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## Pain and Joy of a Panel Survey on Transport Studies

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### Abstract

Over ten years ago, it was established that the most frequent reason that motivates a panel survey on transport studies is the evaluation of a change in the transportation system, or a specific transportation-planning project, especially when the project involves novel elements. From a statistical viewpoint, a panel survey has the definite advantage to offer more accurate estimates of changes than cross-sectional surveys for the same sample size. Observing travel patterns of individuals and households over several consecutive days, has offered insights into activity scheduling and travel planning. Variability in travel patterns has important policy implications as well, but how much effort is worth to design a panel survey?

To evaluate the effects of the transport policies introduced in Madrid during the last five years, a ‘short-long’ panel survey was built, based on a sample of a Madrid-worker subpopulation most affected by those recent changes in transport policy. The paper describes both the design and construction of the panel based on GPS technology, and presents some results based on an analysis of its two waves; for example, it registered an increment of public transport use and walking trips in 10%. The panel overcomes the known attrition problem thanks to providing incentives, maintaining contact, using the same interviewer for the same respondents, and conducting face-to-face interviews.

*Keywords:* panel survey; travel patterns; GPS; attrition; fatigue.

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### 1. Introduction

Apart from the advances in methodologies and new variables included on the last travel behavior studies, the treatment of a database coming from a panel survey is increasing (it refers to statistical analysis of panel data which consists of observations made repeatedly of the same sample). Among the advantages that panel data offer are:

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increased statistical efficiency, possibility of improved prediction, and the ability to observe changes and examine behavioral dynamics (Kitamura, 1990). The disadvantages emerge from the added biases and costs, and the increased complexity involved in the analysis.

The most frequent reason for researchers to design a panel survey is the evaluation of the impact of a change in the transportation system, or a specific transportation planning project, especially when the project involves novel elements (Golob et al., 1997). Indeed, Kitamura (1990) gives an overview of panel studies in transport planning concluding that a panel survey uniquely allow to observe changes in travel behavior and to relate these changes to contributing factors.

Panel surveys can be classified into “long survey panels”, which consist of repeating the same survey (i.e. with the same methodology and design) at “separate times”, for example once or twice a year for a certain number of years, or before-and-after an important event; and “short survey panels”, which are multi-day data where repeated measurements on the same sample of units are gathered over a “continuous” period of time (e.g. seven or more successive days), but the survey is not repeated in subsequent years.

There are a few examples of panel data mostly gathered for general purposes and, unfortunately, interrupted. The Puget Sound Transportation Panel in Seattle ran 10 waves (Murakami and Watterson, 1989), but with a 2-day travel diary, which raised the question whether two days would be enough for an accurate measurement of changes between subsequent waves of the panel (Ortúzar et al., 2010). In Canada 2 sophisticated panel surveys about daily activity behaviour were conducted this century. One in Toronto with 2 waves, and one in Quebec with 3 waves. Both panels last 12 months, and involved around 300 respondents with relatively high attrition (Roorda et al., 2005). In Adelaide, Australia, approximately 1,000 households participated in a fairly revolutionary panel, with a total of 9 waves (every 4 months), aimed to evaluate voluntarily users’ travel behaviour change programmes (Stopher and Swann, 2008). In Spain there is evidence of at least two panels. The first had 3 waves and only 143 respondents; it was designed to study season ticket use in the Valencia metropolitan area (Ruiz, 2004). The second is the Madrid-Barcelona Corridor Panel (Ruiz et al., 2008) on long distance travel. In Japan a series of 7 panel surveys were taken between 1987 and 2005. The German panel mobility survey (Zumkeller, 2009) is the only survey existing today at a national level. Here a 3-year rotating panel was used, where each year about 350 “fresh” households were recruited. The Mobidrive survey is maybe the most famous short panel dataset. It was a six-week activity diary held in Karlsruhe (Germany) in 1999, which involved 160 households and 360 individuals in the main survey (Axhausen et al., 2002). The Santiago Panel in Chile (Yáñez et al., 2010) combined both short and long surveys, but only trip to work were reported and only for a particular day. Individuals were then asked if they made the same trip every day of the week.

Good quality data are essential to estimate reliable demand models. This motivated the choice of using the most advanced technology to measuring and collecting the characteristics of the current trips. Recently the use of technology such as GPS (often integrated in smart phones) has been proposed to track individual movements. This allows measuring with high precision important characteristics of the trip such as origin/destination and all travel times. Moreover, information is available in real time and all the movements are recorded avoiding the typical errors of omitting short trips or overestimating travel times. Using this technology alleviates also the task of the respondents, as they do not have to remember or take notes of all the trips made. On the other hand, although the technology available is very good, there are still some problems such as capturing correctly the signal, especially in urban areas, which requires studying a methodology (a) to improve the measurement precision and the strength of the signal, to avoid errors in the tracks; (b) to increase the number of coordinates (seconds between signals) reducing the charge consumption; (c) to use appropriated algorithms to align typical zigzag erroneous measures; (d) to use map-matching algorithms to match GPS signals with the network implemented in GIS and, finally, (e) to automate the passage between the information collected into a dataset ready to be used for the mathematical analyses.

So, while the GPS itself gives information regarding time and space, a more “traditional” survey is still needed to gather information about the activities performed and some other characteristics of the individuals. However, technology such as smart phones or interactive web-page interviews will be used for this task, which has great advantages especially in terms of coding the information. Moreover, when this type of interview is associated with the GPS information, there is also a great benefit in terms of quality of information, because individuals can be

present with the tour they made (as recorded by the GPS) and then asked only to tell the activities they were performing at each destination, with whom, the mode used, how much they paid for, and so on. For the people interviewed, this task is much easier than remembering all the characteristics of their trips. Finally, it is also important to mention that using this technology is substantially cheaper than the standard method of interviewing and later measuring the level of service in the field of urban transport.

This paper shows all these advantages and disadvantages thought a ‘short-long’ panel survey based on a sample of a Madrid-worker subpopulation. The structure of the paper is as follows: an introduction to the topic, a section 2 to describe the construction of the survey used, a section 3 to sum up the lessons learnt, and a section 4 with the main conclusions.

## 2. Construction of the ‘short-long’ panel survey

### 2.1. General aspects

The data used in this paper comes from a smartphone-based panel survey conducted in the HABIT project (Habit and inertia in mode choice behavior: a data panel for Madrid). This panel survey has features of both ‘short’ and ‘long’ panel surveys used for other authors. ‘Short’ because a smartphone with a survey application was given to the respondents to capture all the trips during a working week (five days). In fact, Cherchi and Cirilo (2010) showed that if the interest of the panel was in modelling mode choice, the ideal length of the panel could be just a week, provided the sample is not too small. And ‘long’, because the smartphones -with a survey application- were distributed at two different points in time (2011-2012). At the beginning, the authors had conceived the panel with three waves: one before the new metro stations inaugurated in Madrid during March 2011; and the second and third waves during the sixth (September 2011) and eighteenth months (September 2012), respectively, after the inauguration. However, due to administrative troubles, it was decided to start the first wave on September 2011 and the second wave one year after in order to study the willingness to change patterns of urban mobility with the introduction of transport policy measures (not only new public transport infrastructures, but also those above mentioned).

To compute the first wave, during fall 2011 and winter 2012, two groups were given a smartphone with the panel-survey application for one week: (1) 91 workers from the Regional Health Department within the catchment area of the new metro stations; and (2) 164 workers from the Universidad Politécnica de Madrid- making use of their close proximity to the authors-, thus easily producing a random sample of 5774 workers (2011 census data). As it had been indicated previously, it discarded the most common sampling unit used in transport surveys (i.e. the household), and based the panel survey on a sample of a worker subpopulation. In fact, the treatment of this subpopulation and the smartphone technology are useful to reduce the effect of the three most important disadvantages in a panel survey: high cost, attrition and fatigue. The second wave took place during the fall of 2012 and winter 2013 with a total of 190 respondents.

Before conducting the panel survey, three focus groups were organized with residents of the new metro stations’ catchment areas; these allowed improving the questionnaire design, to understand the perception of the new metro lines and to determine the profile definitions of the residents and workers to be recruited (Aizer and Curie, 2002). The focus groups were also used to design the incentives to attract individuals to participate in the survey.

### 2.2. Sample size determination

Following the approach used in the Santiago Panel (Yáñez et al., 2010), the simple size ( $n$ ) is computed using:

$$n = \frac{CV^2 \cdot Z_\alpha^2}{E^2} \quad (1)$$

where  $CV$  is the coefficient of variation of the variable under HABIT project. As the aim was to measure the willingness to change patterns of urban mobility, it is necessary to ensure the presence of every mode. Monzón et al.

(2013) fixes the Madrid’s modal distribution as: 45% (car), 40% (public transport) and 12% (walk and bike). It determines the CV value according to:

$$CV = \text{st. deviation} / \text{mean} = \sqrt{p(1-p)} / p; p = 0.12 \quad (2)$$

Then, assuming a level of accuracy ( $E$ ) equal to 25% and a confidence level of 90% ( $Z_{\alpha}^2=1.282$ ), the sample size should be:

$$n = \frac{((\sqrt{0.12(1-0.12)} / 0.12) \cdot 1.282)^2}{0.25^2} = 193 \quad (3)$$

Furthermore, to justify the sample size for the SEM applications used in HABIT project, although sample size is important in factor analysis (first step in a SEM methodology), there are varying opinions and several guiding rules of thumb are cited in the literature. Hair et al. (1995) suggested that sample sizes should be 100 or greater. A number of textbooks cite the work of Comrey and Lee (1973) in their guide to sample sizes: 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1000 or more as excellent.

Summarizing, the sample size used in two waves (255 and 190, respectively) is reasonable to justify the objectives of the whole HABIT project (see Di Ciommo et. al, 2014).

### 2.3. The smartphone-based panel survey and its evolution

As stated above, five research centers participated in the smartphone-based panel survey design. A so huge group was necessary since it was the first experience in a panel survey that collected these three aspects: (i) the development of a smartphone application to register each one of the respondent’s trips (by G@TV-UPM); (ii) the definition of the GIS information necessary to establish some urban environmental variables; and (iii) the benefits of the Santiago Panel in Chile (UC and DTU) as the last most famous panel survey developed.

The smartphone-based survey (Fig. 1a) for the first wave (September 2011) had two main phases. The first consisted of a face-to-face interview to gather personal data on the respondent. As in the more typical cross-sectional surveys, it considered the variables age, sex, education level, income, number of working hours per week, number and type of cars, number of bicycles and possession of driver’s license, etcetera. Moreover, following the results of the pilot survey, respondents also answered an attitudinal and perception questionnaire with Likert scales covering comfort, security, and accessibility topics about Madrid’s public transport; this interview was also used to explain the context and objectives of the survey (Fig. 1b). In the second phase, they were given the smartphone and asked to register the daily trips they made during the five workdays (Monday to Friday) (Fig. 1c). The variables considered were mode used, departure and arrival times, transfer times (for intermodal or mixed modes), cost (fare for public modes; parking and toll charges for private modes), and number and location of mode interchanges.

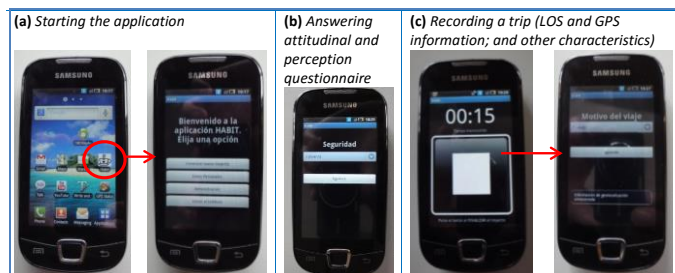


Fig. 1. An overview of the smartphone application.

The trips were monitored in real time, and respondents were contacted at the end of the day to correct or clarify the information. The participants were also given a chart to manually register any trips that were not recorded on the smartphone. The complete registration of daily trips took about 20 seconds per trip by car or on foot, and one minute for a journey by public transport. At the end of the trip, the data were automatically sent to a server accessible by the authors. Updating the first wave questionnaires (face-to-face interview and level of service measures) was an interactive procedure between the previous five researcher centers that involved three steps (Goulias et al., 1990): (i) using three focus groups to identify questionnaire items that may have caused inaccurate responses or technical problems with the application, as it explained in the beginning of this subchapter; (ii) with this information, changes to the layout, presentation, wording and contents were made; and (iii) the changes were evaluated between the people of the HABIT project, and the process was iterated by going back to either previous steps.

For the second wave (September 2012) a few changes were introduced with the experience of the first wave, but without producing any substantial change.

When revealed preference data are gathered, it is crucial to clearly define which modes individuals have available for each trip. Then the same quality requirements of the chosen alternatives must be achieved for the non-chosen, but available. To measure this information was crucial to carefully process the data gathered in order to check for all those aspects that might constrain the availability of some alternative, such as tours made during the whole day, interactions among family members and/or friends, collecting materials or picking up children at school and so on. This diagnostic was needed to carefully define the choice set for each trip of each individual.

Having done that, the characteristics of the non-chosen modes needed to be quantitatively measured using times scheduled from the public transport companies (EMT Navega por Madrid ©2010; Viaja en Metro, ©2013) and with direct measurements in the network with instrumented vehicles (©2013 Google).

Although initial quality is very important in any type of survey, panels present an additional requirement: it is necessary to maintain quality over time. In that respect the main problem is how to avoid attrition (Kitamura, 1990b); then various effective maintenance methodologies were applied, such as:

- Providing incentives. This is useful in panels as it is necessary to maintain respondents motivated across waves (Yáñez et al., 2010). Some authors have reported using cash or gifts as incentives, while others raffled different prizes. Within the HABIT Project both incentives were used; but the latter had better acceptance. (Fig. 2).



Fig. 2. Incentives used for maintaining respondents.

- Maintaining contact. The idea was to keep respondents interested in the study. Thus, short e-mail reminders were sent, as well as summary reports and letters of gratitude between waves.
- Conducting face-to-face interviews. This is the most expensive way to gather data, but it was used because gave the best alternative in terms of answer quality and response rates (Tourangeau et al. 1997).
- Using the same interviewer for the same respondents, as other panels have reported lower attrition rates with this measure (Van Wissen and Meurs 1989). Thus, the first author of this paper was personally responsible for delivering and picking all the smartphones to the respondents.

Applying these maintenance methodologies it was possible to retain the 75% respondents from the first (255) to the second wave (190). As mentioned before, some incentives were provided as a means to control attrition; furthermore, different types of incentives were tested to know which one could have a higher impact. Unfortunately, it was not possible to extract conclusive recommendations for future panels, as attrition figures were so low.

### 3. Lessons from the ‘short-long’ panel survey

#### 3.1. Data check and descriptive analysis

The analyses performed in this point are mainly based on the information provided by the Encuesta Domiciliaria de Movilidad (Mobility Household Survey -EDM) conducted by the Madrid Transport Authority (Consortio de Transportes de Madrid, CTM) in 2004, which is, despite the date, the best available material to reach an appropriate knowledge of the current situation. Statistical data from INE (2011) and Monzón et al. (2013) were used to compare characteristics of the worker population of Madrid with a sample. To understand the urban model, Geographical Information Systems were used for the incorporation and analysis of available cartography of the Madrid region: land use, land survey and planning department information for each municipality contained in the MadPlan application. The transport systems analysis will be likewise supported by the GIS, using the information georeferenced from the Networks included in the Mobility GIS of the CTM.

All the available data were analyzed in depth in order to provide the following features for the area of Madrid:

1. Analysis of the urban structure in terms of location of major activities, density of population, density of workers for type of work, opening and closure times of activities, type of urbanization and so on.
2. Analysis of the socio-economic characteristics of the population such as age, sex, family size, number of children, income, occupation and so on
3. Analysis of the present characteristics of the transport system in terms of available modes and their main features, such as times (in vehicle, waiting, walking, parking, transfers and so on), costs, interchanges, frequency and so on.

Firstly, although the panel sample included only workers from the Universidad Politécnica de Madrid and the Regional Health Department, their household locations are satisfactory widespread over the city of Madrid. The changes of location are limited mainly by the proximity of the two waves. In fact it was observed that around 3% of respondents changed location between waves. These household changes did not affected the attrition rates. On the other hand, some work changes also took place between waves, responsible for a part of the attrition (as it uses work-place interviews). Fortunately, the share of work changes was low as well (2%).

Secondly, regarding the traditional socioeconomic characteristics, Table 1 shows that while the average age increased slightly between waves and the number of family members decreased slightly, the average income presented more variation. Also Table 3 shows that despite the restrictions for choosing the respondents, the sample well represents the Madrid worker population (INE, 2011; Monzón et al., 2013). The reason for the income increase between the first and the second wave is that many of those 65 respondents who did not repeat the survey were people with precarious employment contracts.

Table 1. Sample socioeconomic characteristics

Variables	Natural Travelling Working Population in Madrid Metropolitan Area*	Wave 1 (n=255) <i>Average (St. Dev)</i>	Wave 2 (n=190) <i>Average (St. Dev)</i>
Male (%)	51	52	51
Age	40	43 (9.2)	44 (11.6)
Income (€)	2500	2100 (410)	2220 (320)
# family	2.7	3.1 (0.5)	3.0 (0.3)

\*(MMA) Source: INE (2011) and Monzón et al. (2013)

Furthermore, a new labor law that increased the number of working hours/week was introduced by the Spanish government between the first two waves (February 2012) and, at the same time, some of the respondents increased their salary, while others suffered a decrease mainly due to the suppression of the Christmas bonus. And thirdly, regarding mobility characteristics there are more differences between waves, as it can see at Table 2.

Table 2. Daily mobility characteristics

Variables	Mobility	Wave 1 (n=255)	Wave 2 (n=190)
	Working Population in Madrid Metropolitan Area*	Average (St. Dev)	Average (St. Dev)
# trips	2.6	2.4 (0.3)	2.1 (0.4)
Travel time (min)	28.6	32.7 (5.8)	30.5 (6.1)
Commuting distance (km)	6.0	7.9 (3.7)	6.5 (2.6)
Car use (%)	45.0	57.3	55.4
Public Transport use (%)	40.0	34.4	34.8
	12.0	8.1	9.5

\*(MMA) Source: INE (2011) and Monzón et al. (2013)

When examining the database it was found a significant share of people with a driving license having daily car availability, and a very low percentage of survey participants with a public transport monthly travel pass. This means that the sample is more private transport-oriented than the average population of the MMA. A simple statistical analysis (Table 2) reveals relevant changes after the implementation of the new transport policies. The only mode that lose market share was the car (from 57.3 to 55.4%) whilst walking increased the most (from 8.1 to 9.5%); this is mainly due to the economic crisis (Monzón et al., 2013). Moreover, travel time and commuting distance decreased between waves.

### 3.2. Pain and Joy

Someone said that without pain we could not know joy. However, as another one added, the existence of broccoli does not affect the taste of chocolate. In other words, after the hardships experienced by the research team, trying to convince and keep the interviewees' faith -as will be explained below-, one is left feeling that, instead the initial joy, perhaps so much distress would not have been necessary to achieve the same results.

Our joy was systematically phased out: first, the task of encouraging and involving ordinary people in the well-being of their city and citizens (let us say, a commitment for a better world). Second, for the researchers' despair, the delusion of verifying the abandonment of our volunteers' army.

Indeed, after a first control of the public institutions in the surrounding areas, the project was presented by telephone, asking for their collaboration. This meant about 2000 potential surveys, but in the end, only 3 Public Health Centres, 1 School and 1 Elder's home agreed to hold a meeting to know about the project and carry out a pilot survey: it seemed easy to recruit at least those 200 people needed. First lesson learnt: people are not aware of the importance of this kind of studies for their own sake. Even worst: if only a few were convinced for beginning the survey, yet many few were recruited to complete the second wave; not to mention the amount of smartphones gathered empty of information when the survey was finished..

Given the financial constraints, only 50 smartphones were bought, where a specifically designed app was installed. The goal was to reach 200 interviewees sending out the 50 phones weekly, in such a way that every interviewer should ensure that the app was right uploaded, the phone with the batteries loaded and, most of all, to assure the recruitment lists and the mobile delivery (and the gathering at the end of the survey). Finally, only 92 people were recruited. From the very beginning a lot of troubles were found: unexpected leaves, disability to

manage the smartphone (people over 50 years, inconvenience of dealing with 2 phones, etc.), laziness to complete the survey, lost, thefts, etc.

Second lesson learnt: maybe the purchase of the smartphones was not worth: a compatible app with every operative system would have been enough. Then, each interviewee could have downloaded it on their own phone.

When the time arrived for the second wave, those problems – and some more such as several dismissals- were shown up, and then it was decided to address interviewees from the University, much more familiarized with the concept of “research” and, hence, much more prone to collaborate eventually. In any case, the marketing effort was the same.

Certainly, the researchers failed in understanding how big an effort was being required. Effort that no prize or reward seemed to overcome. Neither a weekend in a romantic place nor a voucher 20€ worth (had it been greater?) was challenging enough to stimulate people to collaborate. Since without data coming from the real world no serious research can be done, This is definitely the more frustrating part of this and future jobs..

Hence, the third and the last lesson learnt: no matter how much faith in our neighbors may be deceived: researchers must not falter.

#### 4. Conclusion

To evaluate the effects of the transport policies that have been introduced in Madrid during the last five years, it was decided to build a ‘short-long’ panel survey based on a sample of a Madrid-worker subpopulation most affected by those recent changes in transport policy. As a result of this experience, the authors have wanted to recall some pains and joys worthy to have into account with future transport studies.

Joy. A panel survey has the definite advantage to offer more accurate estimates of changes than cross-sectional surveys for the same sample size. Other advantage regards the multi-day travel behavior. Observing travel patterns of individuals and households over several consecutive days, offers insights into activity scheduling and travel planning. Variability in travel patterns has important policy implications as well.

Pain. A panel survey has some disadvantages to be taken into account: (i) high costs, in terms of time and money are typically the biggest limitations when gathering data; (ii) the attrition (loosing respondents) between successive waves; and (iii) the fatigue, i.e., respondents get tired of keeping detailed records of their journeys after a few days. Further research must be carried on to explore how to overcome these barriers.

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