ceder (2010) showed that missed transfer is one of the main determinants of service unreliability. Guo and Wilson (2011) suggested that an improvement of transfer coordination would significantly improve the service reliability because from passengers' perspective the number of transfer has much higher cost than other sources of unreliability such as initial waiting time, in-vehicle travel time, transfer waiting time and transfer walking time.

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List of abbreviations

AD	actual dispatch time
AFC	automatic fare collection
AS	alighting stop
AT	alighting time
AVL	automatic vehicle location
BS	boarding stop
BT	boarding time
CD	controlled departure time
CDF	cumulative density function
DT	dwell time
EMAS	event-based multi agent simulation
EWT	extra waiting time
FV	feeding vehicle
PA	passenger agent
PTT	planned transfer time
RT	running time
RV	receiving vehicle
SD	scheduled dispatch time
SEQ	south-east queensland
TF	transfer time
TTT	total travel time
VA	vehicle agent
W	wait time

Transfer coordination therefore becomes essential to enhance transfer service. Timed transfer as defined in Abkowitz et al. (1987) is a transit schedule and operational control problem to improve the probability of two or more vehicles to simultaneously dwell at a transfer terminal and allow passenger transfer. In transit schedule planning, timed transfer defines a value of Planned Transfer Time (PTT) between the schedule arrival of a Feeding Vehicle (FV) to the departure of a Receiving Vehicle (RV) to enable passenger transfer. In operational control, timed transfer defines a Slack Time (ST) on top of the PTT so that a RV is held at a transfer stop to wait until a FV arrives. ST is only used if the FV arrival is behind its schedule.

In an ideal condition without travel time variability where every transit vehicle operates as schedule, PTT would be equal to the amount of time for all transferring passengers to alight from a FV and board a RV while ST would be zero. However, because of travel time variability, transit vehicles dispatch from the depot and arrive to the transfer stop earlier or later than their schedule. While the value of both PTT and ST should not be too tight to accommodate all the randomness in vehicle travel time and reduce missed connection, they could also unnecessary increases total journey time and decreases the overall station capacity utilisation. The objective of timed transfer is to determine values of PTT and ST that improve the transfer service quality by reducing passenger transfer time and probability of missing a transfer. This is a conflicting objective as a small transfer time generally implies a large probability of missed transfer. The determination of ST is even more important, where too tight ST would result in RV holding without a successful transfer because the FV has not yet arrived and too large ST would be unfavourable for on-board passengers as the RV is held at the transfer stop beyond its departing schedule.

Timed transfer is therefore a challenging problem for two main reasons. First, transit vehicle operates in a dynamic environment where various factors could affect its travel time. Variability (of travel time and dispatch time) is an inevitable part of transit operations from dispatch to the end stop of a service. Any model to represent the transit system should sufficiently integrate dispatch time variability and travel time variability in the model. Second, the interaction between passenger demand and transit operations also significantly affects the timed transfer planning. More passenger means longer dwell time and more stopping at stops. High transfer demand also requires special need for a well-planned transfer schedule.

This paper aims to evaluate different timed transfer strategies. An Event based Multi-Agent Simulation (EMAS) model is developed to archive the objective. Urban public transport system has a complex mechanism made of various distributed and interacting entities under dynamic behaviours and phenomena which are not easily captured using statistical or analytical models. This paper solves this problem by integrating travel time variability and passenger demand knowledge from observed Automatic Vehicle Location (AVL) and Automatic Fare Collection (AFC) data to develop a simple EMAS model that effectively represents the transit operation and evaluates different timed transfer strategies. Therefore, this paper extends the prior studies in timed transfer coordination by integrating observed knowledge from AVL and AFC data into the EMAS model to evaluate timed transfer coordination in both schedule planning and operational control.

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