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Demand-responsive public transportation re-scheduling for adjusting to the joint leisure activity demand

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ABSTRACT

Fixed daily trips such as trips to work/school have fixed departure/arrival times and destination points. The recurrent nature of fixed activities facilitates individuals on making more well-informed decisions about the transport mode selection. On the contrary, selecting a transportation mode for non-recurrent leisure trips, which can account for up to 60% of trips in some cities (Transport for London, 2014), is a more complex task due to the fact that individuals have little knowledge about the alternative modal options. In this paper, we try to improve the operations of demand-responsive public transportation systems by increasing their service quality and their ridership related to joint-leisure-trips via timetable rescheduling. First, we model the public transport service re-scheduling problem considering operational regulations and the quality of service. Then, a sequential heuristic method is introduced for re-scheduling the timetables of demand-responsive public transport modes in near-real time and accommodating the joint leisure activity demand without deteriorating the quality of service. The public transport re-scheduling for increasing the joint leisure activity ridership was tested in a case study using user-generated data from social media in Stockholm and the General Transit Feed Specification (GTFS) data from Sweden focusing especially on central bus lines 1 and 4.

1. Introduction

Joint leisure activities can account for up to 60% of trips in some cities (Transport for London, 2014) and require the timely arrival of several individuals at one pre-defined place which can be the location of an event or the location of a leisure activity. Nowadays, non-traditional data sources such as user-generated Social Media (SM) data, Floating Car Data (FCD), Cellular Data (CD) and Automated Fair Collection (AFC) data can provide more insights on individuals' preferences and enhance the location selection process for a joint leisure activity. For instance, Musolesi and Mascolo, 2007 utilized CD logs for correlating the mobility patterns of an individual with the mobility patterns of his friends and acquaintances. Theoretical concepts were also developed by Carrasco et al. (2008), Arentze and Timmermans (2008) and Chen et al. (2014) on predicting agents' mobility based on their social networks. Predicting the trips of individuals and deriving the OD matrices in urban areas are the main objectives of user-generated CD research including the works of De Domenico et al. (2013), Calabrese et al. (2011a, b), Gonzalez et al. (2008), Zhang et al. (2010) and Sohn and Kim, 2008. SM data from social networks like Facebook, Twitter, Foursquare and the image sharing service, Flickr, have also been used for capturing users' activities at different locations and

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day times via advanced spatio-temporal analysis and educated rules (refer to Alesiani et al. (2014), Gkiotsalitis and Stathopoulos (2015, 2016) and Sun (2016).

Processing and analyzing continuously updated user-generated data over time provides a better estimate of individuals' preferences and enables the selection of a more efficient joint leisure activity location. Unlike fixed trips, the joint leisure activity participants have less knowledge of the availability and punctuality of transport mode alternatives. For instance, one individual is aware of the alternative mode options for traveling to his/her work place but he/she is less aware of the mode options, their travel cost and their punctuality (i.e., travel time variability) when it comes to leisure trips to locations that the individual is not familiar with. This lack of information can deteriorate the perceived utility of the activity participants due to: i) the excess waiting time that individuals can wait at the joint leisure activity location until all individuals have arrived there; and ii) the inefficient selection of transport modes that can increase the travel cost.

Works on activity-based models from Miller et al. (2005) and Janssens et al. (2004) described two different decision-making models focused either on perceived utility maximization or rule-based selection. The work of Miller et al. (2005) focused on the selection of transport modes for participating at activities from all members of a household by utilizing the concept of Random Utility Maximization (RUM) and adding constraints to the selection problem (i.e., private mode availability subject to the use from another member of the household). Although, the literature on disaggregate (e.g., Asensio, 2002) or tour-based (e.g., Bowman and Ben-Akiva, 2000) mode choice is vast, the work of Miller et al. (2005) is one of the closest prior arts since it tackles the problem of mode selection for a joint activity from several household members. However, the transport mode selection for a joint leisure activity has a higher complexity level than the household-based activity planning because: (i) joint leisure activity participants start their trip from different origins and not from a common location (i.e., not necessarily home-based), (ii) the arrival time punctuality at the location of the leisure activity matters since the arrival time variance of all activity participants should be low to avoid excess waiting before the activity starts.

Due to that, this paper focuses on modeling and improving the joint-leisure-activity ridership of demand-responsive transportation via rescheduling the timetables of public transport modes subject to a set of operational constraints. In Section 2, the problem of public transport service re-scheduling considering operational regulations and the quality of service is modeled. In Section 3, a computational efficient heuristic search method for dynamic re-scheduling the public transport schedules of demand-responsive systems and increasing their ridership related to joint leisure trips is introduced. Finally, a case study utilizing Social Media and the General Transit Feed Specification (GTFS) data from Stockholm is presented in Section 4, followed by the concluding remarks in Section 5.

2. Modeling the public transport rescheduling problem for increasing the passenger ridership related to joint leisure activity trips

To increase public transportation ridership for trips related to joint leisure activities, the planned schedules of public transport modes should be adapted the joint-leisure-activity travelers' requirements. Demand responsive public transportation (DRPT) has been viewed as a mean of passenger communication with the transport operator in a direct way allowing the transport operator to create custom routes based on a priori knowledge of the passengers' locations, destinations, and schedules (Mauri and Lorena, 2009; Castex et al., 2004).

In this paper however, we assume fixed DRPT routes where only their timeschedules (i.e., departure times) can change subject to spatio-temporal demand variations related to joint leisure activities. The key individual-based data for deriving Joint Leisure activities demand variation in space and time is obtained from Smartphone apps that can open one-way communication channels between the travelers and the public transport operator (i.e., social media apps). In the past, smartphone apps have utilized for improving dynamic travel decisions (Dickinson et al., 2014). In our work, Smartphone data from Social Media Apps is transmitted to the control center of the transport operator (either via direct transmission or via a data crawling campaign) and provides information of joint-leisure-activity demand for adapting the DRPT operations to it via changing the planned timeschedules.

Let us assume that over the time period of a day a number of public transport trips $\pi = \{\pi_1, \pi_2, \ldots, \pi_\pi\}$ can serve joint leisure activity passengers. Those public transport trips belong, in general, to different public transport services while, some of them, can belong to the same public transport service (i.e., the bus service line). Let for instance a trip $\pi_i \in \pi$ to be part of a public transport service p. This public transport service has a planned daily schedule (service timetable). If this service serves $S_p = \{S_{p,1}, S_{p,2}, \ldots, S_{p,|S_p|}\}$ public transport stations and has a number of n_p trips during the day, where the trips are denoted as $K_p = \{K_{p,1}, K_{p,2}, \ldots, K_{p,|K_p|}\}$, then the planned daily schedule of service p is represented by a D: $|K_p| \times |S_p|$ dimensional matrix with integer elements denoting the planned arrival time of each trip $K_{p,j} \in K_p$ to each station $S_{p,i} \in S_p$.

Let $S_{p,i} \in S_p$ be the station of trip $K_{p,i} \equiv \pi_i \in K_p$ where one or more boardings from joint leisure activity passengers can occur and $S_{p,j} \in S_p$ be the alighting station of the joint leisure activity passenger/s which is the closest station to the location of the joint leisure activity Λ. The joint leisure activity passenger will be more tempted to use this public transport service if the alighting at the destination station occurs close to the time of the joint leisure activity. Given the joint leisure activity location Λ and the starting time of this activity t, we introduce a utility score for using the public transport service:

$$z = (t - t^w - D_{K_{p,i},S_{p_j}})^2 \tag{1}$$