The Itinerum Open Smartphone Travel Survey Platform

TRIP Lab Working Paper: 2017-102

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With the advent of smartphones, their ability to know their location as well as the ability to develop and easily distribute applications run on them, many options exist to collect location data for many purposes, including travel-related research. While the ability to create smartphone travel survey applications is potentially revolutionary, the development of such applications remains sufficiently difficult to be beyond a typical transportation researcher's ability. Of course, development of an *app* is only the first challenge associated with using such tools; once one has an app and can collect data, one also has to be able to process, make sense of, and infer information from the collected data. The Itinerum platform was created to help overcome both of these barriers facing the use of smartphones for transportation research. The Itinerum platform is a smartphone travel survey platform that allows researchers to tailor the Itinerum app with their own questions and prompts, distribute these surveys, monitor, visualize and increasingly process collected data. This paper describes the origins of the Itinerum platform, its core functionality and two examples of how it has bee used in two studies that were live as the paper was written.

1 Introduction

Since the 1950s, the workhorse for the collection of regional scale transportation demand data has been the household survey. Initially administered in person, face-to-face interviews were replaced in the 1970s with telephone interviews, eventually assisted with computers Meyer and Miller [2001]. One problem confronting traditional surveys is a general trend toward declining response rates, something that has been noted since at least the mid-2000s Stopher and Greaves [2007]. There are several possible explanations for this trend: caller-id display on phones making it easier for people to not respond to unfamiliar telephone numbers; response fatigue as a result of a rise in telemarketing; and decreasing numbers of households/people without fixed telephones. If this trend were randomly distributed throughout the population, it would be less of a concern, but response rates do not appear to be changing in the same way for all demographics. In particular, it has been documented that non-response bias among young adults is common with these traditional data collection methods Bricka et al. [2009]. We have also reported a similar finding in previous work on the topic Patterson and Fitzsimmons [2016].

These challenges have arisen as GPS technologies have come of age, and at the same time as the advent of location-aware smartphones that can operate custom programs called applications (*apps*), available through the app distribution infrastructure of tech giants such as Apple and Google. The potential to use smartphones and their so-called app ecosystems for data collection was observed relatively quickly among transportation researchers. The result has been an explosion in the development of many different apps by researchers in the public (e.g. Hood et al. [2011]), academic (e.g. Cottrill et al. [2013], Safi et al. [2015], Patterson and Fitzsimmons [2016]) and private sectors (e.g. rMove[1]).

While interest in the development of travel survey apps clearly demonstrates their potential, this does not mean they are easily accessible to a typical transportation researcher. There are three main challenges to using smartphones as travel survey instruments. First is the programming of the apps themselves. For widespread use, this requires development on at least the two major platforms (iOS and Android) in two different programming languages. Second, development on the "backend" is required to receive and store the data. Due to the personal nature of the data, expertise in server security and secure transmission of data is essential. Finally, once a researcher has access to the collected data, large amounts of geographic data need to be processed. Once processed, the data need to be converted into useful information such as trip mode, purpose, etc. While many transportation researchers will have had experience with geographic data processing, continual geographic data is large and easily cumbersome. Methods for inferring information from data are developing in many areas and indeed, this is what has received the largest amount of attention in the academic literature.

In the transportation planning literature, this has involved the development of methods allowing the inference of the main aspects of transportation demand required for traditional trip-based transportation demand forecasting, namely: trip origin and destination time and location, trip mode, trip purpose and trip itinerary.

Typically the first information to be inferred from smartphone locational data is the start and stop of trips; also one of the earliest questions to be broached in the literature (e.g. Stopher and Greaves [2007]), but one which continues to have (primarily rule-

[1] https://rmove.rsginc.com

based methods) methods developed (e.g. Zhao et al. [2015], Patterson and Fitzsimmons [2016]).

Mode is perhaps the trip characteristic that has received the greatest amount of attention in the literature with respect to methods used to infer it. As with stop detection, the earliest approaches to detecting mode were rule-based (e.g. Bohte and Maat [2009]). Methods quickly evolved to include discrete choice methods of mode detection (e.g. Bierlaire et al. [2013]) as well as machine-learning approaches, such as Neural Networks (NN) Gonzalez et al. [2010], Hidden Markov Model (HMM), Naïve Bayesian (NB), Bayesian Belief Network (BBN), Decision Tree (DT), Random Forest (RF) and Support Vector Machine (SVM) approaches Reddy et al. [2010], Gonzalez et al. [2010].

Purpose detection, while important in transportation demand forecasting, is also the trip characteristic that has turned out to be the most difficult to infer. Rule-based (e.g. Wolf et al. [2001] approaches were the first to be used and have continued to be used (e.g. Shen and Stopher [2013]), although machine learning algorithms have also been used (e.g. McGowen and McNally [2007], Griffin and Huang [2005].

Finally, the inference of routes or itineraries is another type of processing commonly applied to GPS/smartphone travel survey data. Such methods are not particularly relevant to typical transportation demand forecasting since detailed data on itineraries is typically not collected. As such, these methods have come to the fore as a result of the geographically and temporally precise nature of GPS/smartphone data. Map matching methods have evolved from simple approaches associating GPS points with the closest links or nodes of the network (see White et al. [2000]) to more sophisticated probabilistic approaches Bierlaire et al. [2013]. Such map-matching methods have been applied primarily to road networks and particularly to automobiles (e.g. Bierlaire et al. [2013]) and bicycles (e.g. Hood et al. [2011]). Less common are methods for inferring transit itineraries Zahabi et al.. These methods are being developed on datasets from different sources, each with their own particularities, and often not collected by the researchers working on methods themselves.

It is in to this context that the Itinerum[2] platform inserts itself. The purpose of the Itinerum platform is to facilitate the development, deployment and analysis of travel survey data collected with smartphones. It is hoped that it will be able to allow a community of researchers to concentrate their research efforts around a common tool, and indeed to help contribute to its development, as well as to the development of methods in the use of smartphone travel survey data. The next section describes the motivations, origins and development of the Itinerum platform. This is followed by a section describing the first two case studies using the Itinerum platform. The second to last section describes intended future directions of the platform and the last section concludes the paper.

[2]Itinerum is a trademark of Concordia University, registered in Canada as an official mark.

2 The Origins of the Itinerum Platform

The Itinerum platform is the product of a few years of experience in the development of smartphone travel surveys. Our first experience with a smartphone travel survey was a large scale survey that took place at Concordia University in Montreal, Canada in the fall of 2014. The Concordia "DataMobile" study is documented in Patterson and Fitzsimmons [2016]. It involved the development of the travel survey application DataMobile on iOS and Android. All members of the university community (students, faculty and staff) were invited by e-mail to download the app, answer a short survey and leave the app running in the background for up to 14 days. Over 900 people participated in the survey and 4,100 complete person days of travel were collected.

Subsequently, two other apps were developed based on DataMobile in the fall of 2016. The first was CFSMobile. CFS is the acronym for a Public Health Association of Canada grant called the Canada Food Study[3], a project studying the nutritional habits of 18-30 year old Canadians in five cities (Vancouver, Edmonton, Toronto, Montreal and Halifax). The study is seeking to collect information on ten thousand respondents, with a ten percent subsample of participants in a parallel smartphone travel survey. CFSMobile was the name of the application, based on DataMobile, used in the study in October and November of 2016. Almost 700 respondents participated in the CFSMobile study, a study described in greater detail in Widener et al. [2017], Reid et al. [2017]. The second was MTL Trajet (Trajet means trip in French) a large-scale pilot study undertaken with, and for, the City of Montreal. Unlike DataMobile and CFSMobile, MTL Trajet included prompts at the end of trips. These prompts were triggered when the phone was detected to have stopped. The prompts first asked whether a destination had indeed been reached (transfers along a transit route occasionally trigger a prompt) and then mode and purpose of the latest trip. The sampling strategy for this pilot project was opportunistic in the sense that no formal sampling strategy was used. Recruitment for the study was done through traditional, online and social media, as well as video advertising within the city's metro (subway) system. The city's goal was to get 10,000 downloads, which were obtained, and data on 80,000 complete respondent days for travel were collected. Additional information on this study can be found in Patterson and Fitzsimmons [2017]. This spring another instance was developed under the name LAPSMobile (laps.ucs.inrs.ca) for the Institut national de recherche scientifique (INRS) in Montreal. The purpose of LAPSMobile is to study the travel behavior of families with young children.

We referred to the development of applications in this context, i.e. new app instances with different questions and AppStore and Google Play listings, along with new server setups, as the "DataMobile" model of app development. This model, while the ability to administer detailed travel surveys at a large scale with apps was impressive, was not really feasible for a typical transportation researcher. Given the potential for smartphone travel surveys to be used by so many transportation researchers in so many contexts, but given the difficulty of developing apps, setting up servers and analyzing collected data, we decided to take a different approach. This approach became known as the Itinerum

[3]www.canadafoodstudy.ca

platform. Itinerum is a smartphone travel survey app and platform. The platform itself is intended to be a one-stop location for the development and administration of smartphone travel surveys, as well as for the processing of collected data. The Development of the Itinerum platform was made possible by a "Partnership Development Grant" from the Canadian Social Sciences and Humanities Research Council. The partners of the project include both academic (Concordia University, the University of Toronto Scarborough, the University of Toronto and Ryerson University in Toronto) as well as institutional partners (Montreal's regional public transportation planning Agence mtropolitaine de transport (AMT); the bike-sharing system, BIXI; the provincial "Transports Qubec"; and the Montreal transit operator, the Société de transport de Montréal (STM)).

Inspiration for Itinerum comes from open source projects developed by researchers for researchers in different parts of transportation planning, such as MATSim Horni et al. [2016] and BIOGEME Bierlaire [2003]. While the base functionality for Itinerum is in place (as described in Section 3), the vision is for it to be a community project that transportation researchers will be able to use and contribute to. As such, at the end of the project, the platform will become open. Ideally, the use of Itinerum will contribute to research in various aspects of transportation planning; from empirical work on travel behavior, to methodological work on information inference from smartphone travel surveys, to areas of research which we have not imagined.

3 Itinerum Functionality

The Itinerum platform is made up of two main components; the Itinerum web-platform, and the Itinerum app on Android and iOS. (See FIGURE 1.) The web-based platform itself allows interaction between two main agents: the survey administrator and the survey respondent. The survey administrator is the research organization administering the Itinerum survey. The survey administrator is provided a sign-up code and asked to agree to the terms of use of the platform (e.g. respondent data will be secured and never released in any form that would reveal the identity of a respondent). The survey administrator chooses a survey name and is then able to create a survey.

Survey creation requires that the survey administrator provide a consent form that respondents will have to agree to (it must respect the terms of use) as well as "About" information for the survey. They are also able to include their own logo or icon that will visually personalize the survey to the respondent. Once this obligatory information is provided, the survey administrator can add their own questions and personalized prompts. Survey questions appear when the respondent first opens the app. Typical questions relate to respondent home/work/study location, mode of travel to these destinations, socio-demographics and other questions relevant to a given survey. Location, text, number, checkbox (multiple answers) and dropdown (one answer) questions can be asked in the survey. Prompt questions appear when the phone is detected to have stopped. Checkbox and dropdown questions are available for prompts. Typical questions for prompts are mode and purpose of the last trip. The number of prompts to be asked to respondents, as well as the number of days of participation in the survey can

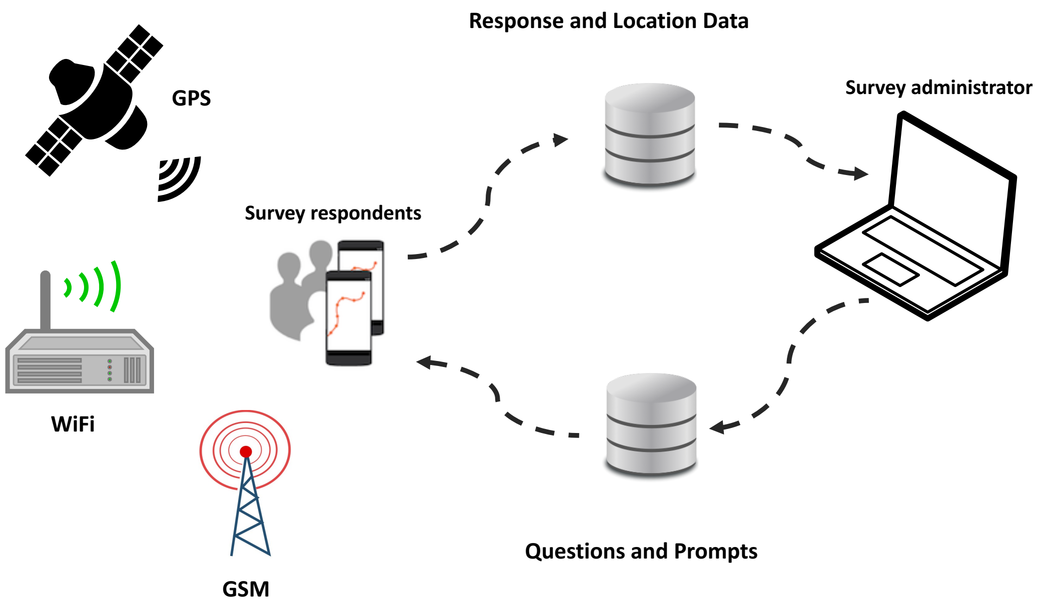

Figure 1: A workflow diagram of the Itinerum platform

be parametrized by the survey administrator.

The stack comprises both existing open-source services and code that will be made publicly available for use by any outside research lab or organization. The central store for data collection is a PostgreSQL database, which allows flexibility in storing denormalized data while providing ACID-compliant transactions for all location data. The custom backend services are 3 RESTful APIs written in Python, which receives and records mobile user updates, displays a web-accessible dashboard for survey administrators to create and monitor ongoing surveys, and provides an internal management panel to allow platform operators for managing active surveys and invitation tokens. Users are managed with roles associating them with a survey and limit access to the allowed endpoints of the web dashboard. Dashboard user passwords and tokens are encrypted using PBKDF2 (SHA-512) key-derivation algorithm, which uses a sliding computational cost to help mitigate brute-force attack.

Each API is packaged within a Docker container to provide a consistent environment when running amongst different cloud providers. A benefit of using containers is each service remains isolated and may be updated independently without affecting other services. For the deployment described in this paper, the Itinerum platform is run on the Amazon Web Services cloud using a load-balancer to deploy additional containers and respond to fluctuations in demand automatically. The database is replicated to minimize interruptions in service from hardware failure and takes an automatic snapshot nightly in the event of needing to restore data to a recent working state. The stack is configured as Infrastructure-as-Code so the platform may be easily cloned to multiple versions (e.g., development, testing, staging) and audited for security. To monitor live server metrics, a Grafana dashboard is used due to monitor time-series events within the Itinerum platform and its dependent cloud services.

The Itinerum app was initially developed as "DataMobile" Patterson and Fitzsimmons [2016] with functionalities being added with each additional release (i.e. CFSMobile, MTL Trajet, and most recently LAPSMobile). The core functionality of the app is as follows. Upon installation, and after agreeing to participate in the study, the respondent is asked to input a survey code. The survey code allows the application to ask the respondent the questions input by the survey administrator. When the respondent comes to a stop, the survey administrators prompts will appear on the respondents phone. Once installed, the respondent does not need to do anything else and trips are automatically logged in the background. All efforts have been made to minimize impact on battery life and GPS is only used when the phone is in transit while being in power-saving mode when the phone is in one location. Collected answers to the survey and prompts, as well as location data over the course of the day are automatically, securely (HTTPS) transmitted to servers managed by the TRIP Lab and located in Canada.

Survey administrators can then access their account and survey on the Itinerum platform. In their account portal they can monitor the number and basic demographics of the respondents to their survey in real time. They can also access survey responses and map the location for each of their respondents. Moreover, all of the data collected can be downloaded. Finally, some processing of the data can also be done. For example, survey administrators can request to have the location data processed so that respondents location data can also be broken in to trips according to the algorithm reported in [Patterson and Fitzsimmons, 2016]. It is also possible for survey administrators to parametrize this algorithm and add location specific information on the location of subway stations and tunnels to help the algorithm perform better. (See screenshot of platform in FIGURE 2.) As information inference methods are developed (e.g. Zahabi et al.) as part of the Itinerum project, they will be added as additional functionality to the data processing on the platform.

4 Itinerum Case Studies

Although a number of studies, mentioned above, have already been undertaken using the code underlying the Itinerum app, the platform only became operational in May of 2017. Since then, two different studies have been launched using the Itinerum platform; that is, survey administrators have created their own survey and prompt questions and asked respondents to download the Itinerum app to participate in their studies. One of the studies has been undertaken by the Montreal transit operator, the Société de transport de Montréal (STM); the other has been undertaken by two researchers at the University of Toronto Scarborough and the University of Toronto.

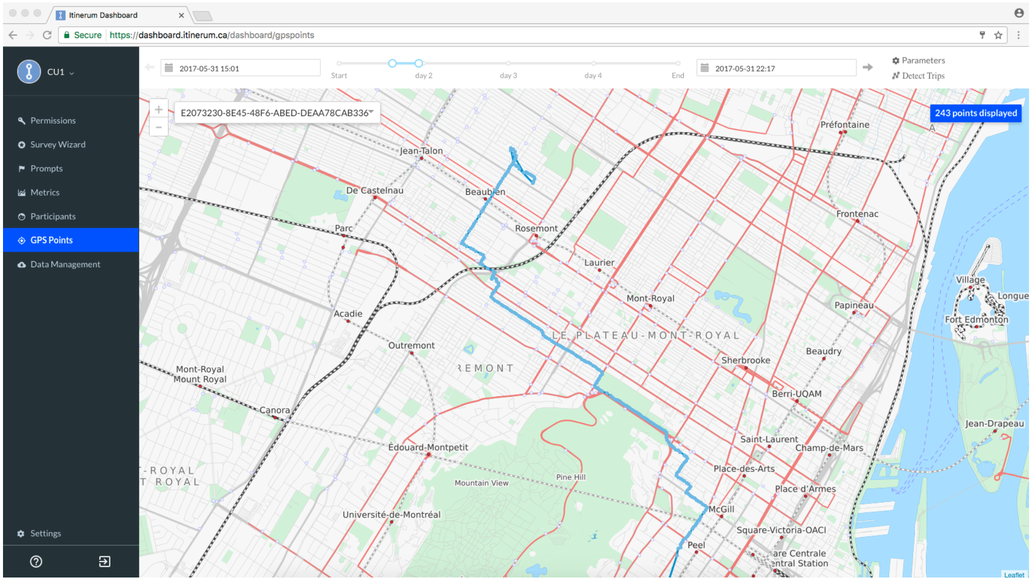

Figure 2: The Itinerum Dashboard displaying points of a respondent (the author)

4.1 STM Multimodal Study

The STM study is being done in collaboration with both the BIXI bike-sharing system and Ville de Montréal. There are a number of motivations for the STM to undertake this study. The first is that the top priority of the STM's strategic plan 2020 Société de transport de Montréal [2012] is to further develop their services. The second of five strategies to do this is to diversify and improve the supply of services of the surface network. One of the axes of intervention to do so is to improve intermodality and encourage the use of "combined mobility." The notion of combined mobility is that several modes can be used together to facilitate the transfer from single occupant vehicle to transit and eventually reduce the number of cars owned. One important aspect of the integration of modes is that between transit and active transportation modes like bike-share systems. Even if one conclusion from the current literature on bike-share systems is that their success has not come at the expense automobile use, but rather of active and public transport Fishman et al. [2013], Montreal sees an opportunity to make bike-sharing and transit work more closely together. As such, the STM, along with BIXI and the City are seeking to better understand combined mobility with a special interest in understanding bike-share user behavior, in order to better integrate bike-share users into the transit system. Finally, even if the STM has data from smart card, AVL and ticket sales data, there's almost no other information about transportation behavior on other modes in the summer; the quinquennial regional household survey being administered during the fall.

As a result, the STM and BIXI have developed an Itinerum survey with the aim of better understanding the interaction between different modes of transport and the transit system in the summer (stm.info/itinerum). To this end, they launched their survey starting the 3rd of July and ending on august 4th. Survey questions are a mixture of standard home/work/study location travel mode between these locations, socio-demographics and questions about modal options available to respondents. For those who have BIXI memberships, their account numbers are asked to allow integration of BIXI data in subsequent analysis. Prompt questions relate to trip purpose, as well as a fine grained multi-option mode of travel for the last trip.

The sampling approach has been opportunistic in the sense that a formal sampling strategy has not been sought. Instead they have been publicizing the survey through e-mail campaigns to members of the STM and BIXI databases, newspapers, as well as through their websites, and social media campaigns via Facebook and Twitter. Respondents are able to participate for up to one week and are allowed to "validate" (answer prompts) on up to 50 trips. Respondents who participate for one week will be entered into a draw to win a number of prizes ranging from an iPad to monthly or yearly transit and bike-share passes. At the time of writing, the survey has resulted in 2,468 respondents signing up to the survey in English and French. There have also been 36,000 trips validated and 12,000 complete days of travel recorded. Since results are still coming in further analysis is required before additional results can be reported.

4.2 UofT Study: Transport Inaccessibility as a Barrier to Participation

The second case study is one led by Assistant Professor Steven Farber of the University of Toronto Scarborough and Assistant Professor Michael Widener of the University of Toronto. The purpose of this study is to evaluate the degree to which transport inaccessibility can be seen as a barrier to participation in activities. Equity in transportation planning has become an important stream of research and planning policy. The desire to take equity considerations into account in planning decisions goes back to at least the 1970s (Lichfield et al. [2016], Krumholz [2011]). Equity in planning was defined by Krumholtz et al. 2011 as the goal for government institutions to give priority to promoting a wider range of choices for residents who have few if any choices. This notion of equity ties in with Chitwood's 1974 oft-cited notion of "vertical equity", which implies equity in the distribution of government services to heterogeneous groups of people (e.g. disadvantaged and wealthy). Interest in equity in transportation planning became more popular in the 1990s as researchers and policy makers began to see equity as an important planning goal (e.g. Masser et al. [1992]. It was also at this time that work began on how to operationalize the concept in planning decision-making (e.g. Khisty [1996]). More recently, researchers have begun examining the role that transportation (and public transportation in particular) plays in providing mobility and accessibility to those without other options, how this affects social exclusion and economic outcomes, and importantly how these differ across different groups of people (e.g. Hine and Mitchell [2001], Lucas [2012]). Interestingly, while intuitive, there is little evidence to support claims that increasing accessibility results in greater levels of participation in activities. Moreover, there is little empirical evidence on the degree to which people are impeded from participation in activities (i.e. excluded from them) as a function of accessibility by transit. This UofT study seeks to gather empirical evidence to test this claims.

In order to do this, the study is looking at residential towers in suburban Toronto characterized by different levels of transit accessibility and income. The goal is to tease out the degree to which residents are satisfied with their ability to access activities through the transit system at different levels of income and accessibility. One aspect of satisfaction is whether or not they are prevented from participating in activities as a result of insufficient accessibility, i.e. whether they are excluded. This distinction is important since people may not participate in activities voluntarily, which should not be considered exclusion. As such, they are seeking to recruit one hundred respondents from four categories of suburban residential towers: low income, high accessibility; high income, high accessibility; low income, low accessibility; and high income, low accessibility. The study was launched in mid-june 2017.

In the survey portion, typical basic socio-demographics as well as frequent travel information is asked. In addition to this, questions about the presence of factors enabling or facilitating transportation by different modes (e.g. bus passes, free parking, etc.) are asked. Finally, respondents are asked about their satisfaction relative to the number and quality of activities in which they can participate. Maximum participation in the survey is 7 days, with no maximum on the number of trips they can validate. In order to encourage participation, respondents are given $5 gift certificates for a local coffee shop, with an additional one being sent to them if they participate in the survey for 7 days.

Since, as with the STM survey, this survey was in the field at the time of writing conclusive results are not available. However, at time of writing, the survey has resulted in 213 respondents signing up to the survey. There have also been 2,075 trips validated and 1,141 complete days of travel recorded.

5 Future Directions and Conclusions

Although, not under the name of the Itinerum app, two other surveys will also be undertaken. The first will be another large-scale survey with the City of Montreal under the name of MTL Trajet in the fall of 2017. Also, the University of Toronto Transportation Research Institute will include a version of Itinerum on iOS as part of their evaluation on the future of travel surveys for their TTS2.0 project.

Apart from additional surveys using the Itinerum platform, our goal is to develop information inference algorithms based on the data that has been (and is being) collected through the platform. These algorithms will, over time, be incorporated into the platform itself. At the end of the SSHRC Partnership Development Grant funding the Itinerum platform will be made open. The aim and goal of this is to ensure the sustainability of the project, and to help it develop further as users contribute to the project while undertaking research that can benefit from the collection of travel data.

The number of projects that have now been undertaken with the Itinerum app, and those that are currently being undertaken show several things: first, that the platform now has a solid framework from which to administer smartphone travel surveys; second, it shows an interest within communities of academic and institutional transportation researchers for such a tool. It is hoped that with further developments of the platform and its transition to an open project it will help the smartphone travel survey to reach its potential in transforming research in transportation into the future.

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