TimeUse+
A comprehensive app-based longitudinal study of travel, time use, and expenditures

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Author(s):
Winkler, Caroline; Meister, Adrian; Schmid, Basil; Axhausen, Kay W.

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TimeUse+: A Comprehensive App-based Longitudinal Study of Travel, Time Use, and Expenditures

Caroline Winkler
Institute for Transport Planning and Systems (IVT)
ETH Zürich, 8093 Zürich, Switzerland
Email: caroline.winkler@ivt.baug.ethz.ch
ORCiD: 0000-0002-0733-8990

Adrian Meister
IVT
ETH Zürich, 8093 Zürich, Switzerland
Email: adrian.meister@ivt.baug.ethz.ch
ORCiD: 0000-0002-3350-9044

Basil Schmid
IVT
ETH Zürich, 8093 Zürich, Switzerland
Email: basil.schmid@ivt.baug.ethz.ch
ORCiD: 0000-0002-3310-9083

Kay W. Axhausen
IVT
ETH Zürich, 8093 Zürich, Switzerland
Email: axhausen@ivt.baug.ethz.ch
ORCiD: 0000-0003-3331-1318

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ABSTRACT

The ubiquity of smartphones has shaped how individuals shop for the goods they wish to consume and how they acquire said goods, whether it involves visiting a physical store or having an item delivered to one’s doorstep. Smartphones have also enabled a “sharing economy” of mobility tools such as car and bicycle sharing that has expanded the array of options available to travel to chosen destinations. Because consumption and travel research is rarely conducted in tandem, we do not have a clear picture of how individuals choose to use different forms of transport to effectively make use of their time, nor how much money is generally spent during everyday activities. Gaps also exist in the literature concerning secondary activities undertaken during travel or at home, what kind of activities (or portions thereof) participants perceive as committed (i.e. necessary), and how several contextual factors affect these behaviors. This paper will present the planned study design developed to identify and analyze the exact mechanisms that drive mentioned behaviors. We will use a hybrid survey method with passive app-based tracking and a conventional survey tools to capture time use, travel, and expenditure data along with sociodemographic, attitudinal, and psychological metrics for a representative sample in German-speaking Switzerland over an entire month.

Keywords: smartphone survey, GPS tracking, travel behavior, time use, household expenditures
INTRODUCTION

Travel behavior research allows us to better understand how and why people navigate their physical environment. Such information serves to inform policy making and transportation planning, leading to improvements in a wide variety of aspects of everyday life from road quality and accessibility to train comfort and level of service standards. Travel diaries are the primary medium by which relevant data are collected to derive metrics that explain how individuals value their travel experiences, whether they are traveling to or from work, off to meet a friend, or picking up groceries. They capture individuals’ mobility behavior in context of the activities they perform over an entire day to obtain a complete picture of individuals’ travel decision-making processes, taking sociodemographic characteristics, past behavior, perceptions, and attitudes into consideration. The most important of the components mentioned can be summarized as time use (activities), travel, and spending (expenditures), which are essential to determine how individuals value their limited 24-hour days.

Jara-Díaz and his colleagues (1, 2) developed a microeconomic framework that pieces together this information into a time use and expenditure allocation model given by

\[ U = \theta_w \log(T_w) + \sum_{i=1}^{n} \theta_i \log(T_i) + \sum_{j=1}^{m} \varphi_j \log(E_j) \]  

(1)

where \( \theta_w \) captures baseline utility of time assigned to paid work \( T_w \), \( \theta_i \) is the baseline utility of time assigned to an activity \( i \), or \( T_i \), and the baseline utility of expenditures on good \( j \) is \( \varphi_j \) and the amount is captured in \( E_j \). Time \( T \) and expenditures \( E \) enter the maximization equation externally and are subject to constraints, i.e. a travel decision is thereby put into time use and expenditure constraints (see (3) for a list and discussion of all pertinent equations and their components).

Evidently, measures of working time along with time assigned to freely chosen activities and money spent on freely chosen goods are needed to evaluate such time value metrics. Traditionally, paper-and-pencil time use and travel diaries have allowed researchers to capture these data. In more recent years, technological advances and the ubiquity of smartphones has prompted researchers to integrate such information and communication technologies (ICT) into the latest surveys. As will be discussed, few time use and travel diary surveys include a component that captures expenses that come with certain activities performed throughout a given day, data central to the estimation of travel time value metrics like value of travel time savings (VTTS) and value of leisure (VoL). VTTS informs policy makers how much individuals are willing to pay to reduce their travel time by one unit, a value that directly and substantially enters cost-benefit analyses (4).

This value has been decomposed into its two components, VoL, the value of time as a resource (i.e. doing something other than traveling) and the value of time assigned to travel (VTAT), which may be positive or negative, and is derived by subtracting VTTS from VoL (5,1). To date, only the Mobility-Activity-Expenditures-Diary (MAED) (6) and Post Car World (PCW) (3) surveys have managed to do so, both exclusively using paper-and-pencil diaries and covering a single week of participants’ lives.

With the intention of building upon the MAED and PCW surveys, we developed the TimeUse+ survey, which includes a mobile application with passive GPS tracking and an active validation component. TimeUse+ aims to be the first survey to use a mobile application to collect rich time use, travel, and expenditure data collected over the course of four weeks for a large sample. The following section of this paper will give a brief overview of existing time use, travel, and expenditure surveys as they are typically conducted. This is followed by an overview of important
gaps in time use and travel literature that we also aim to uncover with our innovative survey platform and the comprehensive dataset it yields. A third section describes the methodology behind the TimeUse+ project, and the last section presents a summary of the planned survey.

4 LITERATURE REVIEW
As in most developing countries, Switzerland has seen a stark increase in use of the Internet since it came about. Rates of Internet usage for persons over the age of 14 is at 92% (compared to 77% in 2011), 87% of whom also use mobile Internet, i.e. smartphones (7). Even when differentiated by age group, 77% of Swiss adults between the ages of 50 and 69 access mobile Internet, and 34% of those over the age of 70 (7). The capabilities of mobile Internet devices are far and wide, making it no surprise that they made their way into empirical studies. Basic smartphone capabilities like GPS, bluetooth, and accelerometers can easily be integrated into mobile applications to better understand individuals’ movements around a given city. We will take advantage of the capabilities of such devices today to collect time use, travel, and expenditure data using an app that passively tracks participants and asks them to validate existing and complete missing information in a diary component. Before we describe our TimeUse+ survey, however, we will discuss the current standing of time use, travel, and expenditure surveys, as well as some gaps in the literature that still merit attention.

18 Time use surveys
Time use surveys record activities an individual engages in throughout an entire day. Most countries’ federal governments conduct time use surveys every couple of years to have an updated idea of how its residents spend their time doing (un)paid work and leisure activities. In larger countries like the United States, time use surveys help uncover which regions have a higher quality of life, for example, which is used to determine in which areas older adults have a high sense of well-being or are completely struggling. The American Time Use Survey is conducted by the U.S. Census Bureau, and their method involves calling participants and asking them to recall the previous day from 4 a.m. to 4 a.m. the morning of the telephone interview. The study conductor asks participants how many hours they usually sleep and which activities they completed that day, for how long, and with whom (8).

The Swiss government itself does not conduct a time use survey, but FORS (9), the Swiss Centre of Expertise in the Social Sciences, conducts the Swiss Household Panel, a yearly panel survey that collects metrics similar to that of a traditional time use survey using a telephone interview. Harmonised European Time Use Surveys (HETUS) (10) have been conducted in 15 European countries in 2000 and 18 European countries in 2010, and the third round planned for 2020 has been delayed by many countries due to the COVID-19 pandemic. Organized by Eurostat, the statistical office of the European Union, HETUS uses standardized guidelines to make results highly comparable between countries and across rounds. Its survey instruments include a personal questionnaire, a household questionnaire, and a time use diary used to record activities in 10-minute intervals during one weekday and one weekend day. Dutch researchers recently tested the feasibility of conducting time use research using mobile apps designed in line with HETUS guidelines and deemed data quality to be acceptable for both experienced and inexperienced smartphone users (11). Elevelt and colleagues (12) later used the final version of this application with the Longitudinal Internet Studies for the Social Sciences (LISS) panel (representative of the Dutch population), as usual recording activities performed every 10 minutes for one weekday and one weekend day.
Though nonresponse rates were deemed similar to those of offline surveys, their estimates did suffer from nonresponse bias; that is, similar groups of people were more/less willing to complete several portions of the survey. A potential for such biases must be taken into account when designing a study, though several strategies like providing rewards or maintaining commitment can help counteract these challenges.

**Travel surveys**

Travel diary surveys are also ordinarily paper-and-pencil format, and participants are asked to report all trips made within a day or two to get a complete picture of individuals’ mobility patterns. State-of-the-art is to use activity-based travel diaries, as a day’s activities are easier for participants to recall, and trips they take to arrive at the location where activities take place are thereby put into context. These make them similar to time use surveys, as activities stand in the forefront, yet without the short time slots. Information captured usually includes start time and location of a given trip, mode used for travel, costs if applicable, trip purpose (activities), arrival time and location of the destination, and whether any known person accompanied the trip. Both MAED and PCW captured these characteristics in a similar fashion. The main difference is that MAED asked participants to report all activities performed at the destination by choosing from a predefined list of activities and having participants specify activity duration and money spent, in similar fashion to HETUS surveys. The PCW survey, on the other hand, simply asked participants to choose a single trip purpose from a list. While this difference arguably allowed for a more differentiated picture of time use in the MAED study because multiple activities per location could be captured, PCW included an online survey that documented how much time participants spent online during a given day (along with expenditures) that allowed them to discriminate a degree of ICT-enabled leisure time.

Moreover, most countries conduct some form of a national travel survey regularly. Though no uniform guidelines similar to HETUS for time use surveys exist for travel surveys, recent efforts have been made to harmonize national travel statistics in Europe by the OPTIMISM Project. In Switzerland, the Federal Office for Spatial Development (ARE) together with the Federal Statistical Office (FSO) conduct the Mobility and Transport Microcensus (MTMC) every five years to statistically evaluate Swiss travel behavior. Computer Assisted Telephone Interviewing (CATI) is used to compile information on personal sociodemographic characteristics, household size and structure, the number and types of vehicles they use and own, and to describe mobility for an entire given day, i.e. all trips made on a single day including mode choice, trip purpose, and other characteristics. The 2020 round of the MTMC has tentatively been postponed, but its data will be used for comparison with TU+’s data as soon as it is made available. Unsurprisingly, mobile phones have successfully made their way into travel diary surveys since the early 2000s. Originally inadequate, GPS-enabled smartphones today are seen as a promising alternative to traditional survey forms.

**Expenditure surveys**

Household budget or expenditure surveys are performed once every few years in virtually every country around the globe. Often performed by government agencies, such surveys help us understand how much individuals in a household earn each month and on what kinds of goods and services this income is being spent. Most countries’ expenditure surveys are conducted once yearly and intend to capture both daily and long-term purchases. In the United States, for example, the
U.S. Census Bureau uses a Diary Survey to capture daily goods such as groceries and personal care products and an Interview Survey for larger expenditures such as rent, insurance, and mobility (16). The Swiss Household Budget Survey (HBS) is similar, and recruits a new set of participants to begin each month of the year (17). Participants receive three booklets to complete: one each for daily and larger expenditures, and a third to record large sums of regular and irregular income of over 300 Swiss Francs (e.g. salary and sales revenue).

As previously stated, the PCW (3) and MAED (6) studies have been the only mobility studies to date to integrate and collect expenditure data as it is needed for the time and expenditure allocation model (2). Other attempts at deriving the VoL without having explicitly collected expenditure data has been done by merging separately probed time use and expenditure data, that is, from a different set of respondents, thereby yielding a synthetic and probabilistic dataset used for estimation (18). The PCW and MAED surveys collected expenditure data within the same study by asking for information pertaining to larger, or long-term, expenditures within their household surveys, as is done by national budget surveys. Daily, or short-term, expenditures were captured by PCW using a separate diary participants were asked to complete daily along with the travel diary. It includes predefined categories (e.g. groceries, food and accommodation, clothing) that participants crossed off and reported the amount spent for that category on a given day. Mobility expenditures were computed for participants based on what type of car they had and whether or not they held a public transportation subscription. MAED included both short-term expenditures for mobility and activities within the travel diary. The price paid for a train ticket could therefore be entered directly into the diary form and expenses on goods were to be filled in by participants and were later coded according to COICOP, the Classification of Individual Consumption by Purpose set by Eurostat, also used for the categorization of expenditures in the Swiss HBS (19, 17). For a comparison of the shares of committed vs. non-committed expenditures for both PCW and MAED and the 2005 Swiss household budget survey, see (20).

Furthermore, several studies to date have incorporated the use of mobile apps to collect daily expenditure data. Understanding Society, the UK Household Longitudinal Study, is a major large-scale project that aims to better understand society as a whole and how its members experience life. Jäeckle and colleagues recently tested a mobile app survey with a representative sample of nearly 2,400 UK Understanding Society Innovation Panel members as part of their Spending Study (21). Of those members, only 273 participants reported a total of 11,468 expenses over the course of a month. Participants were asked to scan all receipts they received from purchases or to manually report a purchase if no receipt was available, and to assign it to one of 11 expenditure categories defined. Though participation was low, authors also report a low drop out rate of only 20% over the entire course of the month (22).

Existing gaps in travel research
This section discusses a selection of relevant elements related to time use, travel, and expenditures that inconsistently and usually independently arise in relevant diary studies that merit further investigation. As recently mentioned by Calastri and colleagues (23), many of these important dimensions are overlooked during data collection, and more should be included in a single survey if the overarching goal is to truly consider travel in the extensive context in which it occurs.
Effects of ICT on travel behavior and secondary activities

Independently, plenty of studies have been conducted investigating the relationship between ICT and travel and time use. In general, ICT is said to either substitute, complement, modify, or not at all change travel behavior (24), whether we consider travel for shopping, work, or leisure activities, or a combination thereof. Performing both personal and work activities using ICT, for example, has been found to free up time that can be used for travel. So, while a substitution effect may be evident for performing errands or work that can be done online, this may lead in an increase in leisure trips, and the effects of ICT on travel can be seen as complementary (25). A review of mobile ICT and physical mobility supports the notion that ICT will substitute and complement travel demand in different situations and that estimating a net effect is therefore difficult (26).

That being said, online activity, and online shopping in particular, is becoming more popular each year, yet not adequately captured in travel diary surveys. Many studies investigate the relationship of travel for shopping purposes to a physical store, but online shopping for goods and services is a multi-billion dollar per year industry that 82% of Swiss Internet users engage in, and can therefore not be ignored (7). While some time use diaries have managed to document time spent online, travel surveys like MAED missed this opportunity. MAED participants recorded time spent online as either work, education, errands, or leisure, but researchers had no way of knowing whether those activities were performed online or physically in person. The PCW study on the other hand used a separate online diary besides the travel and expenditure booklets where participants could, in great detail, describe what kind of activities they had performed online on a given day and how much money they spent during such activities (3). Of course, including this as a separate task for participants must have increased response burden to a significant degree. This important distinction must be considered for future travel diary designs and presented simply as to not increase response burden.

Secondary activities are a topic often included in time use diaries, but usually neglected by travel surveys. Individuals are often performing more than one activity at once –like listening to music while cleaning or working during the morning commute– and these affect the context and overall utility of the activity. ICT also plays a grand role here, as it not only affects the activities we can engage in at home, but also those on the go. We may use an app on our smartphone to send a friend our share of a bill while sitting in front of them at a restaurant or we may be getting work done on our laptop during our train commute. These, however, represent two distinct types of secondary activities: those performed along with other activities at a certain location versus those we engage in when we travel. HETUS studies allow for the reporting of secondary activities at both levels, but travel diaries, including MAED and PCW, have not given secondary activities importance. This is troubling even if we purely focus on travel behavior because whether an individual is able to use an ICT device to work or socialize or has a book along to read for leisure surely influences how that traveler perceives his or her trip.

Consequently, Lyons and Urry (27) conducted an investigation to challenge the notion that travel time is unproductive time and were thereby one of the first to question the extent to which ICT devices can change the way and the perception of the way we travel. The authors conclude that, overall, one’s travel time budget may not be negatively affected if an individual perceives a trip to be productive in any way, though this may be trip-specific (i.e. cannot be generalized across all modes for all times of day). This is of course not in line with the microeconomic theory used in our time allocation models that assume that travel time poses a disutility. In order dissect the issue, travel diaries need to more carefully analyze what type of activities are being performed
on the go and the extent to which travelers perceive these as productive or pleasant (see (28) for a discussion). Such results are also in line with estimates of the VTAT, which consistently reflect high values for public transport (29) [30] [3]. These latest studies used MAED and PCW data, and attribute the results to the high levels of comfort of Austrian and Swiss public transportation that surely allow for a productive use of time. Documenting actual accounts of the time a participant works or engages in leisure activities while traveling is an important next step for transport research.

Differentiating between committed and non-committed goods (expenses) and time

According to Equation 1, how individuals allocate their time and money depends on their wage rate, committed expenses, committed time (activities chosen), along with preference parameters (2). Eurostat (31) published guidelines for coding activities reported by participants during their HETUS time use diaries: a total of 116 categories. Since the only important aspect is that committed vs. non-committed (i.e. freely chosen) time are to be differentiated between, activities can easily be aggregated for modeling purposes. The MAED survey (6), for instance, used 10 activity categories to distinguish between activities one needs to perform (committed), like those that provide maintenance functions (eating, sleeping, errands), versus non-committed leisure activities. Similar categorizations were implemented in the PCW survey (3), though a further distinction was made for leisure activities performed at home, as participants filled out an online diary that documented how much time they spent online shopping, completing errands, or for entertainment purposes. Some maintenance categories referred to as tertiary activities like sleep have often been discussed in the literature as only being necessary up to a certain threshold, yet incorporating this distinction into a survey’s design proves tricky, and so surveys currently impose educated assumptions for what they classify as committed or non-committed (see (32) for a discussion on the issue). Schmid (20) performed sensitivity analyses on his results based on the assumptions made for (non-)committed time and goods and found support for the notion that both committed time and expenditures are likely overestimated as participants likely surpass the threshold of a technical minimum, by sleeping in for pleasure or owning a luxury car that is much more expensive than the average car, for example. Specifically, when committed time was decreased by 20% and non-committed time was increased proportionally, the median VoL increased 20%, as freed up non-committed time causes the baseline utility of goods consumption relative to time to decrease even more (20). A finer granularity could improve model estimates, which could be addressed by asking participants how long, on average, they feel they need to sleep to be productive, and considering that value as a threshold for what is considered committed. Maintenance activities like cooking or cleaning are also unique in that another person could be paid to perform these activities, in contrast to sleeping or traveling. This also needs to become disentangled, which could be done by including additional questions in the household questionnaire portion of a survey that ask about whether they employ cleaning services and how often, as well as about their meal-planning habits.

Context

Following the idea that we need to study time use and travel behaviors as they occur over the course of a day, several contextual dimensions should also be investigated further, and ideally, within in a single study. Firstly, an integration of time use, travel, and expenditure behavior data collected concurrently could uncover questions that remain concerning how social partners affect travel decisions. Virtually all modern time use and travel surveys thus request information regarding who...
accompanies an individual during a given activity or during a specific trip, but a closer look at how
traveling with or spending time with friends versus family members affects expenditures merits
attention as well. How social networks affect travel decisions has been widely investigated using
name generator and name interpreter tools (e.g. (33, 23)).

Moreover, it is imperative that time use and travel surveys include additional psychometric
questionnaires to account for potential explanatory power an individuals’ risk perception or envi-
ronmental attitudes, for example, that may play a role when deciding what kinds of activities to
engage in or which mode to choose for a trip (or whether to purchase a private vehicle in general;
e.g. (34, 35, 36)). Microeconomic theories and models that dominate the travel behavior literature
are based on the idea that individuals are rational human beings that always strive to maximize
their utility in a given situation. Individuals’ decisions are yet not always well-reasoned and fall
prey to such trade-offs, as well as to habits, attitudes, perceptions, and preferences that need to be
investigated further (37).

Finally, a last argument is that no travel or time use diary survey to date has followed
individuals long enough to capture intra-personal variability that very likely exists concerning time
use, travel, and expenditure patterns. As previously stated, the existing HETUS guidelines simply
require one weekday and one weekend day of data collection, and while no guidelines exist for
travel diary studies, almost all opt for a similar two or three days. Though evidence supports that
two or three days serve as an adequate proxy for a week-long survey (32), two early travel surveys
that ran over five and six weeks reported large amounts of day-to-day variability in travel behavior
especially concerning leisure trips (39). As far as expenditures are concerned, these are
also almost exclusively cross-sectional studies that miss the fluctuations that especially lower- and
middle-income households regularly encounter (40). On the one hand, these types of surveys have
certainly kept to a minimum of recording days because of the large amount of time and resources
required to conduct them, but they are also not feasible using paper-and-pencil methods because
of the drastic response burden implied. This is where mobile apps present a unique opportunity,
as integrating a passive GPS component can eliminate the need for participants to remember and
report all of the places they have traveled to in a day.

PLANNED METHODOLOGY

In line with insights gained after conducting several case studies between 2014 and 2017 using
MEILI, an open-source app- and web-based travel diary (41), Prelipcean and colleagues (42) cre-
ated suggestions for how to set up and conduct travel diary surveys, given the lack of coherence
among travel surveys to date. Their five main steps to collecting travel diaries include design,
distribution, fill-in procedure, retrieval, and analysis. We will describe our planned methodology
according to these guidelines.

Design considerations

Our TimeUse+ survey includes several components to be completed over several stages, all of
which are integrated into our innovative mobile application, and according to Swiss norms for
transportation survey methods (43). The dataset collected by TimeUse+ will include travel, time
use, and expenditure data collected concurrently. In our main study, our aim is to record such
data for at least 1,000 individuals over the course of a month, making it the first of its kind to do
so. TimeUse+ has been developed to serve as a single, central survey medium to perform large-
scale longitudinal time use, travel, and expenditure data and the goal is for TimeUse+ to become
state-of-the-art and widely available for all interested research institutions. Because we want a full picture of individuals’ daily patterns and aim to close in on several gaps in time use and travel diary literature discussed earlier, the following major considerations have been taken during the ongoing development of TimeUse+.

**TU+ application**

- All survey components have been integrated into the TU+ app. The initial invitation to the study and registration code will be sent to participants’ email, but once complete and they have logged in for the first time, all questionnaires, tracking and validation, as well as stated preference experiments will follow using the app.
- The main portion of the TU+ study that runs over four weeks involves using our TU+ application. It includes a GPS passive tracking component, and participants will then be required to validate the trips and locations recorded and, if applicable, complete additional information for certain activities (e.g. expenditures, social partners). We see four weeks as a feasible survey duration because the response burden should be lower compared to traditional pencil-and-paper diaries, as participants will not suffer from recall biases because event locations are presented directly in the app and will serve as triggers.
- A general admin pane has been developed to support researchers who wish to use the TimeUse+ platform. The website lists all active tracking codes (participants) on one page, and all possible activity/trip combinations along with activity/trip-specific attributes on another. This allows for a full re-customization of the app for future studies that hope to delve deeper into other topics of interest. It is this flexibility that will allow us to elaborate upon many of the gaps referred to earlier within a single study.
- Though plenty of surveys have been conducted using mobile apps and/or GPS and other mobile phone sensors in the past two decades, almost no studies have published a formal documentation of the technology they implemented. As emphasized by Gadzinski (15), this is imperative so that researchers can learn from one another and have a better idea of what has already been attempted and what works (or does not). We thereby plan to publish a full documentation on our TU+ survey and all of its components.

**Response Burden**

Any survey needs to consider a measure of response burden to ensure that it is reasonable for participants to complete and be sure that reasonable response rates can be expected. We expect the innovative design of TimeUse+ to allow for a rich collection of varied data, while keeping response burden comparable to that of a traditional paper-and-pencil diary study. We plan to be the first to adapt the calculation of a response burden score, a quantitative measure of how response burden relates to response rate (44), for a mobile app study. The app has been designed to be intuitive and easy to use, so participant engagement should remain high and potential fatigue effects low.

**Incentives**

In line with the argument that monetary incentives are best to use because of their universally understandable nature (45), we plan to provide TU+ survey participants with an amount of money that is reasonable based on findings of the pretest. Additional incentives will be considered if additional household members who wish to participate in either the full study or the passive tracking alone. Continuous motivation will also be ensured by speaking to participants’ internal motiva-
The TU+ application includes several statistics pages where participants can see summaries of their activity, travel, and expenditure data that includes comparisons from week to week. The statistics generated will also be sent to participants via email as a weekly report that includes a thank-you message for their continued support.

**Distribution**

TimeUse+ will run in several stages over several waves in order to reach our complete sample of interest, while keeping the administrative load manageable for our team. Focus groups and pretests will give us a better idea of which recruitment method will suit us best. As suggested by Calastri and colleagues (23), it may in fact be a combination of recruitment approaches. As they suggest, it is crucial that we gain participants’ trust and provide sufficient information/contact channels for any questions they may have. Our desired sample is one that includes at least 1,000 participants and is representative of the German-speaking part of Switzerland. An important consideration is that participants must be employed in order to derive their wage rate that enters the time allocation model (2). We will also recruit a number of participants who do not meet this criterion, however, as we are also interested in descriptive mobility and time use data of unemployed or retired adults who have been found to have more variable daily travel patterns (46). This data will also serve as comparison to the next MTMC survey.

The main study run of TimeUse+ will include a first stage in which person- and household-level sociodemographic, mobility, long-term expenditure information will be collected using an online questionnaire that can be completed within the app. Once completed, participants will begin the four week long passive tracking with validation components as described above. In a second stage, participants will be asked to fill out a variety of attitudinal questionnaires and to complete stated choice (SC) experiments regarding mode choice, route choice, and the like.

As far as our timeline is concerned, the development all TimeUse+ materials will be finalized and will have been tested with focus groups and in a pilot study by the end of 2020. We will conduct a full pretest with at least 50 participants at the beginning of 2021 and will analyze the results by mid-year. The third quarter of 2021 will be used to prepare for the main study that will begin at the end of 2021 and run over several waves over the course of a year.

**Fill-in procedure**

All survey components across both stages can be completed using the TimeUse+ app itself. Participants will see the passively tracked locations upon opening the application and will be required to validate these events. Specifically, for a given day, for all events captured by TimeUse+, participants will confirm their location (or mode of transport in the case that they were moving) and indicate the activities they engaged in at said locations from a predefined list. For certain activities, participants are required to report additional contextual as well as expenditure information. The questionnaires from both stages and the SC experiments can all be completed within the app.

**Retrieval**

Travel diary studies have in part moved toward integrating mobile apps into surveys because of the ease of retrieving data from participants. In the case of TimeUse+, participants’ data is uploaded to our secure back-end that we can access using our admin pane. To not drain their battery or data volume, this only occurs when participants are connected to WiFi.
Analysis

Time use, travel, and expenditure data collected using TimeUse+ will enable us to calculate many travel time value metrics using the time and expenditure allocation model presented in the introduction longitudinally. We will use both revealed preference data from the tracking and validation portion of the study and stated preference data from the SC experiments to best estimate VTTS, VoL and VTAT across modes and for different trip purposes, and add in psychometric data collected from our questionnaires in subsequent analyses.

SUMMARY

Our TimeUse+ survey has been designed to capture a full picture of individuals’ time use, travel patterns, and expenditures over the course of an entire month. It will be the first of its kind to use a mobile application for simultaneous data collection of time use, mobility, and expenditure data. The app serves as a diary in which participants validate passively tracked activity locations and trips and complete information regarding what they were doing, who they were with, and how much money was spent on an activity. Supplemental materials include questionnaires that capture not only personal and household characteristics, but also attitudinal and psychometric questionnaires, and some with specific questions that will allow to address several existing gaps in the time use and travel survey literature. All the while, we expect response burden to be comparable to similar offline surveys and plan to keep motivation high and drop out rates low by providing both external motivation in the form of a monetary incentive and internal motivation by means of personalized weekly reports. Because the survey will run for four weeks in the main study, we will obtain intra-individual data to compare from week to week for the same set of individuals, which provides a novel and unique opportunity for the travel behavior field. Most importantly, the rich dataset collected by TimeUse+ will serve to derive policy-relevant time value metrics and allow us to build upon the existing discrete choice models that allow us to do so. All data will be made public and all methods implemented will be well-documented so that they may be of use to interested research institutions.
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