ANÁLISIS DE FACTIBILIDAD DE USO DE APLICACIONES MÓVILES PARA ELABORACIÓN DE ENCUESTAS DE MOVILIDAD EN CHILE

Cristian Navas (Banco Interamericano de Desarrollo, cristiann@iadb.org), Viviana Muñoz (Ministerio de Transportes y Telecomunicaciones, vmunoz@mtt.gob.cl), Carolina Palma (CityPlanning, cpalma@cityplanning.cl), Fang Zhao and Shari Gershenfeld (Mobile Market Monitor, fang@mobilemarketmonitor.com, shari@mobilemarketmonitor.com), Gabriel Montero (ARISTO Consultores, gmontero@aristo.cl)

RESUMEN

Describimos un proyecto piloto de tres fases orientado a avanzar en la modernización de las encuestas de movilidad, probando la efectividad y viabilidad de reemplazar o complementar el enfoque de recopilación de datos existente con el uso de una plataforma que combina sensorización móvil a través de una aplicación con un motor de aprendizaje automático para inferir una línea de tiempo de viajes que los participantes pueden ver, editar y verificar. Como canales complementarios se utilizó una encuesta web y una telefónica para quienes no podían usar un teléfono inteligente. Se probaron esquemas de incentivos para determinar su efectividad en lograr que los hogares participen y completen los requisitos de la encuesta.

Palabras clave: encuestas de movilidad, aplicaciones móviles, incentivos para encuestas

ABSTRACT

We describe a three-phase pilot project aimed at advancing the modernization of mobility surveys, testing the effectiveness and feasibility of replacing or complementing the existing data collection approach with the use of a platform that combines mobile sensing through a mobile application with a machine learning engine to infer a travel timeline that participants can view, edit and verify. As complementary channels, a web survey and a telephone survey were used for those who could not use a smartphone. Incentive schemes were tested to determine their effectiveness in getting households to participate and complete the survey requirements.

Keywords: mobility surveys, travel surveys, mobile applications, survey incentives

1. INTRODUCTION

Understanding how people move around cities to carry out their activities is a central element for the development of public mobility and urban development policies, a problem that has historically been addressed in Chile through the development of household-based origin-destination surveys (EOD-H). This survey instrument has been based on a detailed interview with all members of a sample of households in the city, aimed at gathering information about the trips taken on a specific day, as well as a series of additional characterization indicators that allow for the subsequent deduction of travel matrices for the entire city through expansion processes.

The history of EOD-H development has been successful in Chile, and currently, there are several survey versions available for different cities, starting with the EOD-H of Santiago in 1977. Over time, strong methodologies have been established, yielding satisfactory results that have enabled the formulation of strategic transport planning models, investment plans, and have fed into tactical analysis processes of transportation projects.

However, a series of factors suggest the need to explore new mechanisms for studying urban mobility. On one hand, there are practical considerations associated with increasing difficulties in conducting surveys, such as a higher non-response rate. For example, in the 2001 Santiago EOD-H, there were 3,300 non-responses out of a total of 15,500 completed surveyed households, while in the 2012 version, this ratio changed to 8,300:18,300. There are also issues regarding the security of survey personnel who are doing door-to-door interviewing and in-home visits. In a study conducted in the high zone of Valparaíso in 2016, the data collection methodology had to be modified due to the lack of basic public security conditions, as advised by the Police, and as subsequently experienced during the pilot phase, with several interviewers intimidated or assaulted. These and other difficulties have led to increased costs and delays in obtaining surveys, raising doubts about the feasibility of the process in the future.

An additional factor is the significant technological developments in recent years that enable higher quality data to be obtained. While recent survey developments have made some use of mobile devices and geolocation services, the prevailing paradigm has been to simply generate electronic (e.g. web-based) versions of historically used paper diaries collected in-person. However, the possibilities opened up by the improvement and cost reduction of communications, information management, and geolocation services expand the range of much more innovative processes.

Finally, the profound changes and greater heterogeneity in mobility and activity patterns in recent years have increased the importance of collecting not only more detailed and multi-day data, but also of collecting it more frequently or continuously.

Complementary approaches for obtaining mobility data are beginning to emerge worldwide, transitioning from scientific research and experimental development to becoming the state of practice. Chilean authorities have been attentive to this development, with the Ministry of Transportation and Telecommunications, for example, initiating a study to generate travel matrices from passive mobile phone data. Progress has also been made in the development and use of travel matrices in public transportation based on the passive data generated in

Transantiago's electronic payment transactions using a locally developed methodology exported to other contexts, such as Transmilenio.

The experience reported in this paper explores a new possibility of data collection based on the use of mobile applications through which the mobile device passively collects data that are processed and interpreted as trips and activities using machine learning algorithms and other data sources and are presented to the user in the form a trip diary to actively validate/supplement the information. Mobile Market Monitor's (MMM) software platform, which includes the X-ING smartphone app, was customized and deployed for data collection in Chile. The MMM system is based on the Future Mobility Sensing (FMS) software developed by MIT researchers.

A multi-stage pilot was conducted involving: a first pilot with professionals in the sector; a second pilot with real households using a convenience sample; and a third stage, also designed to test different incentive schemes, involving 300 complete households from a statistically representative sample. Conclusions are presented regarding the effectiveness of the technology, the fieldwork approach and the different incentives tested.

2. LITERATURE REVIEW

2.1 Multi-Channel Data Collection

The advent of mobile sensing, machine learning and increased smartphone penetration have enabled the capture of travel and activity behavioral data that are more accurate, complete and richer than that obtained by methods more heavily relying on participant recall and manual recording and entry of detailed data (Nahmias-Biran et al 2018; Hong et al, 2021). At the same time, travel survey participation rates have been on the decline, which can drive up survey administration costs and lead to non-response bias in survey data (Svaboe et al, 2021).

Individuals who are willing to be recruited for travel surveys have a range of preferences for how they are willing to participate. For example, some smartphone owners will refuse to have their location data collected; other prospective participants may not be willing to spend time on manual entry of their travel and activity data; and many people are reluctant to directly interact with surveyors either in-person or over the phone. There are also segments of the population, such as children, the elderly, and those with disabilities such as blindness, for whom proxies or surveyors need to be involved in order for them to participate. Thus, in order to ensure inclusivity and data representativeness, and to maximize participation and completion rates, travel surveys conducted by public sector transportation agencies often employ multi-channel data collection.

The use of multiple data collection methods for travel surveys has been in practice for decades. Early surveys were conducted with face-to-face interviews, and later on, with interviews over the phone. With the increase of web-accessibility, web-based surveys, either self-administered (CAWI) or administered by surveyors over the phone (CATI), have been used to supplement or replace traditional interview-based surveys to both increase response rate and reduce cost. GPS loggers have also been used in travel surveys to passively capture location data from the users. High smartphone penetration rates in the past decade and advancement in mobile technology have enabled app-based data collection, which brings a new channel with inherently different characteristics from CAWI/CATI into the mix.

Much research has been done on smartphone-based household travel surveys, and a large number of relevant studies have been reported. While many of the studies reported in the literature are academic projects with small sample sizes, there have also been some large scale deployments in city-level household travel surveys (e.g., Hong et al, 2021; Nahmias-Biran et al., 2018). Unlike GPS loggers, smartphones are equipped with multiple sensors, and the technology can make use of wifi, accelerometer and other sensors in addition to GPS to improve data quality. While some studies use smartphones to only do passive data collection (i.e., no user input), most others also provide a web-based or in-app user interface that allows app users to view and edit their data and provide additional trip details.

It has been shown that the use of such technology platforms mitigates some of the known issues of traditional travel surveys, such as under-reporting of trips, over-reporting of no-travel days, and missing short activities (Hong et al, 2021; Zhao et al. 2015). Thanks to the reduced respondent burden, especially over time, the cost of collection of additional days of data from the same respondent is marginal. This opens up the possibility of multi-day data collection from users, or even continuous data collection, which can reveal richers activity patterns as compared to a traditional one-day survey. The high-resolution and rich data collected through these technologies can lead to previously unobtainable insights into mobility behavior and enable better transportation models to be developed.

2.2 Incentives

Household travel surveys often involve some form of monetary incentive to survey participants, such as cash, shopping vouchers, gift cards, chances for a prize in a lottery/lucky draw. In one study in Africa, low-cost Android phones were distributed to participants for data collection, and the phones were used as incentives for participants to keep after the survey (Zegras et al. 2018).

An unconditional advance incentive is one that is given to every contacted household; that is, it is not conditioned on whether the household agrees to participate or not. Unconditional advance incentives given as money have been shown to be more effective than those given as objects (Singer & Ye, 2013; Wenemark et al. 2011, Scheepers & Hoogendoorn-Lanser, 2018). In this case, the unconditional incentive consists of a predetermined amount of money delivered directly to the households via an advance letter or other form of delivery. The objective of this type of incentive is to create a sense of reciprocity, diminishing the sensation of external control that conditional incentives reinforce.

A conditional incentive based on final results of the household's participation aims to increase the probability of response, increasing the reflective motivation of the participants (Ryan & Deci, 2017). From a broad perspective, the amount of the conditional monetary incentive does increase the survey response rate, but at a decreasing rate (Singer & Ye, 2013). It has been shown that monetary incentives can increase participation in transport-related applications (Arriagada et al. 2021). It has been observed that some countries such as the UK have used conditional incentives delivered at the household level for travel surveys (National Travel Survey: 2020 notes and definitions).

The conditional incentive amount could have multiple components. For example, one component could be a function of the number of household members who actually complete the survey

process. A second component could be based on the condition that the entire household has met the requirements of the process. The distinction is made to reinforce the idea that the potential amounts to be delivered to each household will depend on the number of people each household has, that is, it is not a standard amount per household.

3. DESIGN OF EXPERIMENTS

Pilot 1 was designed as a multi-channel, household-based survey and was carried out in the city of Rancagua. The objective was to not only test the different functionalities and capabilities of the smartphone app-based data collection, but also to test the performance of different components of the end-to-end survey process. In particular, since in the large-scale EOD-H, full household participation is required, the same requirement was applied in the pilot as it presents a situation closer to real use and allows additional difficulties to be identified. Additionally, and given that some people cannot use an app (e.g. children, some older adults, those without Internet access), it was deemed appropriate to test a multichannel design that would integrate the app with a web-based (CAWI/CATI) platform. Regarding the design, the following aspects were established:

- Number of participants: 100 households, approximately
- Characteristics of the participants: general public from different socioeconomic groups.
- Study area: the city of Rancagua, particularly three representative sectors of different socioeconomic groups.
- Application of the instrument: 4 days for X-ING app users and one day for telephone survey users
- Support for participants: a help desk was available by e-mail and Whatsapp during the data collection period to assist users
- For sampling purposes, three sets of blocks representative of households of different income levels were defined. Statistical sampling was not carried out within the sectors or blocks. Instead, surveyors traveled within the blocks sequentially and tried to recruit on the first try when knocking on the door, in order to control field costs associated with recruitment.

As a way of encouraging the participation of households, a prize system was established that included a raffle among households that completed the process. The prizes offered were:

- A Samsung Galaxy A7 tablet
- 5 giftcards of $50,000 (Chilean pesos) each, redeemable in a network of department stores
- 20 Metrotren cards with enough charge to make a round trip between Santiago and Rancagua

Pilot 2 sought to identify the potential impact of different incentive schemes for participants in the multichannel origin-destination survey. A total of 300 households were recruited for Pilot 2, and they were divided into three groups, with 100 households in each group. The sample unit was considered to be the block, where three households per block are to be subjected to the same incentive treatment. This cluster experimental design is applied in this case to minimize the probability of interaction between households subjected to different treatments, which could bias the results.

In general terms, the procedure included the following:

- *Dispatch of an invitation letter*. The first approach to the home consisted of the delivery of an invitation letter which was designed to motivate participation, explain the process and describe the incentive scheme. The letter requests the household to make contact or to wait for the next contact by the survey team. If any adult household members are at home at the time of delivery of the letter, this stage merges with the next one.
- *Visit by surveyors.* After the letter is delivered, the household is visited up to three times in order to explain the process in greater detail and recruit the household, a process that includes the acceptance to participate, the assignment of the day for which the travel and activities for all household member will be recorded, the selection of the channels to be used by the different members of the household, the installation of the app on the phones of those household members who choose it (and are at home at the time) and training in its use. The visit may end in a recruited household or may fail if after three attempts there has been no contact made or if the household has explicitly refused to participate.
- *Personalized survey links*. In household-based travel surveys, one member of the household (a self-designated household lead) typically identifies the other household members and is burdened with transmitting information to those members about how to access and complete the survey. For this pilot, a technology approach was developed and implemented within the integrated software platform whereby emails and WhatsApp messages containing personalized survey links were automatically generated and sent to household members upon the household lead entering their contact information within the app or web's pre-survey. By clicking on the personalized links, relevant data elements associated with each household member were systematically pre-populated in each member's version of the app or web survey for use in the Trip Diary. This approach was designed to streamline the process for households and surveyors.
- *Follow-up*. The follow-up stage includes the development of various support activities for different users, depending on the chosen channel such as:
    - App - reminders to install, validate trips and uninstall the app when finished;
    - CAWI - reminder on the day before the assigned travel date, reminders to enter/complete the input of information on the web survey;
    - CATI - reminder on the day before the assigned travel date, a call to request travel information after the assigned travel date.

The incentive scheme used is described in the following table.

Table1 - Summary of the incentive scheme (in CLP)

Treatment	Unconditional incentive	Conditional incentive	
		Per household member using CAWI or CATI	Per household member using App
Treatment 1 (T1)	$5.000	$0	$0
Treatment 2 (T2)	$0	$3.000	$6.000
Treatment 3 (T3)	$0	$6.000	$10.000

In the unconditional case, the incentive is delivered to the household when they are invited to participate, regardless of whether the household decides to participate or not. In the other cases, the incentive is delivered only for those households in which all members complete the process, with the size of the incentive depending on the number of household members and the chosen channel.

The experiment was designed so that all selected households belonging to the same block were subjected to the same incentive, in order to avoid suspicions among neighbors who could compare their incentives. The incentive was communicated to the respondents in two ways: in the first instance, they were given a different letter by treatment and, in the first contact with them, it was explained verbally and with examples by the surveyors.

4. MAIN FINDINGS

4.1 Pilot 1

As mentioned in the previous section, the main objectives for Pilot 1 were to test both the technology as well as the fieldwork process. The fieldwork was carried out in three stages, as follows:

- *First stage*. In this first stage of work, we encountered some issues with the recruitment and registration processes. These factors led to poor performance in terms of household recruitment rate and low participation of the app option compared to the CATI channel. Consequently, it was decided to interrupt the process and reformulate it.
- *Second stage*. After an intense redesign of the recruitment process, an improved process was implemented. We achieved better recruitment levels, although the penetration rate of the use of technology in homes (as opposed to CATI) remained about the same. Given the improvements obtained and the time and budget constraints that rendered additional improvements infeasible, we advanced to a third and final phase.
- *Third stage*. After some additional minor adjustments to the recruitment process, this third stage began, in which the final process previously described was implemented. Recruitment levels were generally maintained.

In this pilot, the recruitment approach involved visiting every household in 4 selected areas of the city of Rancagua. 1860 homes were visited, of which just 149 were recruited. The area with the lowest recruitment percentage corresponded to the area with the greatest income. It is observed that in a little more than 50% of the homes it was not possible to make contact with the residents, and in 42% the person contacted refused to participate. Among the reasons given by those who refused (and provided a reason for it), 36% said they were busy; 18% said it was lunch time, so they could not interact; 16% said they were not interested; and 9% said they were distrustful or that it was very invasive.

The 149 households that did answer constituted 443 individuals. 48% of these individuals decided to use the app and 52% selected CATI. Of the 231 individuals who chose CATI, 103 were adults who did not have smartphones or children, so they would not have been able to use the app. The remaining 128 individuals who chose CATI would have been able to use the app, but chose not to for various reasons (e.g. didn’t want to install the app, don’t have internet, don’t

want to drain the battery, not tech savvy, or non-specified other reasons). The penetration of the app is 62% when based only on those who could conceivably have used it.

Table 1 - Summary Result of the Process: households and individuals

Item	Channel	House-holds	%	Individ-uals	%
Recruited		149	100%	443	100%
Complete		72	48%	205	46%
	APP			*50*	*24%*
	CATI			*155*	*76%*
Rejections		77	52%	238	54%

We also reviewed how many households completed the survey by channel as well as the degree of verification of the data collected. It is observed that 48% of households completed the survey, which corresponds to 205 individuals. Of them, only 50 ended up using the app, the rest either chose CATI or ended up switching because they did not install the app on time. The recruited sample turns out to be balanced in gender, with a relatively uniform age distribution in all ages, with a higher concentration of workers and students. An average household size of 2.9 is observed. 37% of individuals do not receive income and 19% preferred not to answer the question.

48% of households completed the survey, which corresponds to 205 individuals. Of them, only 50 ended up using the app and only 14 of them finished the validation process on the defined day of the survey. It should be noted that the users who used the app collected information more than just the day of the survey and in many cases even validated it.

The rate of trips per person is substantially higher for those who used the app compared to those who used CATI, reinforcing the idea that when users self-report trips, there is significant underreporting. In addition, the rate of one-stage trips with respect to the total number of trips is greater than 82% in both collection methods.

The table below shows the total number of stops and travel stages collected and verified, and it can be seen that about 49% of the stops and 42% of the travel stages collected via the application were verified by the user.

Table 2 - Travel stages and stops collected and verified on the day of the survey, OK households

Type	Colected data App	Verified Data App	% verification	Collected and verified data
Stops	289	141	49%	419
Trip stages	244	102	42%	264

Given the pandemic situation, the sample presents a large number of complete days without trips, well above the values typically observed in pre-pandemic surveys. 74 users reported not traveling on survey day. The main reason was not having a reason to travel, as presented below. This represents 36% of users who do not travel, which is higher than that reported in the 2018 EOD-H (approximately 20%).

In terms of technology, it was demonstrated that the app was able to work well on iPhones and the majority of Android phones. Some of the Android phones built on manufacturer proprietary OS versions may not support the app well. Majority of the app users were able to perform their trip diary verification by themselves, but the system also has an impersonation function that would allow surveyors to verify data on user's behalf if needed.

In order to reduce user verification burden, the app infers trip modes and activities at stops when possible. Mode detection for Rancagua is particularly challenging as the buses and taxi collectivos can pick up and drop off passengers anywhere along their routes, not necessarily at designated stops. This makes it easy for such trips to be mixed up with car trips. Hence, the verification by the user of the trip diary is essential, to ensure data accuracy. Since the verification was required only for one day (at least), we couldn't take much advantage of the fact that user verification feeds back to the backend improving detection accuracy for the same user on future trips.

For activity detection, the algorithm mainly infers them based on user declared frequent places or previous verification for repeated visits to the same places. In addition, the algorithm picks up most of the Mode Change stops automatically. For the other stops, where the user visits for the first time, the diary will leave a question mark for the user to pick the correct activity. This is to avoid users simply 'agree' to the inferred information without checking and correcting carefully

4.2 Pilot 2

The main objective for Pilot 2 is to test the effectiveness of different incentive schemes. The development of the pilots occurred without major inconveniences, beyond those that are reasonably expected in field work of this complexity. Among the singularities that occurred, the following can be mentioned:

- The progress of the field work was much slower than anticipated, due to various factors. The first is that a relatively high staff turnover was faced, making it necessary to recruit teams three times, including their respective training processes. During the field work, there were different long weekends, which made the field work difficult, both due to the low availability of the interviewers, the high proportion of empty households, and the difficulty in matching the time of the interview with the next working day to collect the mobility data.
- At the level of perceptions, the incentives certainly marked a peculiarity of the experiment, drawing the attention of many people, generally in a positive way. However, it is worth mentioning that there were three cases in which people reacted negatively to the unconditional incentive, both due to suspicion of some type of fraud and because they found it "inappropriate". All the cases were resolved quickly and without major

complications, but it is considered convenient to mention it in the report for future reference and because it is not something that can be appreciated in the data analysis.

- Contrary to what was initially anticipated, the critical task of the fieldwork turned out to be follow-up, in the sense that the team was able to recruit households to participate faster than it could get these households to finish participating. deliver your information, through one channel or another.

1,057 households were visited to reach the sample of 307 households that completed the process, as reported in the following table.

Table 5 - Summary of the results of household recruitment by treatment

Item	T1	T2	T3	Total
Number of households visited	301	386	372	1059
Number of households recruited	144	148	151	443
% households recruited over visited	48%	38%	41%	42%
Number of homes completed	103	101	103	307
% completed households over recruited	72%	68%	68%	69%
% homes completed over visits	34%	26%	28%	29%
Number of unfinished homes	41	47	48	136

Table 5 shows the number of households that were visited, recruited, and that completed the survey for each of the treatments. It can be seen that Treatment 1 achieved a higher recruitment percentage of 48% over the 38% and 41% of Treatments 2 and 3 respectively. Treatment 1 also had the highest percentage of homes that completed the process with respect to the total number of homes visited, with 34% over the 26% and 28% of the other treatments. Finally, Treatment 1 had a higher percentage of households that completed the process over the number of households that were recruited with 72%; however, the difference with the other treatments was less, since they have a percentage in both cases of 68%

It can be seen that 27% of the households that were not recruited refused to participate during the contact stage, while 24% refused to participate when the letter was delivered. In 21% of the cases, contact could not be made after the letter was delivered and in 5% of the cases, the dwelling was uninhabited or did not correspond to a dwelling. On the other hand, 9% of the households that refused to participate did so due to mistrust in the government. The next reason was the lack of time with 6%. In third place with 5% corresponds to users who declare they do not answer any type of survey and in fourth place with 4% it is because someone in the family does not want to participate. It is also important to note that Treatment 2 was the one with the largest number of households that refused to participate in the survey.

It was observed that there is not a very different behavior between the treatments and the different days of visits and that Treatment 3 had a greater number of households that were enrolled, but that did not finish the process, although the difference is small with the other treatments.

It is observed that 73.1% of the recruited users completed the survey, which corresponds to 974 individuals. Of these, 960 users are considered to be in fully validated households, the rest

correspond to users who completed the survey but some member of the household did not complete the process. Among the users from completed households, only 243 ended up using the app to collect data, the rest either chose CATI at the beginning or switched to this channel eventually.

Of the 960 users from completed households, approximately half of the users of the households that completed the process correspond to the female gender with a very similar participation in the different treatments.

Figure 1 shows the age ranges according to the treatments that their households received. It can be seen that the majority of users correspond to children between 0 and 9 years of age. Then, the second age range with the greatest presence in the sample corresponds to 20-29 years, followed by 30-39 and 40-49. A chi square test was performed and the value of 30.13 was obtained, greater than the chi square value for 18 degrees of freedom and 95% confidence 28.87, therefore, it is concluded with 95% confidence that the age ranges distribute differently among the treatments.

Figure 1 - Range age according to treatment

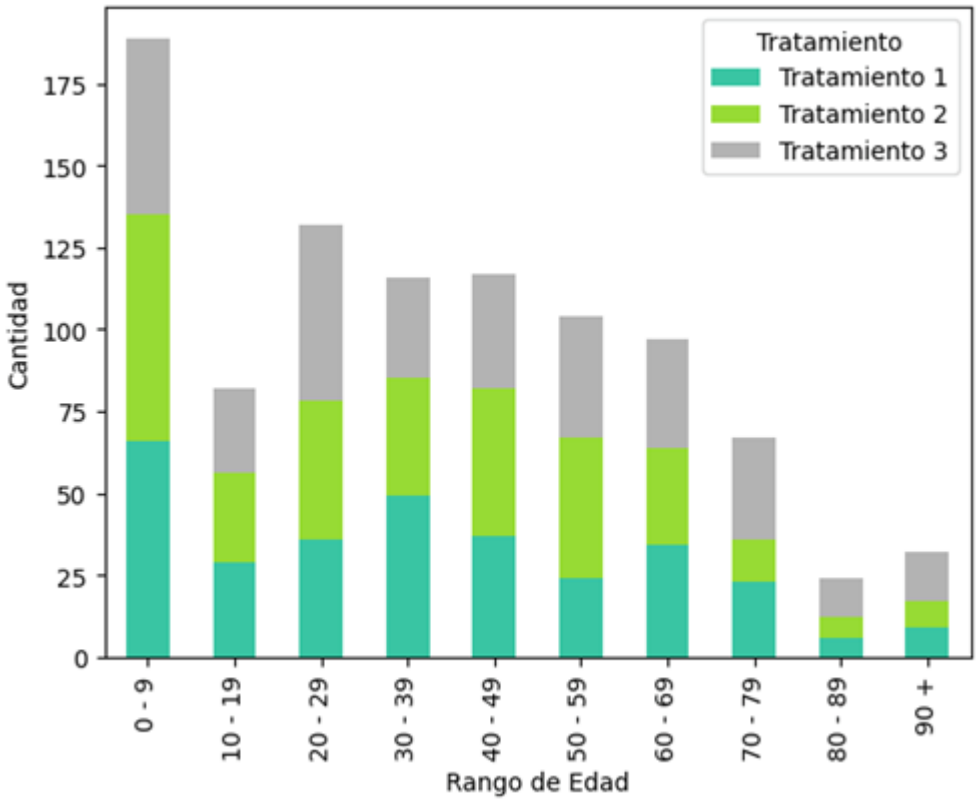
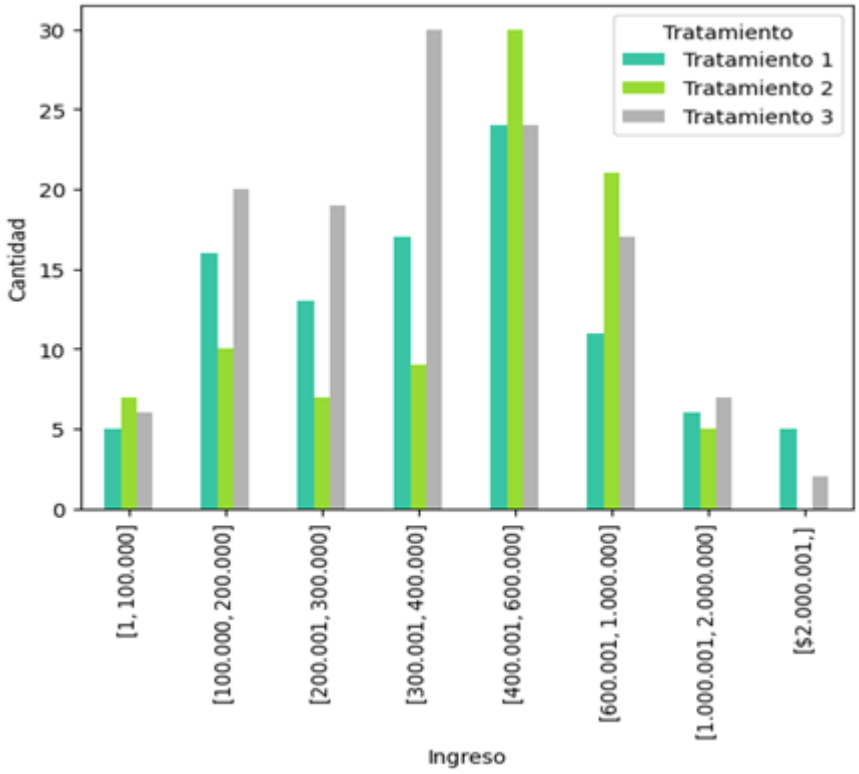


Figure 2 shows the user distribution based on income level and the treatment received by their household. 23% of users prefer not to answer their income level, which corresponds to 219 of the 960 users. Then, the next income segment with the largest number of users corresponds to the "No income" category, with 369 users, that is, 38% of the sample. 6% of the users declared receiving an income between $300,000 and $400,000, that is, 56 users, of which 30 belong to a

household that received the Treatment 3. The highest participation of users corresponds to the income range between $400,001 and $600,000, which translates to 78 participants, of which 30 of them received Treatment 2.

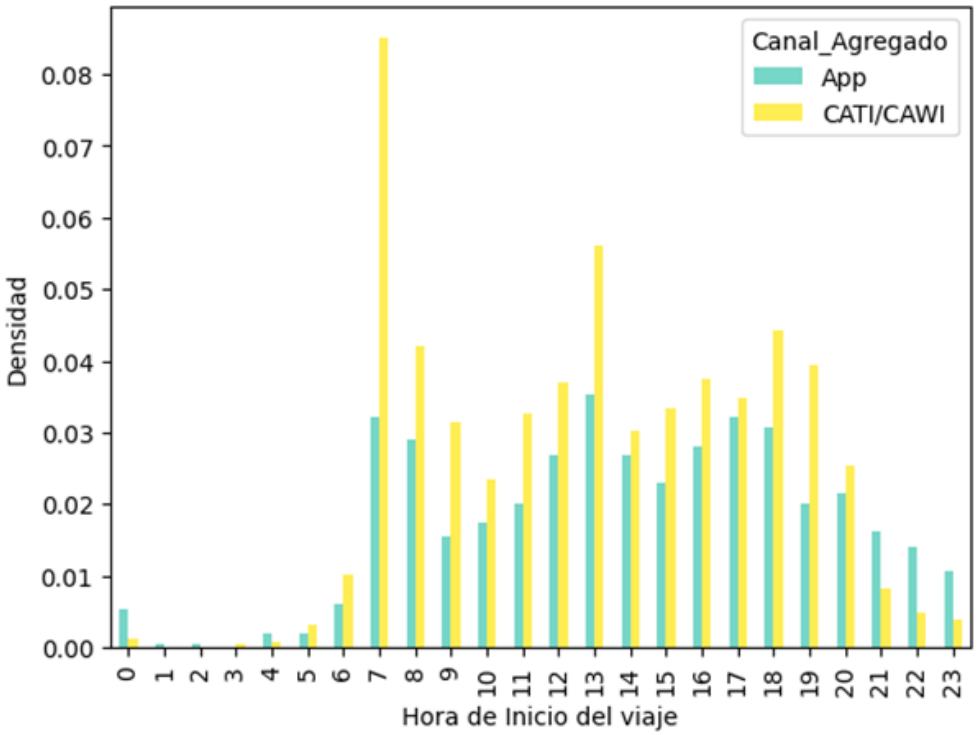
Figure 2 - Number of participants with different income levels



Similar to Pilot, we observed that the trip rates obtained with the app are much higher than those obtained through CATI. The app reported a rate of 3.9 trips per person, as compared to 1.42 trips per person from CATI. On the other hand, it must be borne in mind that according to the EOD-H 2018 of the city of Rancagua-Machalí, during 2018 2.64 trips per person and 7.91 trips/household were generated in one business day.

Figure 3 shows the histogram of trips according to the time of day when the trip starts. The peak hours in the morning, midday and afternoon are clearly distinguished, with valleys in the hours in between and a very marked nighttime hour. However, it is possible to see important differences in the distribution of trips by channel, with the CATI channel showing a much higher concentration in the morning peak, which suggests that the difference in the rate of trips between channels could be concentrated outside of those hours.

Figure 3- Travel time histogram by survey channel



As a conclusion, it can be said that the users of each channel are indeed of different profiles. Women opt for the app in a higher proportion than men. App users are concentrated in the age range of 30 to 49 years old, and are mostly workers.

In turn, when looking at the reported trips, it is possible to verify what was already observed in Phase I of this study, that is, users who choose the app report a higher trip rate than that obtained through CATI. It is therefore worth asking if this difference is explained given the different characteristics and profiles of users between channels or if there is indeed an underreporting of trips in CATI and in traditional survey methodologies. The foregoing, taking into account that the users of the app have carried out a process of data verification of all their trips, so their results should have a high degree of reliability.

5. CONCLUSIONS AND FUTURE DEVELOPMENT

This study demonstrated the effectiveness and feasibility of a multi-channel data collection approach for next-generation household travel surveys that includes app-based data collection, CAWI and CATI. Traditional survey methods have faced increasing complications and difficulties, making the use of mobile sensing and other technologies inevitable. Ultimately, the objective of moving to digital capture of mobility data is to obtain higher quality data than traditional survey methods can provide. The app provided advantages in terms of data quality, allowing for more precise identification of places, times, and routes used. The web survey channel, although not as accurate as the app, enabled those who could not or preferred not to participate via the app to be included. For household surveys in which every household member

is required to participate, such flexibility is essential. This study recommended further exploration of biases across the data collection channels, analysis of options for bias correction, evaluation of data quality, utilization of routing data for transportation purposes, generation of alternative sampling methods, reformulation of transportation models, and other areas of interest.

In terms of incentives, the results showed that the incorporation of incentives led to higher response rates in Pilot 2 as compared to Pilot 1 without incentives. However, the advantage of having incentives was not as high as anticipated. The acceptance rate for the survey increased to 42% in Pilot 2 compared to 13% in Pilot 1, and the completion rate improved to 69% from 48%. The unconditional treatment had the highest recruitment rate and was relatively cost-effective.

Despite these positive outcomes, we also observed differences in sample composition among the treatment groups, indicating a possible selection bias induced by the type of incentive.

In conclusion, while incentives proved effective in increasing response rates, the results emphasized the need for methodological improvements and the consideration of multi-channel approaches in future surveys. The findings contribute to the ongoing efforts of leveraging technology in transportation surveys and addressing the challenges faced by traditional methods.

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