EUROPEAN TRANSPORT CONFERENCE
7 – 9 SEPTEMBER 2022

SMARTPHONE-BASED TRAVEL SURVEY IN TURIN: A NEW DATA-DRIVEN APPROACH TO ASSESS URBAN MOBILITY PATTERNS

Francesco Chirico, Francesca Fermi, Davide Fiorello, Angelo Martino
TRT Trasporti e Territorio, Via Rutilia 10/8, Milan, 20141, Italy

Athena Tsirimpa, Konstantinos Kamargiannis
MOBY X Software, Anexartisias & Athinwn Street, Limassol 3040, Cyprus

Maria Kamargianni, Dimitrios Papelis, Simon Stebbins, Fangqing Song
MaaSLab, University College London (UCL), 14 Upper Woburn Place, WC1H0NN, London UK

Amalia Polydoropoulou, Ioannis Tsouros
TransDeM Lab, University of the Aegean, Korai 2A, 82100, Chios, Greece

The H2020 funded project HARMONY aims to develop a new generation of harmonised spatial and multimodal transport planning tool, representing new forms of mobility for freight and people, enabling metropolitan areas authorities to lead the transition to a low carbon new mobility era in a sustainable manner. More specifically, the main goal of the HARMONY project is to develop a Model Suite (MS) as a multi-scale, software-agnostic, integrated activity-based model system, which enables end-users to link independent models and analyse a portfolio of regional and urban interventions for both passenger and freight mobility. As part of the activities of the HARMONY project, the mobile application *MobyApp* was developed to collect mobility data and a passenger travel survey based on this smartphone application was carried out in the pilot city of Turin (Italy).

This paper provides an overview of the smartphone application and of the data collection process as well as a summary of the outcome of the survey regarding the mobility patterns in the Turin metropolitan area.

1. INTRODUCTION

Availability of rich and high-quality data is a key-driver in travel survey. Given the rapid penetration of smartphones with an accurate integrated GPS, many mobile applications have been developed to collect user data (Zhao et al., 2015). Compared to mobility data collection made by paper-based surveys, using GPS data makes possible tracking the whole trip, with spatial and temporal information (Bowman and Ben-Akiva, 2001, Richardson et al., 1995). Following the data-driven approach, the mobile application *MobyApp* was developed as part of the H2020 funded project HARMONY in order to create an integrated platform to cover all the needs of a travel survey. Thanks to this integrated platform, it is possible to collect additional information, like user preferences on mode choice or travel behaviour, that are not tracked through the GPS.

The use of *MobyApp* allows to collect data to analyse preferences and reactions of different population groups. This type of data is useful to support the modelling application of the HARMONY project. In fact, the Model Suite developed within the project stands within advancements in travel behaviour research and in particular with the conceptualization of activity-based approaches to travel demand forecasting (Bowman and Ben-Akiva, 2001; Goulias et al, 2011, Polydoropoulou et al., 2013). Therefore, advanced data collection methods are needed (Goulias et al., 2013). Specifically, the development in technology and data fusion enables close communication to the respondents in surveys, decreased respondent burden, and increased amount and quality of information (Polydoropoulou et al., 2013 or Matyas, M., & Kamargianni, M. 2019).

Turin is one of the European metropolitan areas in which the HARMONY platform is developed and tested, so collecting information on passenger mobility was crucial. On this purpose, a travel survey making use of *MobyApp* was originally planned for autumn 2020, but the COVID-19 pandemic forced to delay until February 2022.

This paper is organised in two main sections. In section 2, the methodology of the survey is introduced. In section 3 the most relevant results obtained from the data collected through *MobyApp* are shown. Conclusions end the paper.

2. METHODOLOGY

The passenger survey performed in Turin was designed to collect transport data of about 500 participants within the Functional Urban Area (FUA) which includes the city of Turin as well as other 87 surrounding municipalities.

2.1 The sample

The aim of the survey was to collect a representative dataset for the Turin FUA, so that the outcome of the survey could be useful for the modelling application within the HARMONY MS. Thus, the survey specialist company IPSOS was engaged to select a representative sample based on some pre-defined criteria.

A first criterion was that the sample should consist of individuals distributed throughout the whole Turin (FUA), proportionally to population living in different zones. Although the zoning system used in the HARMONY project is highly detailed, for the selection of the survey sample a less detailed zoning system – based on macro-areas – was used. On this respect, 55% of the participants to the survey were recruited from the city of Turin (in turn split into 4 zones), 33% of the sample was from the metropolitan area (split into 3 zones), and the remaining 12% of the sample was selected from the outlying municipalities of the FUA.

The sample was then stratified according to four variables:

- **Gender** (equal distribution between females and males)
- **Age** (40% between 18 and 34 years old, 60% between 35 and 64 years old)
- **Occupation** (60% employed, 10% retired, 30% students)

- **Number of cars** available in the household (25% without cars, 50% with one car, 25% with two or more cars)

The size of each stratum was based on the available statistics of population living in the sampled area.

2.2 The data collection approach

The survey consisted of three main parts.

The first part of the survey aimed at collecting preliminary information on individuals and on its mobility habits.

The second, and main, part concerned the collection of information on individual trips: origin, destination, duration, purpose, mode of transport. This part of the data collection was managed through *MobyApp*.

In the third part, Stated Preference (SP) questions were asked, based on the mobility behaviour registered in the first section. The Stated Preference questions were also managed through *MobyApp*, focusing on the following topics: Dynamic Travel Behaviour, Mode Choice, Mobility Tool Ownership, and Remote Working.

Additionally, at the end of the survey, users were asked to fill the Feedback questionnaire, but it was not mandatory.

2.3 The Survey Integrated Platform

The data collection was performed using primarily the *MobyApp* smartphone application.
Nevertheless, some data expected from the survey to support the HARMONY model suite could not be collected through the App. Thus, a Survey Integrated Platform was developed to merge data collected through the *MobyApp* and through a customised and targeted online survey.

The Survey Integrated Platform consists of four key technology components: i) the **Admin App**, which creates and sets up all the surveys based on the needs of the client; ii) the **Client App**, which provides a survey management tool to those who organise the survey (the clients of MOBY X[1]) to supervise the progress of the survey and check key statistics of the collected data via infographics; iii) the **Smartphone App** (Android and iOS) that collects raw data, such as GPS, GSM, Wi-Fi and accelerometer. Also, it enables users to see their activities/trip diary via the App; and iv) the **Server** that stores the collected data as well as contextual databases and processes it using machine learning algorithms to detect trips and stops and infer activities.

[1] MOBY X is the company responsible for the MobyApp development: http://mobyx.co/

Through the Integrated Platform, the survey manager can monitor the progress of the survey, to perform basic operations on the SP assignments, and to check the trips tracked using *MobyApp*.

2.4 The collection of individual trips

Each participant to the survey had to i) download *MobyApp*, ii) login and iii) fill in the Introductory Questionnaire. The third step was mandatory, in order to collect some basic information on the mobility attitude of the users. Once these steps were completed, the *MobyApp* started to track the trips and the places visited by the user. Some hints could be given to the application, saving specific places, such as “Home”, or “Work”.

MobyApp collected time and duration of the trips, transport modes used, and time spent on each one. More specifically, the *MobyApp* records 5 different transport modes within the same trip and records all movements, including small trips, such as those made to reach the car parked close to the departure place.

The aim of the application is to automatically recognize trips, transport modes and visited places. This is possible thanks to algorithms that associate travel features (especially speed and acceleration) to a transport mode. Nevertheless, the user’ validation is always needed to confirm the transport mode used, since it is not possible for the application to automatically distinguish, for example, private cars and taxi. So, at the end of each day, users were required to review the trips made during the day, namely the transport modes used, and the visited places / activities performed.

In addition, during the validation phase, some complementary information on the trips was collected, such as the number of people travelling with the user, the type of vehicle (private or shared), parking information, etc. These data allowed to provide a more exhaustive picture of the mobility patterns of the user.

At the end of the validation process, a complete travel diary was collected and stored on the survey database through the personal ID, i.e., without personal information associated.

Merging the data recorded by *MobyApp* and verified from the users, and the answers of the preliminary questionnaire, it was possible to have a comprehensive overview of the travel behaviour of the survey participants. Even though the data collected in each section is anonymous, thanks to the common user ID, it was possible to link the two data sources.

2.5 Fieldwork

In November 2021 a pilot test of the survey, involving 30 participants, was performed. Based on the feedback received, some adjustments to the questionnaire were integrated in the mobile application and in the related platform.

The main phase of the survey took place in two waves:

- A first wave in the first half of February 2022 involving 257 individuals
- A second wave in the second half of February 2022 involving 297 individuals

The month of February was chosen to avoid the atypical mobility patterns of December and January, as well as the peak of the latest wave of COVID-19 pandemic.

Each individual sampled was required to download *MobyApp* and to reach the minimum goal of the survey within two weeks' time: i.e., to fill the Introductory Questionnaire, to track and validate at least 4 days of trips and activities, and to fill 2 Stated Preference questionnaires.

3. RESULTS

This section of the paper focuses on the results of the mobility behaviour tracked by *MobyApp*, with a focus on the number of trips and transport mode used. Also, the home-based trips, the multimodality and the sharing mobility are analysed. The results of the Stated Preference questions are not presented in this paper.

3.1 Preliminary data analysis and cleaning

Starting from the raw data collected by the application, the initial step was to check that trips were recorded correctly. Therefore, some cleaning procedures were performed to delete duplications in registered places and trips or other inconsistencies.

The main intervention concerned the classification of the transport mode. As described above, *MobyApp* automatically recognises transport mode, trip duration, and visited places. Nevertheless, a manual validation is always needed, to check that the classification made by the application is correct. In particular, Public Transport is not always automatically detected by the application, since the features of trips like speed and acceleration are often almost identical to those of car mode. Therefore, during the validation phase, at the end of the data registration, when additional information was added by the participants to the survey – such as whether the vehicle used was private or shared or the parking location – the mode associated to the trip should have been checked and, in case, corrected before validating the day. The analysis of the data considered only fully validated days but even among these, it is impossible to know whether a survey participant really checked and corrected transport mode.

Since the resulting share of trips made by public transport was significantly below that provided by other sources, it was assumed that the validation process was not properly carried out by a certain number of individuals who probably failed to check and change the transport mode automatically defined by the application. In order to correct the data, responses from the preliminary questionnaire were used. For example, when in the preliminary questionnaire the respondent declared to not have an available car or to use public transport for her movements, the mode car was changed to public transport.

3.2 Analysis of mobility patterns

Here below some indicators extracted from the data collected with *MobyApp* (and cleaned as mentioned above) are presented. These indicators provide information on mobility patterns in the Turin FUA. It can be mentioned that the mobility pattern of the surveyed period is likely to be not the same as it was before the pandemic because in winter 2022 some restrictions were still active. In future months the mobility patterns could change further. Therefore, the representativeness of the collected data should be considered with care.

On average, the **number of trips** made by the individuals is of 3.1 trips/day. 56% of the individuals of the sample make an average number of trips in the range between 2 and 4 per day. The share of those doing more than 4 trips per day (20%) is slightly lower than the share of those doing less than 2 trips per day (23%).

3 trips per day is much in line with other travel surveys, however one aspect can be noted about the definition of trips. *MobyApp* registers different trips when there is a stop of some minutes. However, in some cases, the intermediate stop can be just a temporary break (e.g. dropping children at school) or the time needed to change mode (e.g. to change from one bus to another). So, the application can sometimes register stages rather than trips.

Comparable data related to the metropolitan area of Turin is reported in the Mobilitaria 2022[2] report, based on ISFORT AUDIMOB dataset[3]. In 2019, an average of 2.4 trips per day per individual was reported in a working day, while the value was 2.7 in 2016: the size of the data seems therefore comparable, taking into account that i) the ISFORT survey excluded short walking trips (less than 5 minutes), ii) non-working days are not considered and iii) MobyApp might occasionally have tracked stages instead of full trips.

MobyApp records **the origin and the destination activities** of the trips. Looking at the data, it can be noted that about one third of registered trips are home-based (31%), to be taken considering the comment above related to stages of trips registered by the App. The distribution of trips by destination activity (Figure 1) shows that most of the trips are made to return home (33% on the full sample of individuals), followed by *Other* (19%), *Work/education* (17%) and *Leisure* (14%). The analysis by employment status of individuals highlights that, reasonably, students show the higher share for *Leisure*, employed for *Work* and retired / unemployed for *Other, Shopping* and *Personal tasks*. This data could be compared with other surveys reporting the purpose of trips, such as the IMQ 2013 travel survey[4] and the ISFORT AUDIMOB dataset.

[2] https://www.cnr.it/it/nota-stampa/n-11090/rapporto-mobilitaria-2022
[3] https://www.isfort.it/2021/11/12/18-rapporto-audimob-sulla-mobilita-degli-italiani/
[4] https://mtm.torino.it/it/dati-statistiche/indagini/indagine-imq-2013/

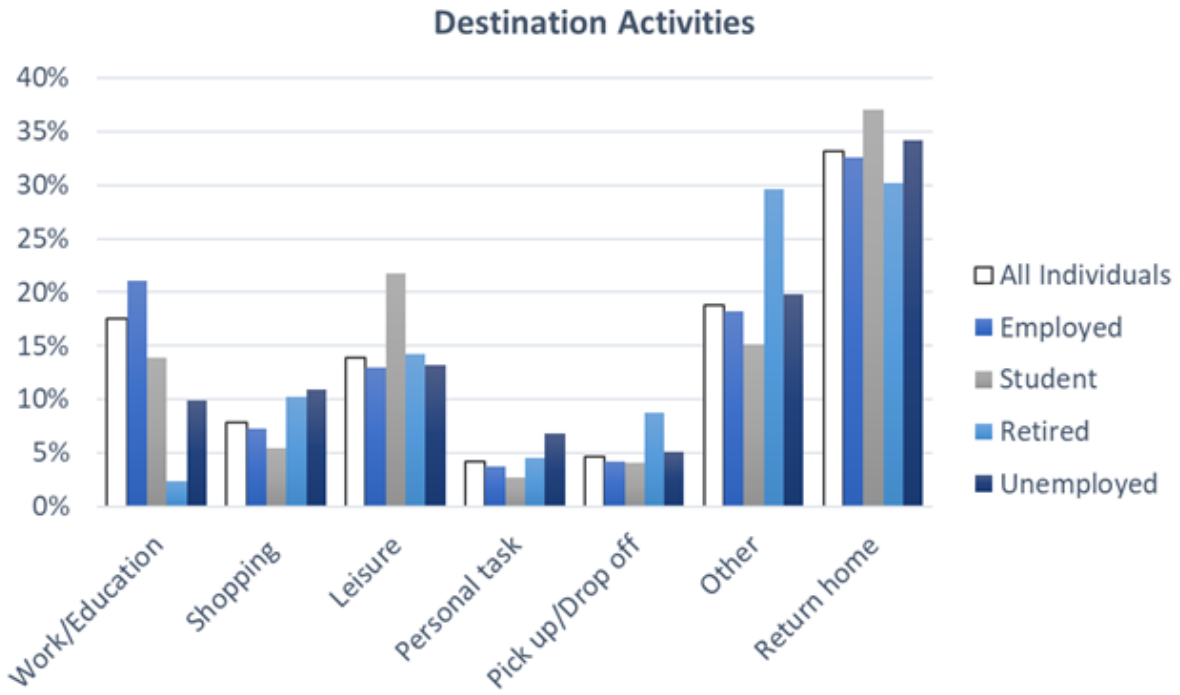

Figure 1 - Trip distribution by destination activity

Excluding the *return to home* trips, the share of *pick-up/drop-off* trips registered by the *MobyApp* 2021 survey is 6.9%, against 7.5% reported in IMQ 2013, while the share of *work/education* trips is 26.2% against 36.7% in IMQ 2013 and 33% in 2017/2019 (Mobilitaria 2022). The difference in the *work/education* trips can be also explained by the diffusion of remote working in the latest years, especially after the COVID-19 pandemic.

In general, a caveat similar to the one mentioned about the number of trips can be made regarding the classification of the origins and of the destinations. A visited place is recognised by the application only if the user stays there at least 6 minutes. Otherwise, the place is stored just as an intermediate stop, like a traffic light waiting. This threshold was calibrated to find an equilibrium between false negatives (locations visited but not recognised) and false positives (locations where only an intermediate stop was made but classified as destinations). Thus, if a user starts from home and come back to home after a quick stop for task not recognised by the application (e.g. pick up/drop off, shopping, etc.), *MobyApp* registers one single trip with “home” both as origin and destination. Actually, in the data the proportion of return to home trips is the same even for trips where origin is home. So, there can be some inconsistencies about the places defined by the application. Individuals could always correct the data in the validation phase, adding or removing a place but, as demonstrated by the relatively high share of trips for which the destination was undefined, this kind of correction was probably not widely made.

As regard of the **transport modes** used for the trips (Figure 2), *MobyApp* is able to collect combinations of up to 5 modes for each trip. With this information, it is possible to analyse the full combination of modes used by the individuals. With this respect, multi-modal trips can be analysed. Nevertheless, since also walking trips and waiting time are detected by the App, a post-processing of data was needed to avoid a misinterpretation. As a result, the survey shows a share of trips with more than one mode of about 1.3%, which seems reasonable in the urban / suburban context of application. Data from IMQ 2013 travel survey shows a comparable percentage, with about 2.5% of multi-modal trips.
Excluding multi-modal trips, the mode split obtained from the survey sees car as the most used mode (49%). Walking trips are also a significant share (33%) while public transport trips represent 16% of the mobility. Bikes are used for a minority of trips (less than 3%).

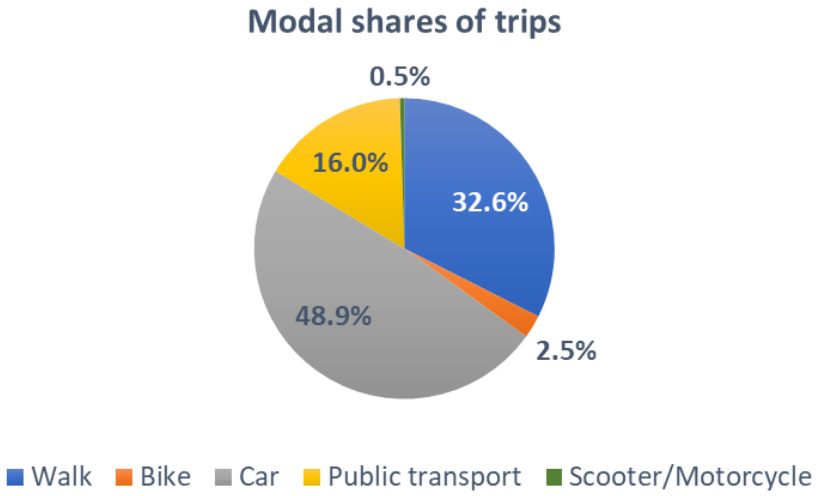

Figure 2 – Modal split

In addition, the analysis of mode split by employment status provides some hints on the different mobility habits. As shown in Figure 3, students (although above 18 years) use car largely less than the average. Instead, they move much more by public transport, bicycle and on foot. Employed and retired show similar modal split, with a large use of car (more than 50%) a share of trips performed by public transport below the average. Unemployed walk and use public transport comparatively more than the average.

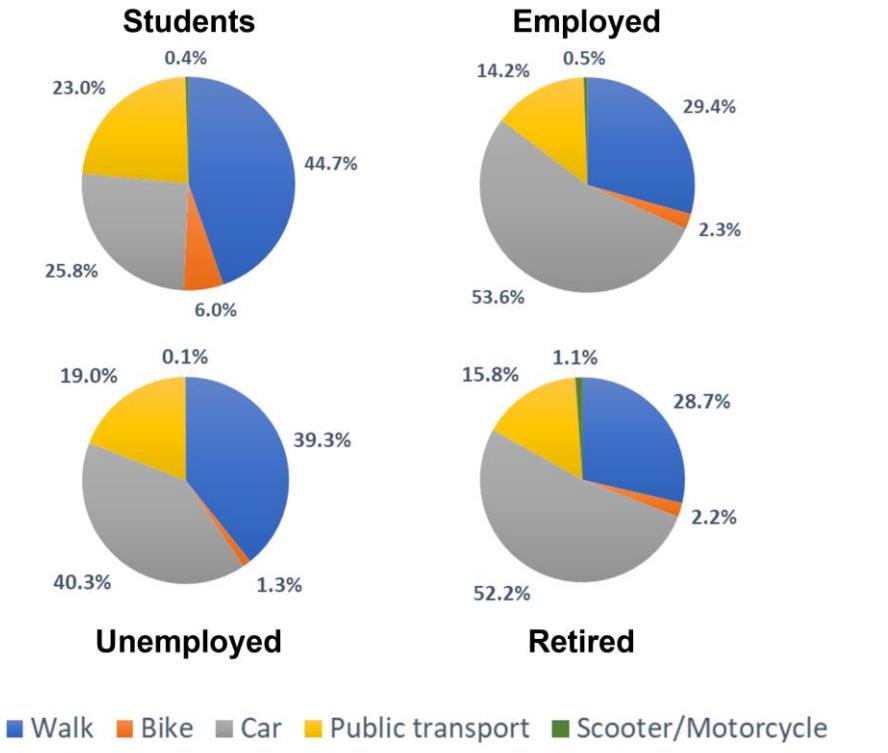

Figure 3 - Model split by users' employment status

Another interesting information about the trips is their **duration** (Figure 4), recorded by *MobyApp* together with the start and end times. About half of the trips lasts less than 15 minutes; 35% of all trips last 10 minutes or less, and on average, travel time per trip is 23.5 minutes. With this respect, considering Italian cities, the forthcoming EU publication on New Mobility Patterns[5] indicates about 29 minutes per trip in 2021, while the ISFORT AUDIMOB dataset reports 19 minutes per trips in 2019.
About 20% of trips last more than 30 minutes. Here the remark above about the possibility that the application registered stages rather than trips should be taken into account.
Performing the same analysis on duration with respect to car trips, the share of short trips (up to 10 minutes) is slightly lower (24%) and the share of trips longer than 30 minutes is larger (30%). Nevertheless, it is remarkable that almost one third of all registered car trips are very short. Therefore, the survey demonstrate that car is widely used even for very short distances on which active modes could be very competitive. In this sense, there is room to support tailored policies for promoting active modes and move toward a more sustainable urban mobility.

[5] The project Study on New Mobility Patterns in European Cities was launched by the DG MOVE of the European Commission to define mobility data for all EU countries according to a common methodology. Results of the study are under publication.

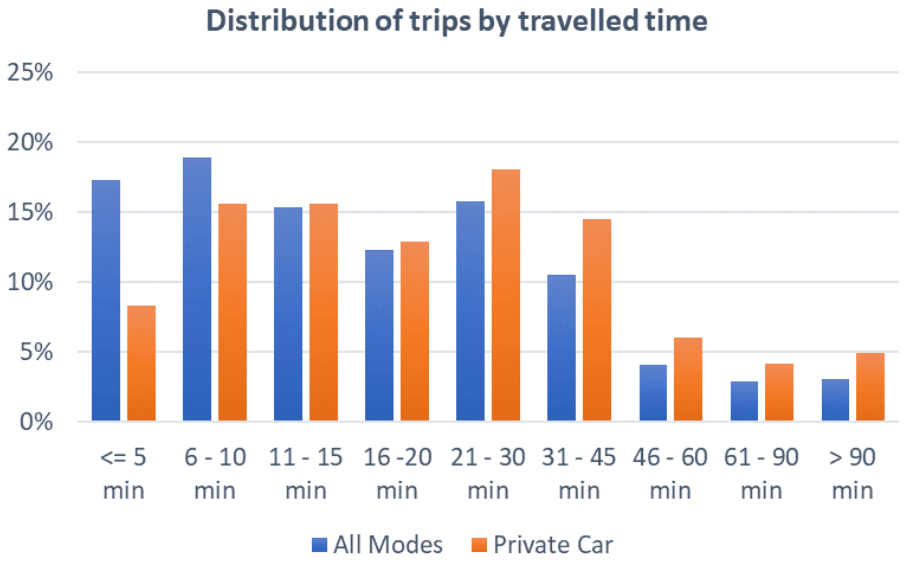

Figure 4 - Distribution of all trips by travelled time

Within the same transport mode used, the MobyApp survey allows to distinguish between private and shared vehicles. This feature is not automatically detected, but it is asked during the validation process of the trips for all transport modes (except Public Transport, Walking and Running). Taking as a reference the whole set of valid trips, 5.2% was classified as car-sharing service, and 1.4% as performed with long-term rented cars. With respect to car trips only, the collected data shows that 86% are declared as private vehicles, 11% as shared vehicles and 4% as rented cars. The proportion of shared vehicles looks quite high (since it implies that basically 1 out of ten cars circulating in the Turin is shared). Therefore, on one hand there is the possibility that users may have misinterpreted or overlooked the question. Nevertheless, it should be considered that the sample of Turin users has been selected under the condition that 25% of them does not own a private car. This option will therefore be further investigated linking the *MobyApp* data with the introductory questionnaire data. As a final consideration, it should be noted that in Turin there are two free-floating services and one station-based, for a total of about 900 vehicles and 280,000 subscriptions. According to the Italian Sharing Mobility report[6] performed in 2021 and 2020, Turin seems to show a significant use of car sharing mobility services, with about 1,7 million of trips in 2019 and 1,1 in 2020, and a rotation rate (trips per car/day) of the vehicles as large as 6 in 2019 (as Milan) and 4 in 2020 (against 3 in Milan and Rome).

4. CONCLUSIONS

This paper has presented some results drawn from a sample survey carried out in the Functional Urban Area of Turin by means of the mobile phone application *MobyApp* developed as part of the activities of the EC funded project HARMONY.

[6] https://osservatoriosharingmobility.it/

The data collected by *MobyApp* ranges from the number of trips made, to the activities in origin and destination, to the transport mode used. Other information, like the use of private or shared modes, was collected with additional questions still administered through the application.

The results shown demonstrate that the use of the application provides a reasonable overall picture of the personal mobility in the area. Nevertheless, further analysis of results and further investigation will be needed to explain some less obvious results and to take the opportunity for improving the technical features of *MobyApp*. For instance, a more precise algorithm would be needed to detect the use of public transport mode. For developing this algorithm, a detailed description of scheduled service (such as GTFM) would be needed as a minimum. Including this kind of data and a more precise algorithm would improve the usability of the application. This was not feasible within the time frame of the project but could be an option for future research.

Even in this version, the *MobyApp* application demonstrated that this approach for collecting mobility data works. Most of the individuals sampled for the survey who filled in the Feedback questionnaire declared to prefer this kind of survey over paper-based surveys (Figure 5). A similar portion of the users claimed to have had a good experience with *MobyApp*.

The conclusion drawn from this survey is that the use of a mobile phone application to collect individual mobility data is a promising approach even though progress should be made on the technical features of the application as well as on the organisation of the fieldwork to ensure the active engagement of participants to check and integrate the information collected, so to improve the quality of the overall results.

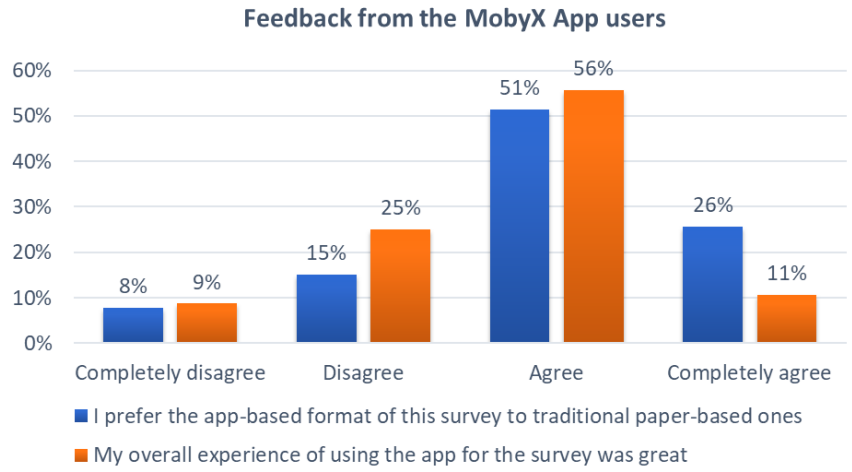

Figure 5 - Main outcomes of the Feedback questionnaire

ACKNOWLEDGEMENTS

This research is funded by the H2020 project HARMONY (Nº815269).

BIBLIOGRAPHY

Agenzia della mobilità piemontese – Rapporti IMQ 2013 (https://mtm.torino.it/it/dati-statistiche/indagini/indagine-imq-2013/)

Bowman, J.L. and Ben-Akiva, M. (2001), 'Activity-Based Disaggregate Travel Demand Model System with Activity Schedules,' Transportation Research Part A, vol.35, pp. 1-28

CNR – Rapporto MobilitAria 2022 (https://www.cnr.it/it/nota-stampa/n-11090/rapporto-mobilitaria-2022)

Goulias K. G. (2011) Transportation Planning and Modeling, Chapter 10 in Handbook of Transportation Engineering, Volume I: Systems and Operations, 2nd Edition, (eds Myer Kutz), McGraw-Hill, New York, NY. Pages 10-3 to 10- 27.

Kamargianni, M., Matyas, M., Li, W., Muscat, J., Yfantis, L., (2018). The MaaS Dictionary. MaaSLab, Energy Institute, University College London.

Matyas, M., & Kamargianni, M. (2019). Survey design for exploring demand for Mobility as a Service plans. Transportation, 46(5), 1525–1558. https://doi.org/10.1007/s11116-018-9938-8

OSSERVATORIO NAZIONALE SHARING MOBILITY (https://osservatoriosharingmobility.it/)

Polydoropoulou, A., Goulias, K. G., Tsirimpa, A., Kamargianni, M., Kourounioti, I., & Tsouros, I. (2013). INNOVATIVE DATA COLLECTION FOR MODELING GREEN TRANSPORT IN ISLANDS. 17.

Richardson, A. J., Ampt, E. S., & Meyburg, A. H. (1995). Survey methods for transport planning. Melbourne: Eucalyptus Press.

Zhao, F., Pereira, F. C., Ball, R., Kim, Y., Han, Y., Zegras, C., & Ben-Akiva, M. (2015). Exploratory Analysis of a Smartphone-Based Travel Survey in Singapore. Transportation Research Record: Journal of the Transportation Research Board, 2494(1), 45–56. https://doi.org/10.3141/2494-06