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Estimation of Origin-Destination matrices under Automatic Fare Collection: the case study of Porto transportation system

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Abstract

Entry-only Automatic Fare Collection (AFC) systems are widely used in urban transports. Its main advantages include easy usability by passengers, improvement of the efficiency of revenue management, adequacy to integrate inter-modality approaches, easy cooperation between operators, systematic data collection and gathering tools, contributing to improve the planning process. This work starts with the literature review on applications of the Trip-Chaining Method (TCM) to the estimation of Origin-Destination (OD) matrices using entry-only AFC data. The main contribution of this study is to provide an OD matrix for the city of Porto, allowing to improve the quality of its public transport system. The paper reports the implementation of the TCM to estimate the alighting locations at the disaggregated level in the case study of Porto. The main assumptions adopted are: passengers start the next journey stage at or near the alighting location of their previous trip, passengers end the last trip of the day at the boarding location of the first trip of the day, passengers can only alight in the sequence of stops not yet traveled by the route / direction they boarded, passengers have a maximum interchange distance, above which the destination of that journey stage is not inferred.

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Keywords: Automatic Fare Collection (AFC); Urban Transportation Systems; Optimization; Origin-Destination (OD) matrix

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1. Introduction

Public transport is essential to urban sustainability, by enhancing the mobility of citizens, by reducing traffic congestion and air pollution, and by contributing to social equity. The mobility patterns in urban areas have changed dramatically during the last decades, mainly fostered by the socioeconomic growth, by the increased demand for personalized mobility and by the urban sprawl (Kepaptsoglou and Karlaftis 2009). The increasing ownership of private vehicles pressures a decrease on the share of public transports in daily commuting. At the same time the demand for urban transports has increased together with the growth of cities (Ibarra-Rojas et al. 2015). Several efforts have been made to boost the use of public transports, such as improving the quality of the transportation service, improving the capacity of lines and its service frequency, coverage, reliability and comfort (Kepaptsoglou and Karlaftis 2009), enhancing traffic safety, environmental sustainability and energy efficiency (UNECE 2015).

Urban operators are investing in technology to monitor and store data of real operations. With the technological advent observed in recent decades, urban transport operators started to possess the means for the accurate gather and storage of data on the geographic position of buses, travel times, stopping times, and passenger counts. These include Global Positioning System (GPS), farebox and Automatic Fare Collection (AFC) systems, among others. From these means, operators improved real time control practices, with the dynamic handling of unexpected events in operations, as well as the planning phase, with the construction of solutions aligned towards the specificity of each system.

During the last two decades, several studies applied the Trip-Chaining Method (TCM) to estimate the alighting stops in transportation systems using entry-only AFC. The estimation of the alighting stops in these systems enables the inference of the respective Origin-Destination (OD) matrices. This procedure for the estimation of OD matrices is more accurate and of lower cost than the traditional manual surveys. The relevance of studying algorithms able to infer OD matrices in transportation systems with several operators sharing the same ticketing system relates not only with transport demand estimation, it is also vital for the different operators to base the ticketing revenue management.

This work reports the implementation of the TCM to estimate the alighting locations of journey stages at the disaggregated level in the case study of Porto, considering four assumptions: passengers start the next journey stage at or near the alighting location of their previous trip (Barry et al., 2002), passengers end the last trip of the day at the boarding location of the first trip of the day (Barry et al., 2002); passengers can only alight in the sequence of stops not yet traveled by the route / direction they boarded (Trépanier et al., 2007); passengers have a maximum interchange distance, above which the destination of that journey stage is not inferred (Nunes et al., 2016). The dataset used in this study encompasses all trips made in Porto by bus, tram and metro for one month. The results are further used to estimate the OD matrix of this system.

2. Literature Review

Nowadays, AFC systems are widely used in urban transportation systems. Entry-only AFC systems require the passengers to tap a smart card only when entering the system, whilst entry-exit AFC systems require the passengers to tap a smart card when entering and leaving the system. Operators have been investing in AFC systems, with the main motivation of improving the efficiency of ticketing and revenue collection processes. Nevertheless, these systems encompass many advantages, including easy passenger usability, improved efficiency of revenue management, easy integration of inter-modality, easy cooperation between different operators, systematic data collection and gathering tools (Barry et al., 2009; Nunes et al., 2016). The data obtained from these systems is more accurate, cheaper and of faster availability than the data retrieved from manual surveys (Barry et al., 2002), and can be mined to improve the planning process and to quantify travel patterns.

The data collected through AFC systems cannot be directly applied to estimate OD matrices. The main tasks addressed in the literature to enable the estimation of OD matrices from AFC data are: i) inference of boarding locations, ii) inference of alighting locations, iii) estimation of route / service and iv) identification of transfers (Nassir et al., 2015). This study focuses on the problem of inferring alighting locations. This problem is usually addressed with the TCM, which estimates the sequence of trips made by each passenger in each day, by connecting trip-legs recorded in each smart card ID. The literature on this topic counts with several implementations to different transport systems worldwide, which differ mainly by the set of assumptions implemented. The following list summarizes the