Travel Behaviour and Society 7 (2017) 34–42

Contents lists available at ScienceDirect

Travel Behaviour and Society

journal homepage: www.elsevier.com/locate/tbs

An examination of the accuracy of an activity-based travel simulation against smartcard and navigation device data

Jeong Hwan Hwang [a], Hyunmyung Kim [b], Sungjin Cho [c], Tom Bellemans [c], Won Do Lee [d], Keechoo Choi [d], Seung Hoon Cheon [e], Chang-Hyeon Joh [a,*]

[a] Department of Geography, Kyung Hee University, Dongdaemun-gu, Seoul 02447, Republic of Korea
[b] Department of Transportation Engineering, Myongji University, Cheoin-gu, Yongin, Gyeonggi-do 17058, Republic of Korea
[c] Instituut voor Mobiliteit (IMOB), Hasselt University, Diepenbeek B-3590, Belgium
[d] Department of Transportation System Engineering, Ajou University, Yeongtong-gu, Suwon, Gyeonggi-do 16499, Republic of Korea
[e] DB Center, Korea Transport Institute, Sejong, 339007, Republic of Korea

A R T I C L E I N F O

Article history:
Received 14 November 2015
Received in revised form 9 January 2017
Accepted 21 January 2017
Available online 1 February 2017

Keywords:
FEATHERS Seoul (FS)
Household travel survey (HTS) data
Simulated travel
Smartcard data
Navigation device data

A B S T R A C T

Activity-based travel simulators have been experiencing difficulty obtaining high quality activity-travel data and network information, which limits the applicability of the simulator to real world problems. For example, accurate information regarding travel time, link traffic volume and trip distribution is essential for sensitivity analysis using an activity-based travel simulator. Survey data, which relies on respondents' memories, is typically inaccurate. The recent development of big data engineering has enabled us to use passively collected big data such as from smartcards and navigation devices; their travel time and spatial information is highly accurate. Activity-based travel simulation based on the household travel survey (HTS) can therefore identify inaccuracies in simulated travels by comparing smartcard and navigation device data. This paper aims to examine the accuracy of journeys simulated by an activity-based travel simulator, FEATHERS Seoul (FS), against smartcard and car navigation device data collected in Seoul. The analysis found that the activity-based simulator performs well and reproduces individual travel decisions, as reflected by the overall trip frequency and distance, but it partly fails to correctly reproduce geographical distributions in flexible, non-work trip destinations. The results imply that an activity-based travel simulator needs to improve its incorporation of geographical characteristics using big data engineering to enhance the simulated travel accuracy.

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1. Introduction

Several practical problems of activity-based travel simulators limit their real-world applicability, despite their potential to better evaluate transportation policy measures (Pendyla and Bhat, 2008). One of their major problems is data accuracy; several review articles (McNally and Rindt, 2000; Rasouli and Timmermans, 2014) dictate the limitations of the traditional four-step model (FSM) in its assessment of contemporary policy measures that focus on transportation demand management and emphasize the potential strengths of the activity-based model (ABM). However, the strength of ABM can only be achieved by securing data accuracy, because of the model's complex and synthetic nature that combines activity engagement, trips, network environments, and individual socio-spatial characteristics.

The only available large-scale data set that can currently be used to estimate the activity-based simulation of individual travel behavior is the household travel survey (HTS), which often has accuracy problems. A wide variety of socio-economic scenario-based policy evaluations are available through activity-based travel simulators that utilize information about individual socio-economic and geographical characteristics and implement individual travel decision models. The simulator typically uses a set of data that includes the census data of population characteristics, networks, and location data regarding transportation environment characteristics and the travel survey data of individual travel record details. Among these, the travel survey data particularly suffers the accuracy problem.

HTS data provides information such as trip start and end times and locations, which are unfortunately generally inaccurate. Travel surveys solely rely on respondents' memories. No one can precisely

* Corresponding author.
E-mail addresses: hwangjhn@naver.com (J.H. Hwang), khclsy@gmail.com (H. Kim), sungjin.cho@uhasselt.be (S. Cho), tom.bellemans@uhasselt.be (T. Bellemans), whiteowl30@gmail.com (W.D. Lee), keechoo@ajou.ac.kr (K. Choi), shc1000@hanmail.net (S.H. Cheon), bwchjoh@khu.ac.kr (C.-H. Joh).

http://dx.doi.org/10.1016/j.tbs.2017.01.001
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remember trip start and end times that were conducted in previous days. Furthermore, respondents may omit some trip records due to memory limitations or, in some cases, privacy reasons. These are the major sources of information inaccuracies for variables such as travel time, trip distribution, and link traffic volume, which are crucial for activity-based model estimations (Cho et al., 2014; Lee et al., 2014).

The inherently problematic nature of travel surveys has prompted use of alternative data sources such as GPS logs and smartcard data. Several research studies have observed improved accuracy for trip frequency, trip duration, and trip distance when employing passive data collection rather than diary design (Park and Schneeberger, 2003; Roorda et al., 2008; Bellemans et al., 2008). Digital technology–based unobtrusive data collection methods by definition outperform their more traditional counterparts in terms of time–space measurement. Therefore, passively collected data is better suited for the particular purpose of transportation planning.

However, activity-based travel simulators have yet to rely on HTS data for estimation, because passively collected data does not provide information about the individual characteristics that are absolutely necessary for simulating travel-related decisions in response to policy scenarios. Thus, the role of very accurate, passively collected data about travel behavior supports activity-based travel simulator's policy scenario evaluation. One way it does this is that passively collected data examines whether the activity-based simulator estimation in a travel diary correctly simulates a journey. That is, the passively collected data does not replace the existing travel diary but provides information about whether the simulated travel behavior represents a real world instance of transportation.

Two types of passively collected data are used to examine the accuracy of an activity-based travel simulator. The first is a transaction-based scanner, and the second is a GPS-based travel detector. The first examines travel using public transportation, while the second examines car travel. The travel scanner and travel detector have different properties, and hence one may expect the results of examining diary-based simulated travel to have different details. Smartcard and navigation device data are respectively representative examples of a travel scanner and travel detector. Several research studies have analyzed the accuracy of bolstering diary-based simulators using either smartcard or navigation device data (Cheon and Kim, 2013; Devillaine et al., 2012; Bouman et al., 2012; Pelletier et al., 2011; Cho et al., 2015). Those studies found that analyzing smartcard and navigation device data can reveal individuals' travel behavior and presents the possibility of analyzing the travel simulator's accuracy (Cheon and Kim, 2013; Devillaine et al., 2012; Bouman et al., 2012; Pelletier et al., 2011). In addition, research to validate the travel simulator has been carried out on the verification of the use of passenger measurement in specific areas and verification using GPS (Park and Schneeberger, 2003; Roorda et al., 2008; Cho et al., 2015). This study proposes a method of evaluating and verifying the accuracy of a travel simulator using big data about travel obtained from various sources.

This paper aims to develop a method to examine the accuracy of the simulated travel behavior by comparing with smartcard data for public mode use and navigation device data for private car use to identify which aspects of diary data should be improved. The main purpose of this study is to evaluate how realistic simulations can reflect and simulate the reality of travel behavior using precise transport big data that reflects reality. Thus, this paper is organized as follows. Section 2 briefly reports the characteristics of travel behavior in Seoul, Section 3 suggests the paper's research concepts, and Section 4 summarizes the analysis results. The paper ends with a summary of the analysis and future research suggestions in Section 5.

2. Study area

Seoul is illustrated in Fig 1; it has a population of 10 million spread over 605 km^2. This is approximately 20% of the country's entire population and 0.5% of its total size. The country's population density is 517 persons per km^2, whereas that in Seoul is 16,542. In other words, the city is highly concentrated as the capital city and densely populated. The area's transportation infrastructure is also highly concentrated. The average number of household members is 2.64. The city has 424 administrative units, called "*dong*," which are also used as transportation analysis zones (TAZs).

The area's public transportation system includes nine subway lines with 311 subway stations, and 411 bus lines with approximately 38,000 bus stops. In total, 11 million trips use public transportation modes each day. There are approximately 3 million registered cars, and 2.4 million people report daily car use. The average car travel time for free floating is approx. 50 min for zone-to-zone, and is weighted 190% in peak hours (7–9 am and 5–7 pm).

Some important characteristics of travel behavior in Seoul that can be summarized by the above-mentioned data are provided as follows. First, travel conducted in Seoul has age and gender distributions as in Table 1, reported by HTS. Approximately 49.4% of the population is male. There are slightly more males than females under 19 years old, whereas there are more females than males over all age classes over 20 years old, as expected.

Fig 2 reports the mode share of Seoul, as summarized by HTS. Approximately 40% of trips use public transportation including metro/train and bus, while private car driving and car passengers account for 23% of trips. Approximately 40% of conducted trips were walking or bike/motorcycle riding.

Fig 3 shows the distribution of trip purposes for Seoul summarized by HTS. While "home" is the highest proportion of trip purposes, "work-related (work, business, back to work)" represents 22% of trips. Non-work, flexible trips including to private educational institutes, shopping, leisure/recreation, bring/fetching, and other trips account for 20% of trips.

Fig 4 represents the distribution of trip start times for Seoul. All three datasets for HTS, smartcard, and navigation devices report that the morning peak is 7–9 am, and the afternoon peak is 5–7 pm. In the morning peak hours, HTS shows the highest proportion, whereas navigation device data reports the lowest proportion. In the afternoon peak hours, navigation device data shows a lower proportion, while HTS and smartcard data show higher proportions.

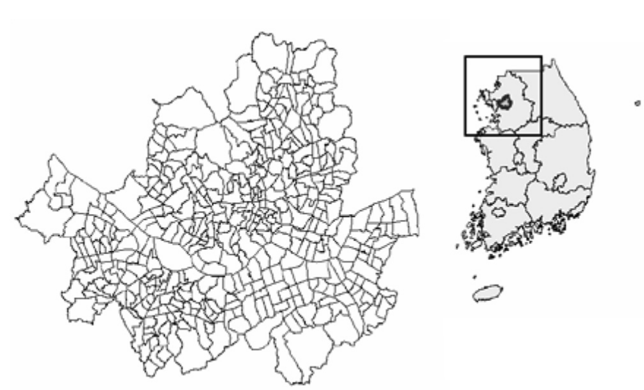

Fig. 1. Seoul, the study area.

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