Department of
Infrastructure Engineering

Victorian Future Mobility Sensing (FMS) Trial

Project Report

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Executive Summary

The Victorian Future Mobility Sensing trial ('FMS Victoria') provided an exciting insight into smartphone technology opportunities for data collection. Participants from all around Melbourne were willing to install an app that tracked their movements. Over a short period, travel from approximately 200 Melburnians generated 35,000 stop records. This included 90 participants who validated a full two weeks of travel, allowing detailed travel habit and route behaviours to be analysed.

The trial was conducted as a way of understanding new opportunities for collecting detailed travel data, particularly compared to traditional paper-based surveys such as the Victorian Integrated Survey of Travel and Activity (VISTA). Unfortunately, robust conclusions from comparison analyses were difficult to draw, mainly because the self-selecting FMS Victoria sample was not thought to be directly comparable to the randomly sampled, geographically spread, VISTA cohort. Nonetheless, the study broadly indicated that:

- FMS Victoria collected more stops per person per day than VISTA.
- FMS Victoria collected more trips per person per day than VISTA.
- Additional activities detected in FMS Victoria were conducted as part of existing home-to-home trip chains, and were typically work-related, social and recreational in nature. An obvious example was travel to eat and drink from a work base, prior to returning to work.
- Automatic detection of trips to pick up or drop off a passenger was difficult using FMS.
- Individual trip lengths were typically longer in FMS Victoria than VISTA, with the exception of train and bicycle travel. The large number of longer train trips from the outer suburbs of Melbourne, in particular, led to a higher VISTA estimate of daily person kilometres travelled compared to FMS Victoria.
- An extremely different view of mode share is generated using FMS Victoria data, with substantially more walking and public transport travel reported compared to VISTA. The degree of difference suggests that this was a manifestation of the self-selected, inner-city weighted, FMS sample, with further exploration of the data needed to confirm this.
- A smooth travel time distribution is available through FMS Victoria, compared to the known bias in VISTA where self-reported travel is rounded to the closest 5/10/15/30 minutes.

Perhaps most importantly:

- The collection of travel routes through FMS Victoria provides an extremely rich source of contextual information. This opens new opportunities to detect missing stops, and observe different routes used across the day.
- There were examples of travel being left out of both VISTA and FMS Victoria. Neither method is guaranteed to collect all travel in isolation.

The response to FMS Victoria was lower than anticipated. While initial recruitment numbers of 400 registrations met expectations of the trial, approximately 40 per cent of this self-selecting sample

dropped out of the study without installing the app or collecting any travel. A further 20 per cent did not validate any of their travel. Just 90 participants met all requirements of the two-week study. Without substantial investment and effort, an expansion of the trial to a random sample of the population would not return VISTA's 47% response rate. The supporting survey infrastructure necessary for a pure app-based data collection – including survey administration steps, collection of data from people without a smartphone, collection of data from young people, household incentives, and data analysis plan – was not considered as part of this report.

Research directions

- Given the difficulties in comparing VISTA and FMS Victoria data directly, further investigation of the case-study survey data – in which the same travel was collected using different instruments – provides a useful research focus. This component of the study was added very late in the trial to obtain feedback on user preferences. The associated travel data from this case-study cohort is currently an untapped resource.
- One of the main advantages of the FMS data is the automated collection of routes. In this study, FMS Victoria data has only been analysed in aggregate, to allow comparison against VISTA data. An examination of the daily, and weekly, route variations will help to better describe travel behaviour in Melbourne. This may also lead to a shift from the shortest path / least-cost assumptions that inform current transport policy.
- Within the trial, there seemed to be significant variation in people's willingness to participate. For instance, one cohort of the FMS Victoria sample was quite willing to leave the app switched on without any validation whatsoever. Improving the usability of this raw data stream, and reducing the need for participant engagement, may substantially enhance the public acceptance of the tool.
- Design and respondent burden issues were identified in both FMS Victoria and VISTA. There are opportunities to therefore broadly review how information is best collected. Respondents seek improved interfaces that simplify data collection and reduce repetition.
- The ability to edit FMS data (in particular the addition of stops) was noted as a specific issue by a number of case-study participants. There is also evidence to suggest some degree of 'click through' validation of data, where a user may endorse the travel description without checking the detail and/or associated map points. Further investment into this travel validation space will therefore be beneficial in transitioning FMS to a mainstream data collection tool.

In considering the best survey to collect household travel, priority must obviously be given to the method that provides the required data, most consistently. This may vary depending on specific research needs. Consideration is also required on the broad range of sampling factors and associated estimates of survey error. Self-reported travel, through a paper-based, interview or online approach, is known to provide a good description of principal activities through the day, e.g. peak hour work, school and shopping trips. At this point in time, use of a smartphone app to *complement* existing data collections may provide a useful technology transition and allow appropriate corrections to the self-reported data to be made, particularly for more nuanced, discretionary travel.

1 Background

The Victorian Future Mobility Sensing (FMS Victoria) trial is a collaborative research project, jointly funded through the University of Melbourne's *Carlton Connect* grant program and the previous Victorian Department of Transport, Planning and Local Infrastructure.

The project was established to consider the benefits and disadvantages of using a smartphone app to collect travel data from survey participants.

While there are a number of smartphone travel survey applications currently under development around the world, the project team negotiated use of the FMS app developed by SMART (Singapore-Alliance for Research and Technology). FMS was first field tested on a large scale as a component of the 2012 Singaporean Household Interview Survey (HITS), where approximately 800 participants completed a 14-day data travel survey using the smart-phone app (Carrion et al., 2014; Zhao, Pereira, et al., 2015). FMS therefore provides a relatively mature application in what is still a new technology space. Using a common FMS platform, SMART provided a localised version of the app which included Melbourne-relevant transport questions.

1.1 Victorian household travel survey context

Within Victoria, the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) collects detailed travel behaviour data using the Victorian Integrated Survey of Travel and Activity (VISTA). VISTA was originally conducted across the 2007-08 and 2009-10 financial years, before a continuous (4 year) survey was initiated in mid-2012.

VISTA is a self-completion paper-based travel diary, designed to collect information on all personal travel made outside of the home on a single nominated survey day. Survey days are spread across the year, to take account of daily and seasonal variations in travel. The VISTA sample is randomly drawn from a list of (residentially zoned) addresses in Melbourne and Geelong, with major regional centres also surveyed on selected years. Data from approximately 4000 households is collected each year, with all members of selected households asked to complete a survey.

VISTA supports transport policy and planning within the Victorian Government by providing a detailed evidence base of travel behaviour. In particular, data from VISTA underpins the travel assumptions used in the government's strategic transport network modelling program – highlighting future growth pressures and infrastructure investment needs.

1.2 Motivation for alternative survey testing

VISTA provides a stable survey platform, generating data that can be read and understood within the current suite of transport analysis tools. However, there is a need to continually investigate alternative data collection methodologies, to ensure that decisions are being made with the best possible picture of daily travel patterns. For instance:

- VISTA provides origins and destinations of travel, but not the actual travel paths used.
- Aggregated data from VISTA provides an illustration of the average day of travel across the entire population, but fails to capture variations in individual travel behaviour.

- Notwithstanding the well-tested survey design and provision of instructions, the travel reported in VISTA reflects a respondent's interpretation of the department's data needs. Peak hour travel is typically accurate when measured against secondary data sources (eg. vehicle screenline counts) as this represents a commonly understood definition of travel ("I went to work"; "I went to school"). However, shorter discretionary trips could be under-reported as they may be perceived as less critical, or not as travel at all ("I walked across the street to buy a coffee"). Some recent commentary on off-peak underreporting in household travel surveys is also provided by Veitch, Paech, and Eaton (2013).
- Following the above point, every trip reported does add to respondent burden. A respondent may overlook some travel if the main trips have been captured. Public transport travel provides a specific example of where burden can grow: a standard public transport trip will normally require at least three travel-legs to be reported (access to public transport stop, travel using public transport, egress from the destination public transport stop) compared to other (door-to-door) modes of travel.
- Some aspects of personal reporting of travel will always be a best estimate by the respondent. Using a common example, travel time is typically rounded to the nearest 5, 10, 15 or 30 minutes.
- The VISTA survey pack can appear cumbersome at first glance, due to the multiple travel diary booklets and complex appearance of stop pages. This may deter some people from participating (an issue potentially magnified for those with lower level literacy or English skills). The survey complexity may ultimately encourage soft-refusals by participants, opting to report 'no travel' on the survey day.

Testing of an FMS-type survey allows some of the perceived limitations of traditional household travel surveys to be explored, while also providing an appreciation of the potential challenges and benefits that a newer technology solution may bring. Ideally, FMS would deliver the following improvements over traditional surveys:

- provision of GPS monitored travel paths
- multiple days of travel collected for each participant with little or no additional administrative cost
- automatic collection of travel to reduce respondent burden
- automatic collection of travel to reduce under-reporting of trips
- accurate travel time data, including specific network slow points
- closer match to increasingly technology supportive respondent expectations.

Early outputs relating to FMS performance in Melbourne are captured in this report.

2 Recruitment

2.1 Sampling methods

Participants in the study were largely recruited using convenience sampling. Specifically, due to the availability of contact information, the primary target group was the staff and students of the

University of Melbourne. Advertisements were placed in university staff and student email bulletins, requesting research participants for a smartphone-based travel survey.

The residents of Carlton and Belgrave were also selected as a secondary target group. The choice of these two areas – inner city Carlton, and metropolitan-fringe Belgrave – was intended to allow comparison of different resident travel patterns. The distinct topographic and urban form features – higher density buildings in and around Carlton compared to the hilly terrain of Belgrave – were also of interest from a mobile phone coverage and tracking perspective. Without a specific sampling frame to draw on, recruitment from these areas used ad hoc project publicity methods to raise awareness. This included the following articles, also included in Appendix A:

- John Faine interview on ABC Radio (22 September 2015)
- ABC news Online article (23 September 2015)
- Small alert article in the RACV Royal Auto magazine (October 2015 edition)
- Article in the Ferntree Gully Belgrave Mail (13 October 2015)
- Public transport posters, located in buses and stations servicing Belgrave (November 2015)

VISTA participants who had flagged an interest in other transport research projects were also emailed an FMS Victoria project invitation (Appendix B). Near the end of the trial, all registered participants were also invited to pass on information about the study to friends and family members who may be interested.

The sampling techniques used in the study are not appropriate for statistical interpretations of the data. Commentary and interpretation of results must take into account the self-selecting nature of the respondents.

3 Incentives

To encourage participation, participants from the nominated study areas who completed all requirements were eligible to receive a $50 WISH e-voucher. Eligibility requirements were as follows:

- They were one of the first 450 respondents (150 from each of the three study area groups) to complete the survey. The three study area groups comprised:
    - Residents of Belgrave (postcode 3160, including Tecoma)
    - Residents of Carlton (postcode 3053)
    - Staff and students of the University of Melbourne, Parkville campus (postcode 3010)
- They were 18 years of age or older as of 1 October 2015.
- They owned a smartphone, and were able to download the FMS survey app onto their smartphone.
- They participated in the survey by logging into the FMS smartphone app and carried their smartphone with them while they travel for **a total of fourteen-days (including at least seven continuous days)** before 1 December 2015.
- They validated the accuracy and completeness of the travel collected each day by the FMS app using an online survey tool.
- Travel days were completed and validated by Friday 4 December 2015.

As publicity for the study was not contained to the specific focus areas, incentives for broader population participants were also made available. Without knowing the level of interest that the study would generate, this additional incentive pool was necessarily capped. All survey participants, except those from the three study areas who had already received a gift card, would be entered into a prize draw for one of fifty WISH Gift Vouchers ($50 value each). Full incentive terms and conditions are provided in Appendix C.

The level of incentive was relatively high for a travel survey, but reflected both the substantial participant commitment required (fourteen days of verified travel, including seven continuous travel days) and the need to attract people's attention without a formal sampling frame. It is noted that the majority of media references to the trial did not mention the incentive, which may partially explain the relatively low participation rate (Section 4).

4 Participants

A target of 500 participants was identified for the study, largely based on the available budget for incentives and practical staff and resource constraints. In total, 400 participants registered to take part in the study, with a substantial amount of interest (250 registrations) in the first week of the trial (Figure 1). Of the 400 registrations, 41 per cent (165 registrants) did not progress to activating the FMS smartphone app. This left travel data from **235 participants**.

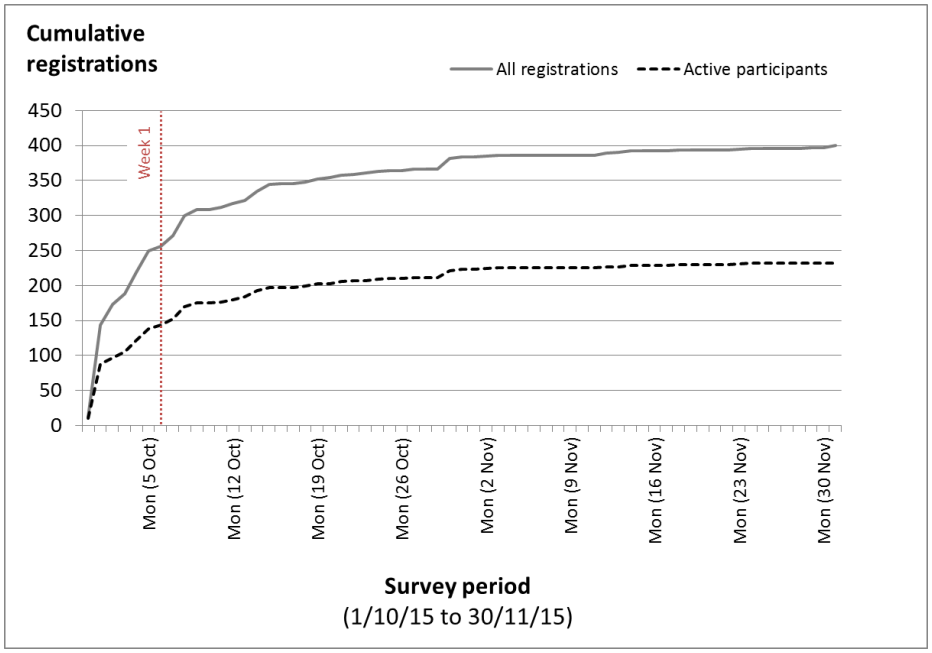


Figure 1 New registrations across the study period

4.1 Active Participants

Of the three target groups, most recruitment success was achieved with University of Melbourne staff and students (31 per cent of active participants, as shown in Figure 2). This is understandable, given direct opportunities to invite participation through university communication channels. Looking across the respondent population more generally, a strong cluster of responses from inner Melbourne was generated, augmented by responses from across the metropolitan region (Figure 3). A few regional centre (Bendigo) responses were also collected.

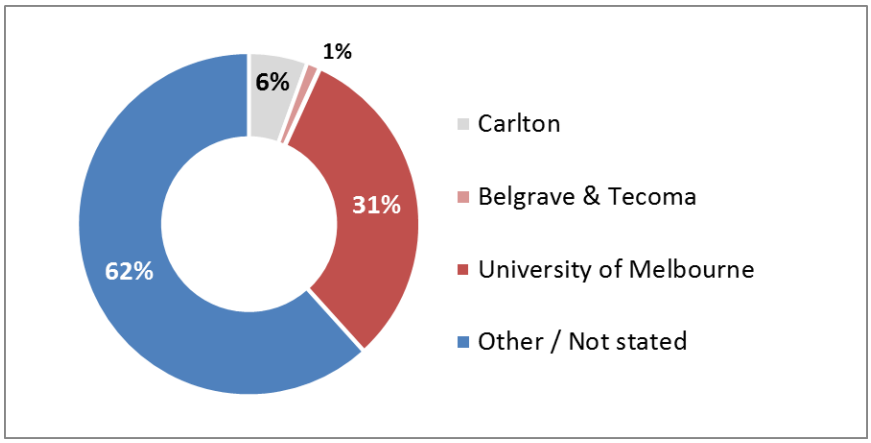


Figure 2 **Active participant groupings**

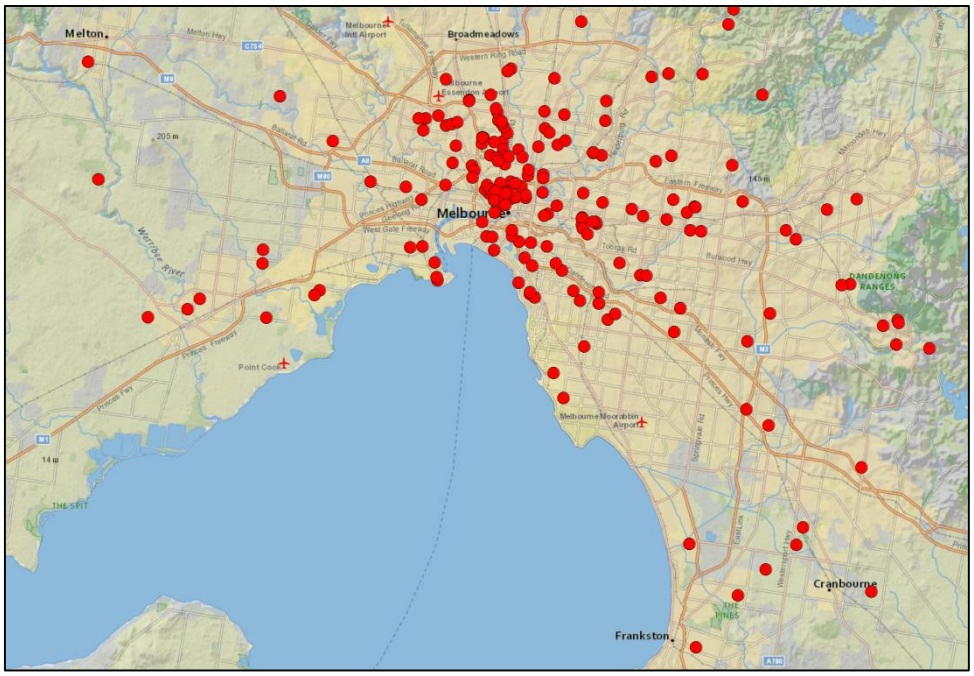


Figure 3 **Active participant home locations**

4.2 Data collection and validation

Within the group of active participants, there were substantially different rates of data collection and validation behaviour. Three broad groups emerge (Figure 4):

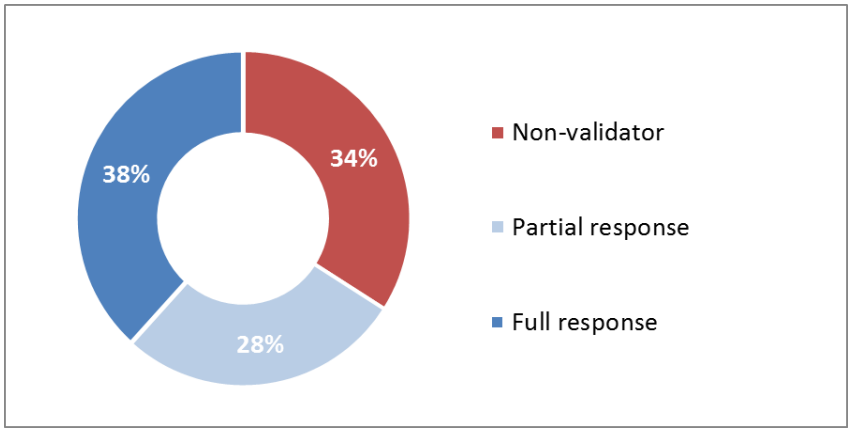


Figure 4 Types of trial participant

The classification of these groups is provided in Table 1.

- Those who did not validate their data at all *('Non-validator'; 80 participants)*
- Those who did not travel for 14 days, or validated only a portion of their travel *('Partial response'; 65 respondents)*
- Those who validated data for at least two weeks, including seven continuous days *('Full response'; 90 respondents)*

Table 1 Participant Classification

Travel days collected	Total days validated	Continuous days validated	Classification	Sample size
1	0	0	Non-validator	16
	1	1	Partial response	10
2 - 13	0	0	Non-validator	36
	1-13	1 to 6	Partial response	23
14 +	0	0	Non-validator	28
	1-13	1 to 6	Partial response	28
	1-13	7 +	Partial response	2
	14 +	1 to 6	Partial response	2
	14 +	**7 +**	**Full Response**	**90**
			Total	**235**

Validated responses provide the closest comparison to a traditional household travel survey. Through the validation process, a travel description is returned that provides an origin, destination, purpose of travel (FMS allows for multiple purposes and a main purpose), method of travel and some selected mode-specific attributes (e.g. number of people who travelled; route number; driver or passenger status). The route of travel is collected through the phone-GPS. However, all responses provided through the study provide a rich dataset for subsequent investigation. Comparisons of travel by participants with different validation behaviours, for instance, allows the automatic predictions of travel to be improved.

The non-validators provide an interesting sub-sample, from both a travel behaviour and survey response perspective. Almost a quarter of all respondents collected data for more than a day, but chose not to verify it. Many of these, approximately 12 per cent of all study participants, collected data without validating it for more than two-weeks (Figure 5). This reveals interest from participants for easy, longer term, tracking of their travel behaviour. By definition, someone who did not validate was not entitled to an incentive, but many participants maintained over two months of data collection (even following a reminder to let them know that the app was still active on their phone). Cleaning this data using the validating sample, or seeking alternative methods of capturing complementary information, provide useful avenues of research beyond this trial.

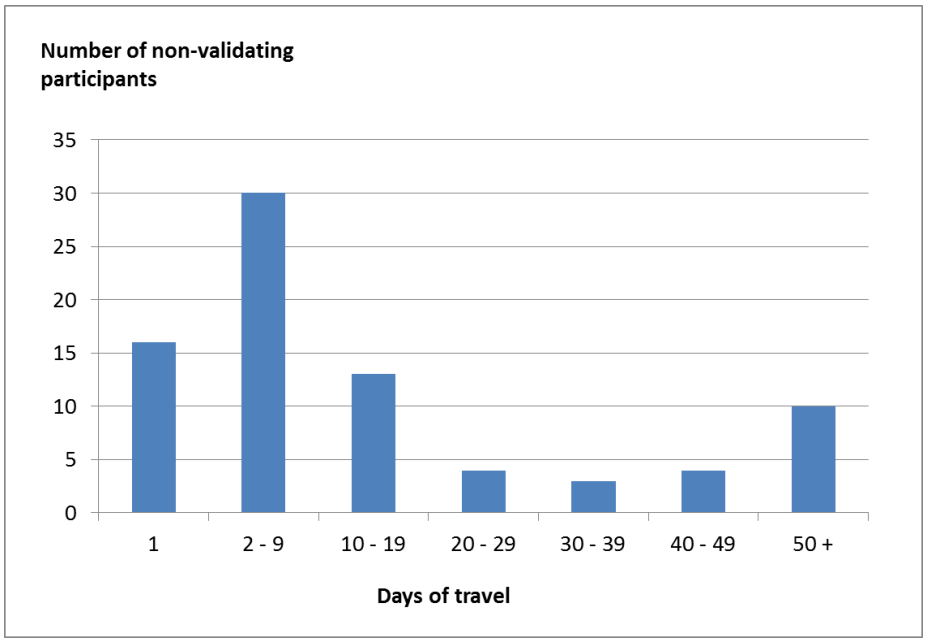


Figure 5 Participation by 'non-validators'

4.3 Demographics

All demographic and personal characteristics, except where otherwise stated, relate to 234 of the 235 initially active participants (1 participant did not complete the registration survey). It is reiterated that FMS is a small self-selecting sample, and is not expected to match to population totals. (Accompanying VISTA data has not been expanded to population estimates. The VISTA data shown is restricted to Melbourne residents aged 18-plus.)

Age and gender

As expected, given the targeting of university students for a mobile phone tracking survey, participants in the study were generally younger than the equivalent VISTA cohort.

Approximately 85 per cent of FMS study respondents were under 50 years of age, compared to 55 per cent of the unweighted VISTA sample (Figure 6).

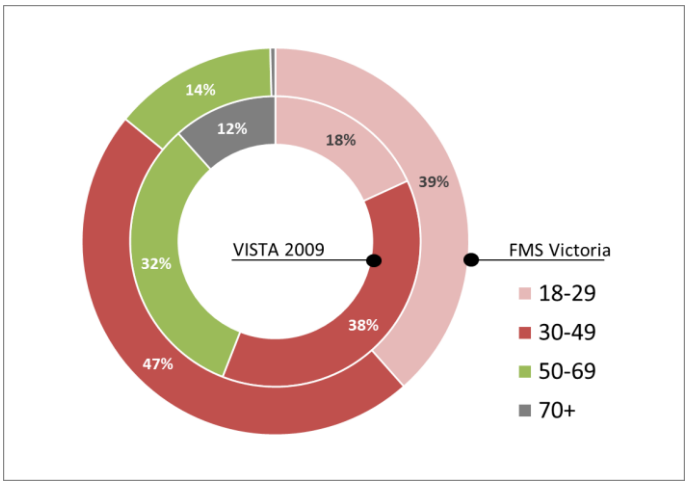


Figure 6 **Age profile of participants**

Age

A higher proportion of men than women participated in the study compared to VISTA (Figure 7). The unweighted VISTA sample was closer to broader Victorian population figures, where 51.1% of those aged 20 and over are female. (Australian Bureau of Statistics [ABS], 2014)

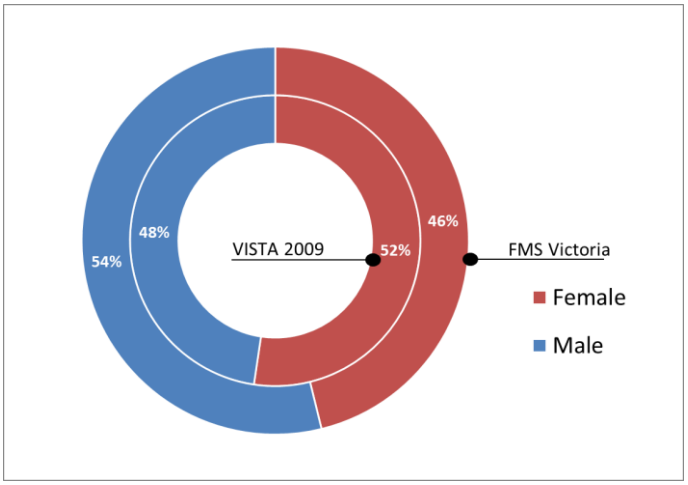


Figure 7 **Gender profile of participants**

Education and income

The distinct nature of the university-focussed sample is highlighted in Figure 8, where three-quarters of the FMS participants are shown to have a Bachelor degree qualification or higher. While this data is not obtained for VISTA, the Victorian state-wide equivalent is approximately 24% (Australian Bureau of Statistics [ABS], 2012).

High education and employment levels naturally cascade to higher average incomes for the FMS sample (Figure 9).

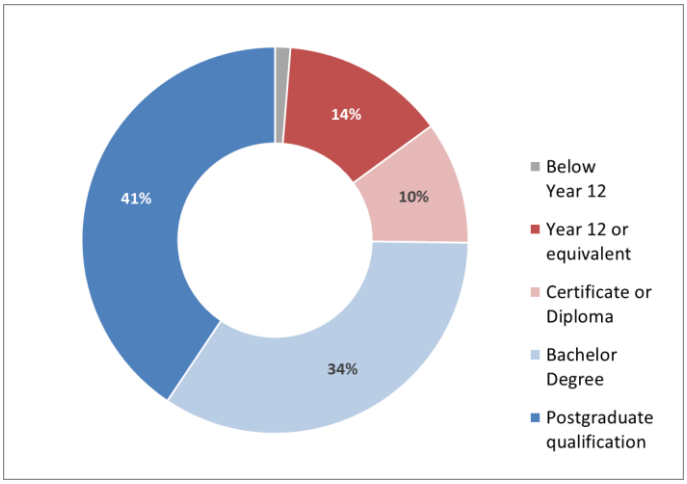


Figure 8 Highest education level

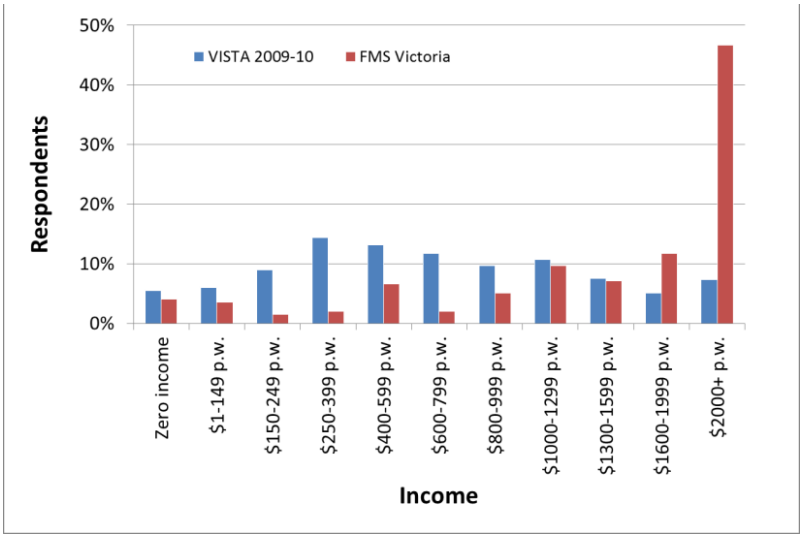


Figure 9 Average weekly income

Household mobility

From a car ownership perspective, there are a large number of FMS participants with no household vehicles (Figure 10).

This is complemented by a relatively high degree of bicycle ownership. Almost half of FMS participant households have more than 2 adult bikes in working condition (Figure 11),

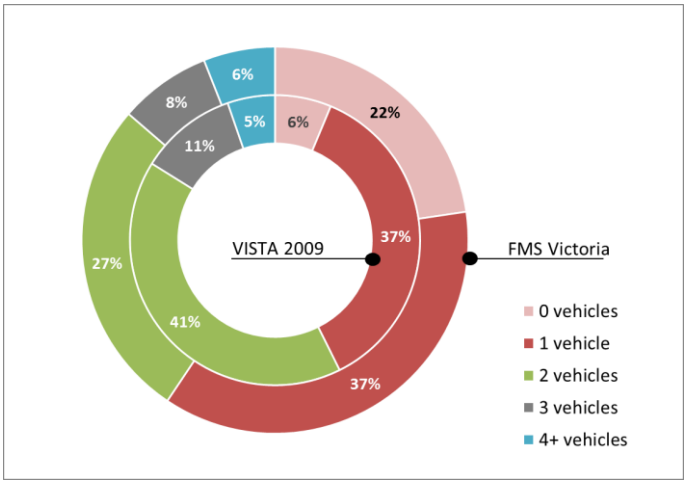


Figure 10 Car ownership

reflecting both the high proportion of inner city participants and younger demographic identified previously.

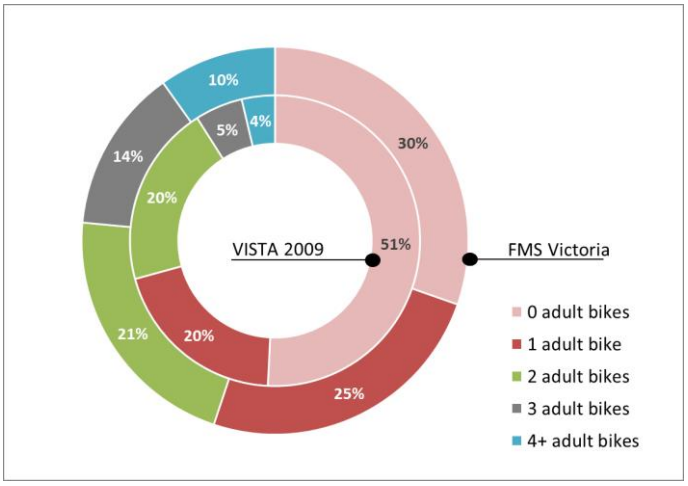


Figure 11 Bicycle ownership

Household characteristics

Substantially more FMS participants are renters compared to the VISTA sample (Figure 12), an outcome of the relatively high student and inner city numbers.

This also generates a greater proportion of share housing, leading to slightly large household sizes in FMS (Figure 13).

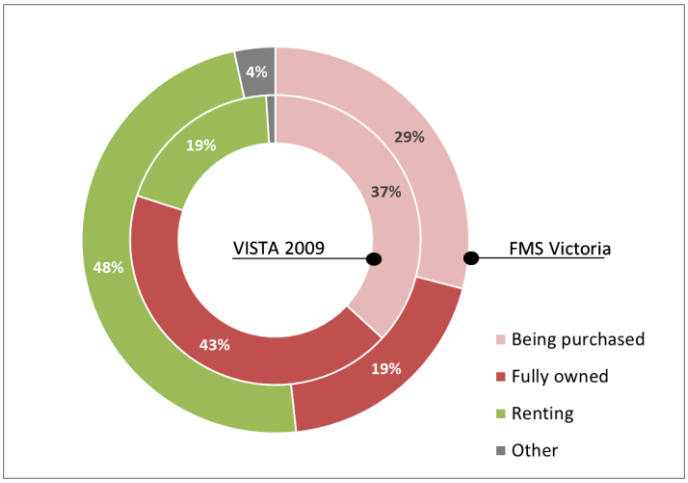


Figure 12 Household ownership

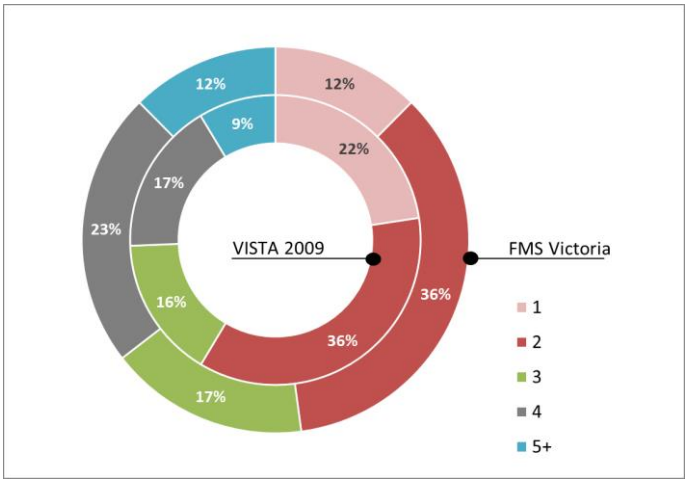


Figure 13 Household size

5 Data collection

Data is collected by FMS across several phases.

- Registration Phase
- Travel Phase
- Validation Phase

5.1 Registration phase

The registration phase collects information about participants' demographic, mobility and household characteristics. This data is only collected once consent to the project has been provided (Figure 1).

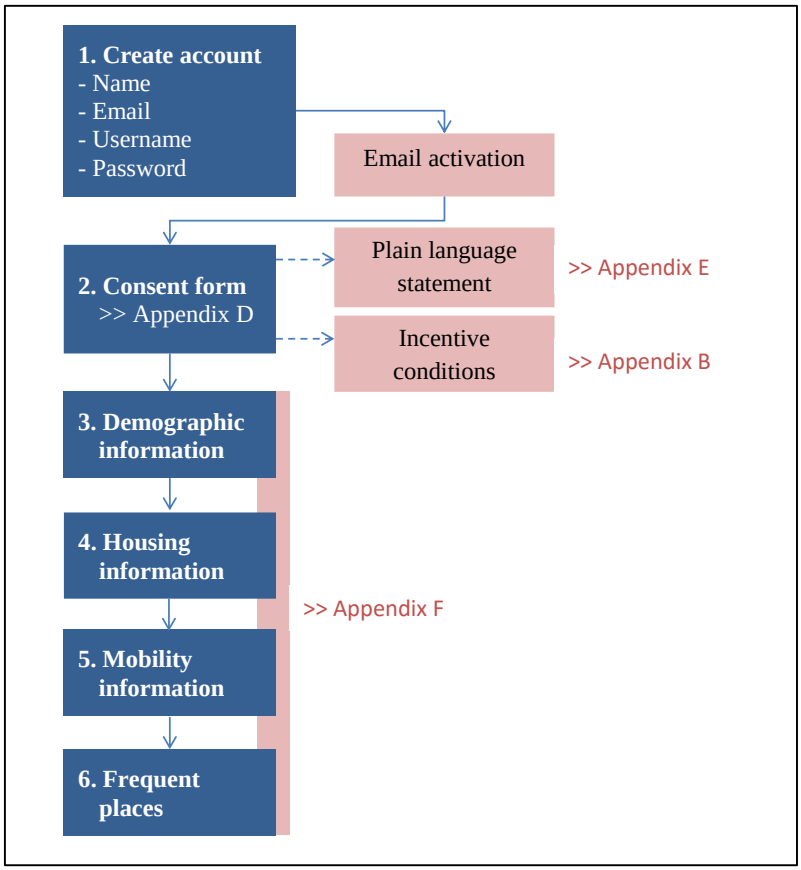


Figure 14 Registration survey

5.2 Travel phase

Once the app is installed and activated, the phone collects travel data through a combination of technologies (Zhao, Ghorpade, Pereira, Zegras, & Ben-Akiva, 2015):

- Phone GPS monitors travel paths
- Wi-Fi signals and GSM cell tower information are used to estimate location when GPS signal is weak or not available

- Wi-Fi and GSM signatures further assist in identifying regular stops
- Accelerometer data confirms whether phone is stationary (even if GSM or Wi-Fi signals are implying movement through signal fluctuations).
- Accelerometer data, in combination with speed attributes and locational data, is also used in the prediction of travel mode.

The resulting temporal and spatial data allows for stop inferences to be made. In a simple example, points that are clustered within a 50m radius for at least a minute are identified as a candidate stop. Candidate stops may then be cleaned and merged following additional criteria. For instance, two candidate stops, within 150m and three minutes of each other, would be initially merged as one, as are two candidate stops within 50m and a break in data (e.g. a phone being turned off overnight).

5.3 Validation phase

The validation phase allows data to be verified and, where necessary, adjusted by the participants prior to it being stored as an accurate representation of travel.

- Participants are shown a map and summary 'stop-chain' of travel for a given survey day, including system predictions of modes and activities. All unverified travel purposes and modes are shown in grey; participant validated stops are shown in pink (Figure 15).
- Activities and modes are represented using symbols, with text descriptions available by hovering the mouse over each icon.
- Each activity and travel leg can be checked and additional information to be stored. In a variation on typical household travel surveys, multiple purposes and a main purpose can be selected for any location (Figure 16).
- The method of travel verification includes complementary questions about the specific mode selected (Figure 17). For private vehicle, this includes whether the participant was the driver or passenger, how many people travelled with them, and where the vehicle was parked. A full list of complementary questions is provided in Table 2.
- Incorrect system generated stops can be deleted, and any missing stops manually added.

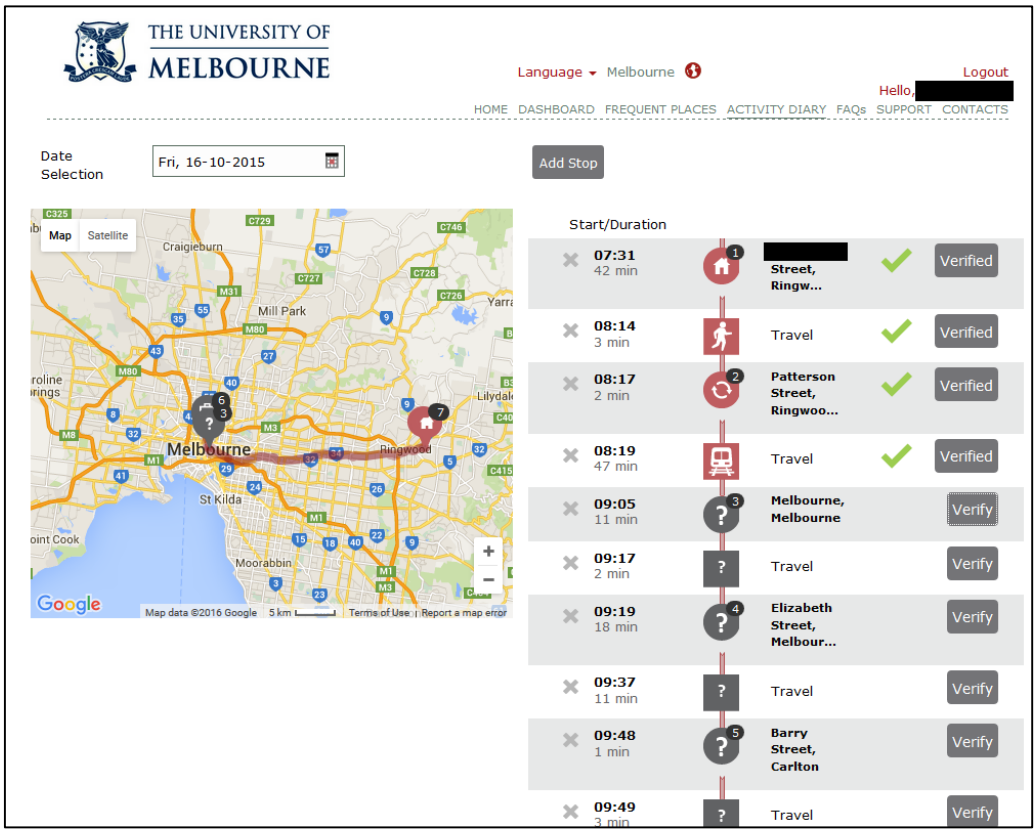


Figure 15 **Online travel validation interface**

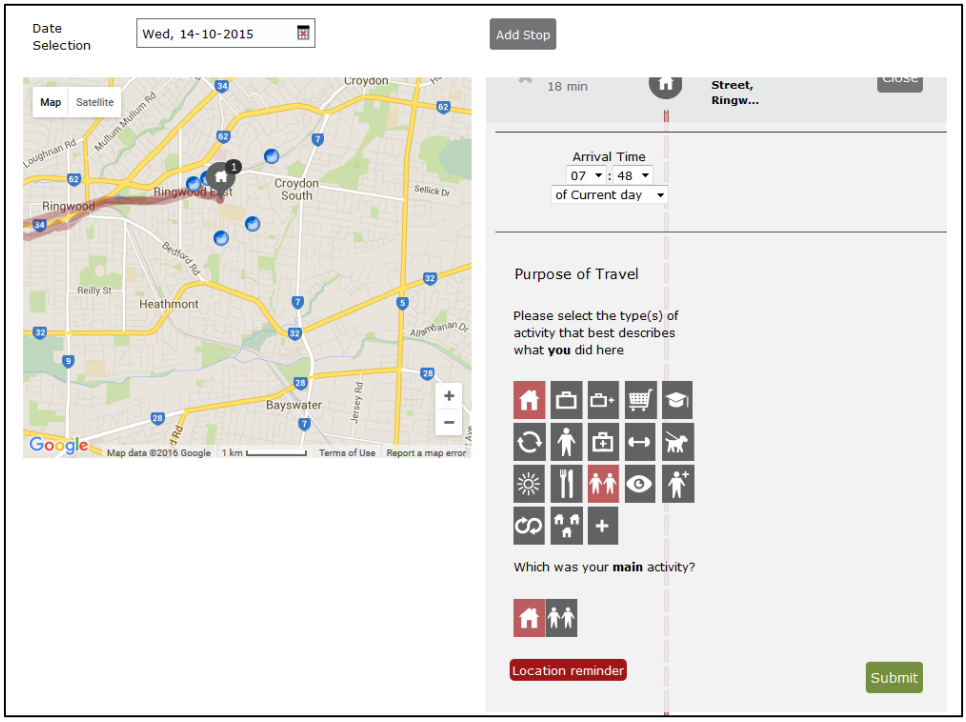


Figure 16 **Verifying purpose(s)**

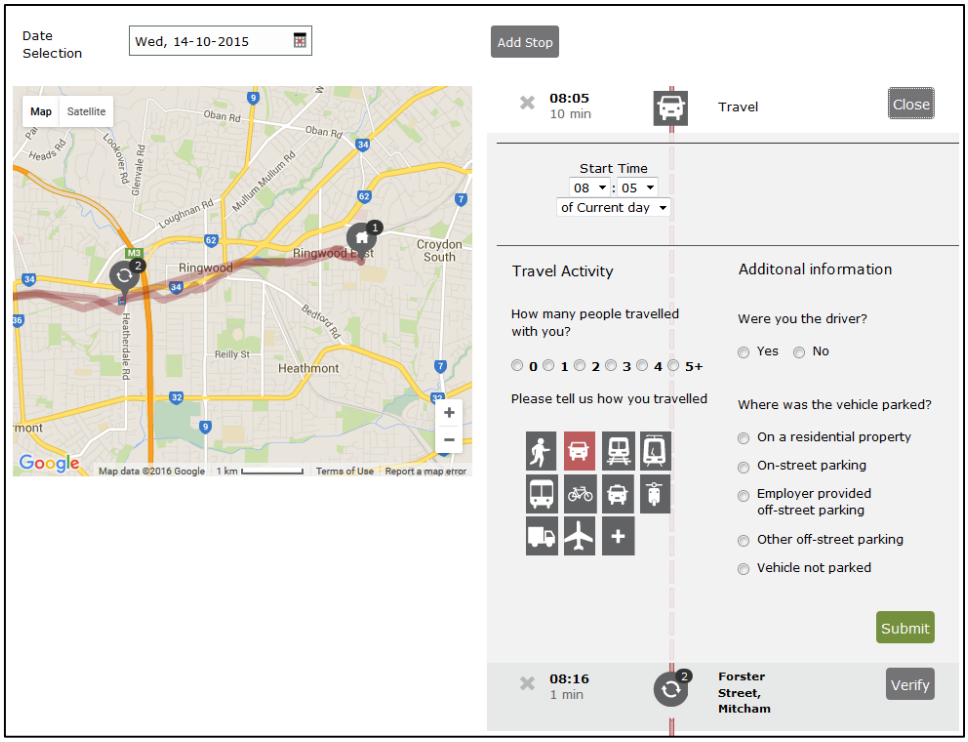


Figure 17 Verifying and appending mode information

Table 2 Additional mode questions

Additional questions asked	Mode selected										
	Car / passenger vehicle	Walk	Bicycle	Train	Bus	Tram	Motorbike	Van / Truck	Taxi	Plane	Other
How many people travelled with you? *[0; 1; 2; 3; 4; 5+]*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Were you the driver? *[Yes; No]*	✓						✓				
Where was vehicle parked? *[On a residential property; On-street parking; Employer provided off-street parking; Other off-street parking; Vehicle not parked]*	✓										
Fare type? *[Full adult fare; Concession fare; Some other fare; No fare required]*				✓	✓	✓					
Route number (if known)?					✓	✓					
Bus type? *[School bus; Public bus; Other bus]*					✓						
How was the taxi fare paid? *[My work paid for the taxi fare; I paid for the taxi fare; Someone else paid for the taxi fare]*									✓		
Please specify [text box]											✓

5.4 Data summary

In contrast to traditional household travel surveys such as VISTA, where the lengthy nature of the data collection process and follow up data auditing can equate to an 18-month project delivery period, the Victorian FMS trial was effective in generating a substantial amount of geocoded travel data in a short time period.

At the end of the data collection cycle 45,259 stop records were generated by the 235 active participants. These were cleaned to remove obvious data quality issues:

- stops which had been flagged by users as deleted were permanently removed
- 'home stops' were removed where no travel was made from a house across the entire day
- stops were removed where consecutive home activities had no external travel (e.g. exercise) between them
- duplicate stops were removed, where multiple purposes were linked to the same stop number.

This left an initial stop file of 41,202 valid stops by 213 participants.

6 Initial data checks

6.1 Automatically recorded GIS traces

Route data is stored in FMS using an Google encoded polyline format (Google Developers, 2016). This stores polyline path coordinates as a single text string. Conversion of the data to GIS coordinates was adapted from an existing Python programming script (Cheng, 2009) and reproduced in Appendix G.

Visual checks of the data were made to confirm appropriate data translation, and examples reproduced below. As expected, following the targeted sampling of University of Melbourne staff and students, there was a substantial return of GPS data points along Royal Parade to the west of the University's Parkville campus, and Swanston St to the east (Figure 1). Actual traces within campus are more dispersed as staff and students walk between buildings. Specific recreational behaviours are apparent, with laps run around the university's athletics track detected. (This latter type of active travel behaviour may be overlooked as part of a traditional survey, which would at best reported the activity as a single exercise activity point with accompanying travel to and from the site).

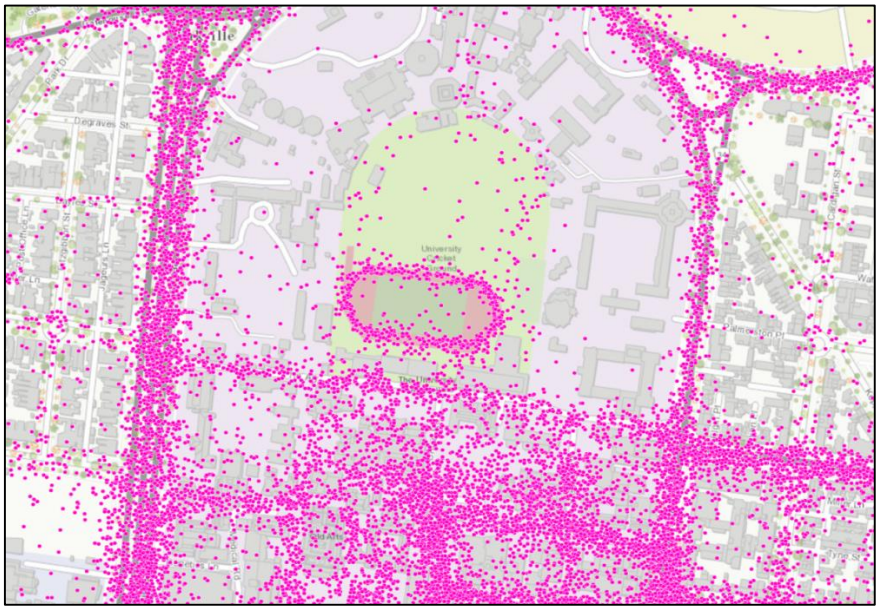


Figure 18 GPS traces collected in and around the University of Melbourne

Travel on the road network is generally picked up very well through the FMS Victoria trial. For instance, a tight buffer of points is found along the West Gate Freeway through Fishermans bend (Figure 19). Converting these to route polylines shows there are some background straight line paths (where traces have been missed between origin and destination, but that the route data is otherwise accurate (Figure 20).

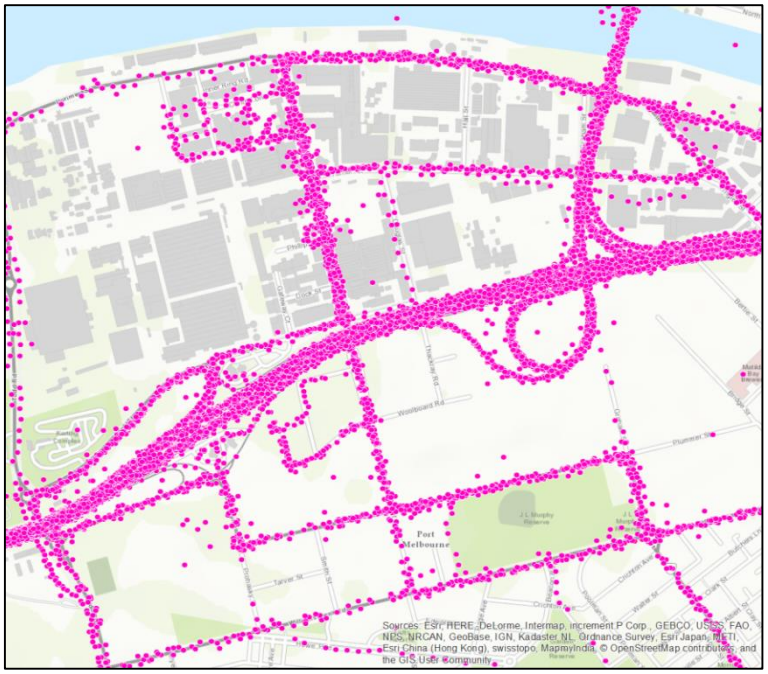


Figure 19 Surveyed GPS points detected on and around the West gate Freeway

Figure 20 Converted polyline route traces on and around the West gate Freeway

The detection of straight lines was investigated further to ensure that the GPS trace data wasn't being compromised through the conversion process. An example of a questionable straight line path, across the bay, is shown in Figure 21.

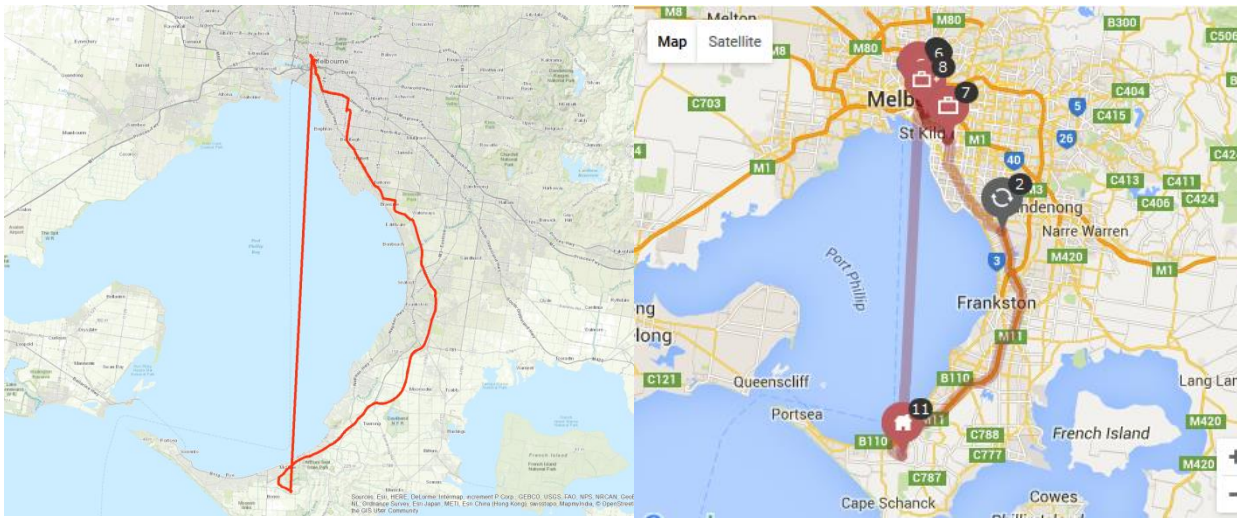


Figure 21 Comparison of post-processed (left) and user-interface (right) data

The processed data in Figure 21 matches with the user validation experience. In this instance, a low battery level (or app being manually turned off) has resulted in a final city origin point that is directly linked across the bay to the home destination point (established once the battery was recharged or app reactivated).

Other obvious straight line points emerge from the airport, as expected (Figure 22). Route data is curtailed as the app is switched off, only to link with a straight line to a destination data point in another state or country (although some tracking data is still visible on both the north-south and east-west runways). Similar issues emerge with traffic exiting through the Burnley Tunnel. Selecting points just outside the tunnel, the associated polylines run in a straight line to the tunnel entrance in South Melbourne (Figure 23).

Road traces appear to have a better match than public transport. Using train as an example, the travel on the Belgrave-Lilydale line is clearly detected as a main east-west movement in Figure 24. Conversion to polylines sees a greater proportion of straight-line approximations than nearby road travel (Figure 25), likely linked to a lack of consistent GPS signals from within train carriages, rail line canyons, and emergence from underground and sunken stations.

Corrections for the identified GPS constraints can be applied in a systematic fashion outside of this summary project report.

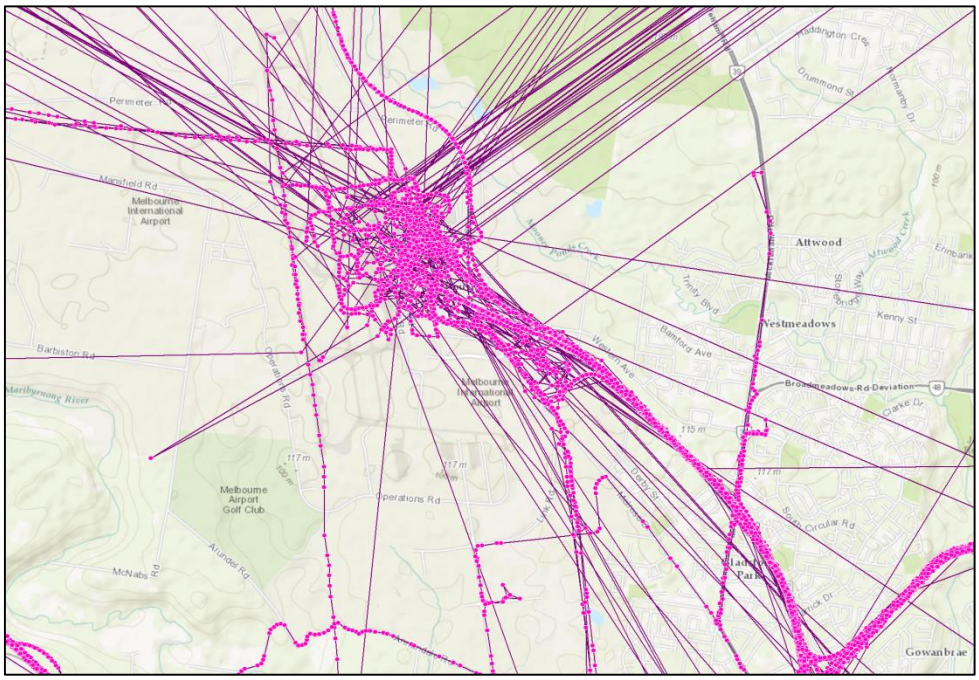


Figure 22 **Surveyed GPS points detected at and around Melbourne Airport**

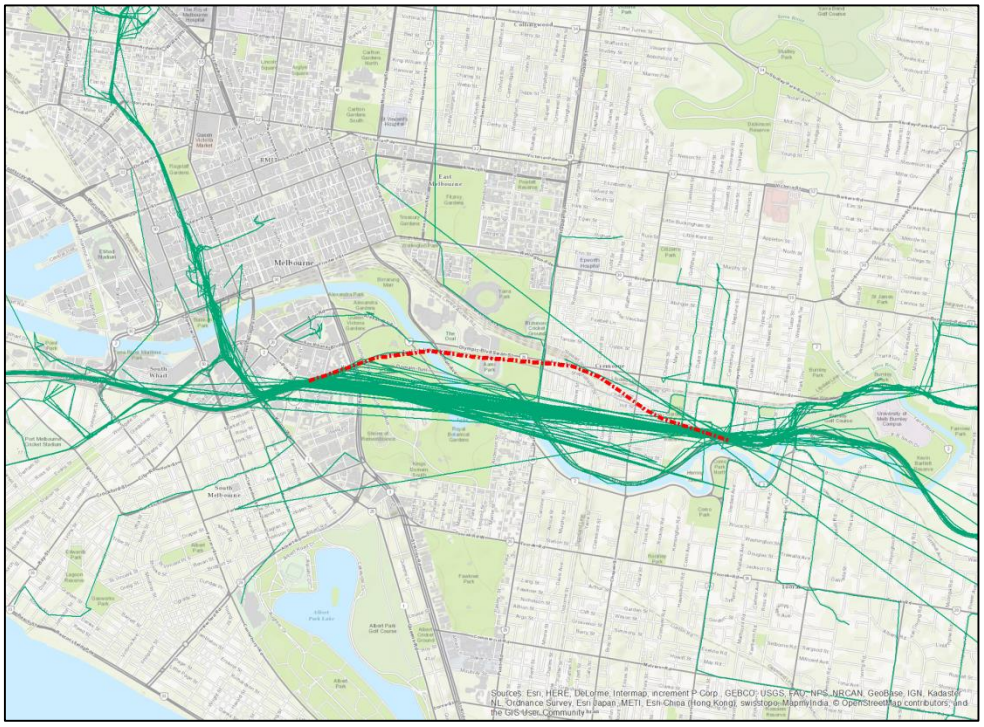


Figure 23 **Simplified route traces (green) through the Burnley Tunnel (dashed line)**

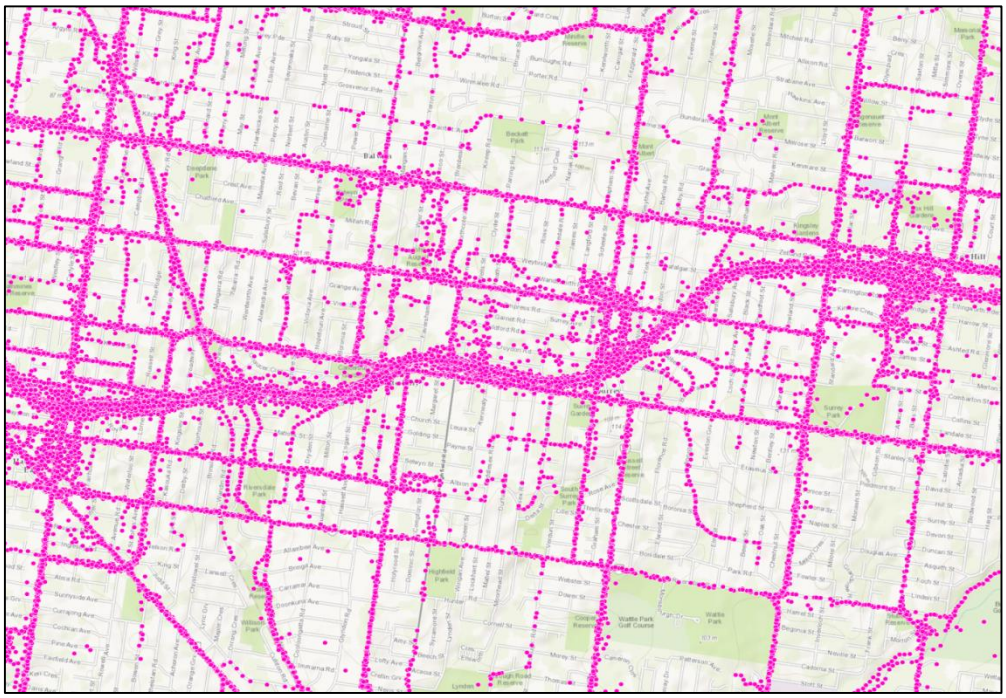


Figure 24 GPS points detected along and near the Belgrave-Lilydale train line (main east-west movement)

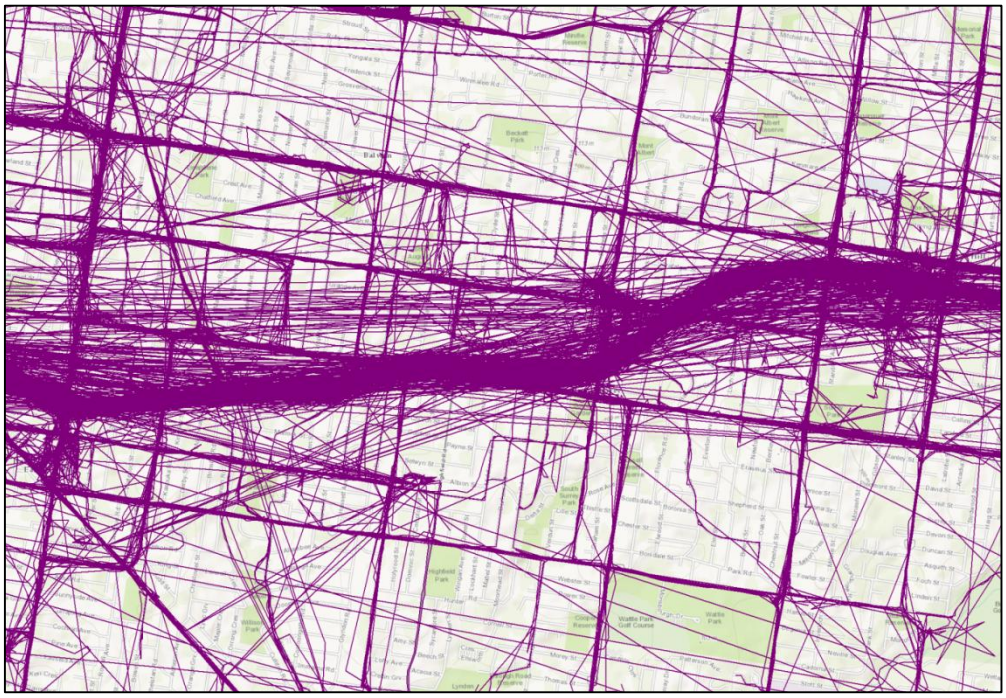


Figure 25 Route polylines along and near the Belgrave-Lilydale train line (main east-west movement)

6.2 User added stops, and missing route traces

GIS data is automatically associated with stop records: the points at which the FMS server determines that an activity has occurred. During the travel validation phase, respondents also have the opportunity to add stops that have not been detected by the app. These added stops are stored in the correct order within the trip chain, but do not associated route data.

From a simplified data processing perspective, routes associated with *added stops* are inserted as straight lines between the original origin and destination points, thereby replacing the original route (Figure 26). No attempt is made at this initial stage to use previous elements of a relevant route. In total, 2452 stops (approximately 5%) were missing route data, requiring provisional insertion of straight-line data. Refined route insertions will be investigated outside of this study.

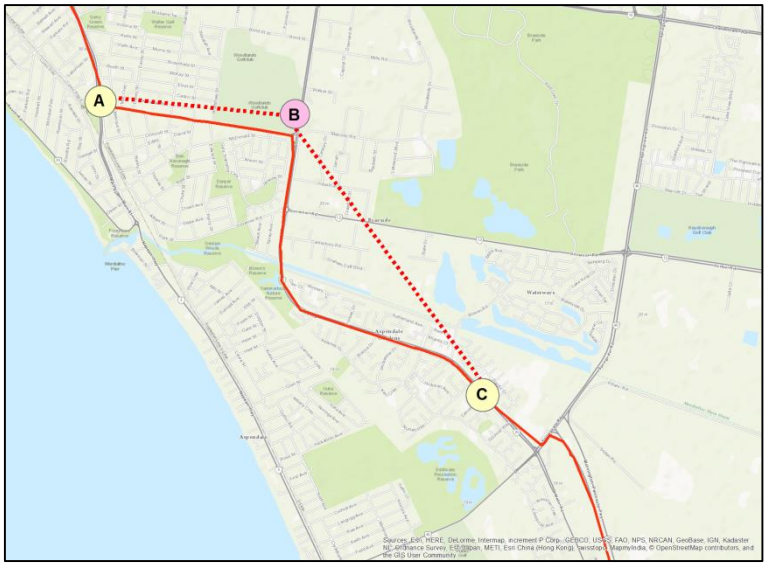


Figure 26 User inserted stop 'B' is linked to existing stops with a simple straight line route

7 Travel behaviour summary

7.1 Data comparability – FMS and VISTA

Prior to analysing the stop and trip rate data from FMS relative to VISTA, the broad comparability of the two surveys needs to be checked. As observed in Section 4.2, the FMS sample is somewhat different from VISTA, particularly regarding personal income (where 21% of participants were women earning $2000+ p/w, approximately 10 times the rate identified in VISTA). A simple attempt to generate a comparable VISTA database was therefore made.

The VISTA comparison sample was selected with the following attributes:

- **Age range**: 18 to 70
- **Home location**: Melbourne metropolitan area
- **Income**: 46% of sub-sample in highest income bracket ($2000+ p/w) *(of which 38% were female, 62% male).*

The resulting VISTA comparison database consisted of 2,395 respondents (50.6% female, 49.4% male). The sub-sample is split relatively evenly between inner, middle and outer areas; sensitivity testing using just a VISTA inner-Melbourne sample could also be conducted to ensure that overarching geographic attributes are not overlooked. Due to sample size limitations, the comparison database was only used in initial stop and trip rate calculations, as described later in the report.

From an FMS perspective, we have data spread across a period from late September 2015 right through to March 2016. This includes local, interstate and overseas travel of participants. To provide some contextual certainty about the data being analysed, additional data filters were applied.

- stops that did not start and end within Victoria were excluded
- stops that were reported outside of the main advertised study period were excluded.

FMS data in the remainder report is therefore of travel within Victoria, occurring between 1 October 2016 to 7 December 2016. Travel of 208 participants was observed in this period, generating 34,960 stops.

The above filters are only applied to allow comparisons with VISTA or similar data. The 45,259 stops made by the broader sample may be analysed outside of this project report

7.2 Stop and trip rates

To analyse travel behaviour, FMS Victoria data is initially split into two groups: travel that has been partially or fully validated, and travel that has not been verified at all. This classification is applied to individual travel days (was the day validated or not) rather than individual respondents (whether the person was generally a good verifier of data or not).

Comparisons are made against:

- the overall VISTA 2009-10 sample, filtered by Melbourne metropolitan residents aged 18 to 70 years of age
- the 'matched' VISTA subsample, which randomly draws a small stratified cohort from VISTA with income characteristics more closely matched to FMS participants (Section 7.1)
- VISTA university students, as an alternative matched cohort
- VISTA fulltime workers, as an alternative matched cohort

An initial stop rate comparison is provided in Table 3.

Table 3 Stop rates #

	FMS Victoria sample	Non-validated sample	Validated travel sample##	*VISTA 2009-10 sample **	*VISTA matched sample ***
Daily stop rate of travellers	7.5	8.0	**6.9**	*4.7*	*4.7*
Weekday stop rate of travellers	7.8	8.4	**7.1**	*4.8*	*4.8*
Weekend stop rate of travellers	6.7	7.1	**6.3**	*4.4*	*4.3*
Weekday stop rate of fulltime workers	8.1	8.8	**7.2**	*4.6*	*4.7*
Weekday stop rate of tertiary students ^	6.4	6.5	**6.3**	*5.5*	*5.9*

 # Non-mobile (stay at home) residents are excluded from both the FMS and VISTA estimate.
At least one stop or activity validated by a respondent on their travel day
** All VISTA 2009-10 respondents aged 18-70 living in metropolitan Melbourne*
*** VISTA 2009-10 subsample, selecting higher income cohort as per Section 7.1.*
^ Only students with an "@student.unimelb" registration counted in the FMS estimate. Other students not using their student email account to log onto the system will be excluded from this measure.

Across all measures, the FMS validated stop rate is less than the non-verified FMS data. This is what we would expect, as the FMS will detect fake activities ('false positives') when the phone position is stationary for a minute. For instance, a passenger on a tram – delayed at an intersection by boarding passengers and a subsequent red traffic signal – may be interpreted by FMS as being at an activity. While thresholds of the activity-detection algorithms are adjustable, FMS purposefully leans towards capturing such false positives; it is easier for users to delete incorrect stops than to add new activities (Pereira et al., 2013).

On average, FMS is detecting just over two stops per person per day more than a broadly comparable VISTA respondent. For fulltime workers this increases to an average of 2.6 stops per person. The discrepancy decreases to less than one stop per day for university students (Figure 27).

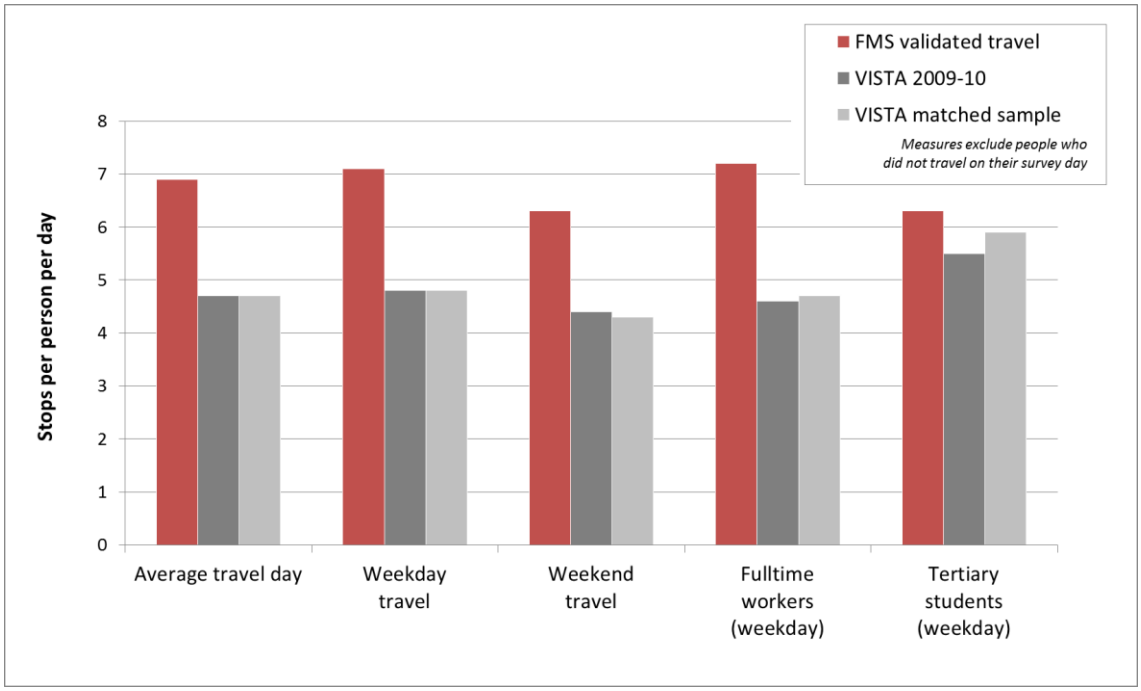


Figure 27 Stop-rate comparison

Stop rates, by themselves, provide only limited information on whether different travel is reported by the two surveys. Converting the data into trips (the broad travel between main activities) should initially smooth out a number of false positives that have made their way through the validation stage.

Trip reporting essentially removes all 'change mode' activities from the data. For example, walking to the bus stop, catching a bus to work, and walking to the office would be reported in FMS and VISTA as three individual stops. Using a trip definition, the same travel would be simplified as a single 'home to work' trip, made by public transport.

Base trip-rates generated from the data is shown in Table 4.

Table 4 Trip rates [#]

	FMS Victoria sample	Non-validated sample	Validated travel sample[##]	*VISTA 2009-10 sample **	*VISTA matched sample ***
Daily trip rate of travellers	4.9	5.2	**4.7**	*3.9*	*4.0*
Weekday trip rate of travellers	5.0	5.2	**4.7**	*3.9*	*3.9*
Weekend trip rate of travellers	4.9	5.1	**4.7**	*4.0*	*4.0*
Weekday trip rate of Fulltime workers	5.0	5.4	**4.6**	*3.7*	*3.7*
Weekday trip rate of tertiary students ^	4.0	4.2	**3.9**	*3.6*	*3.7*

 # Non-mobile (stay at home) residents are excluded from both the FMS and VISTA estimate.
At least one stop or activity validated by a respondent on their travel day
** All VISTA 2009-10 respondents aged 18-70 living in metropolitan Melbourne*
*** Unweighted VISTA 2009-10 subsample, selecting higher income cohort as per Section 7.1.*
^ Only students with an "@student.unimelb" registration counted for the FMS estimate. Other students not using their student email account to log onto the system will be excluded from this measure.

The relative discrepancies observed for stop rates generally hold for trips:

- there are less validated FMS trips per person than the non-validated data, although the discrepancy is now only half a trip per person per day
- there are fewer trips per person identified in VISTA compared to the validated FMS data, with the discrepancy approximately 0.8 trips per person per day
- there are 0.9 fewer trips per person per day made by VISTA fulltime workers compared to FMS fulltime workers.
- The trip rates for tertiary students are quite close, with 0.2 to 0.3 more trips per person per day identified by FMS students compared to VISTA. The similar trip-rate from either survey method may be indicative of a more precise travel reporting behaviour for this cohort.

The main trip rates of interest from Table 4 are illustrated in
Figure 28, and the stops per trip (from VISTA and a validated FMS sub-sample) are shown in Figure 29.

In general, there are more stops per trip identified in the FMS (Figure 29). This is promising, suggesting that more multi-modal travel can potentially be detected with an automated data collection method. However, the data will need to be cleaned further as there are some unanticipated trip-chains captured (e.g. 208 "walk-walk" trips). In these instances, either purpose ('change mode') or method of travel will be incorrect.

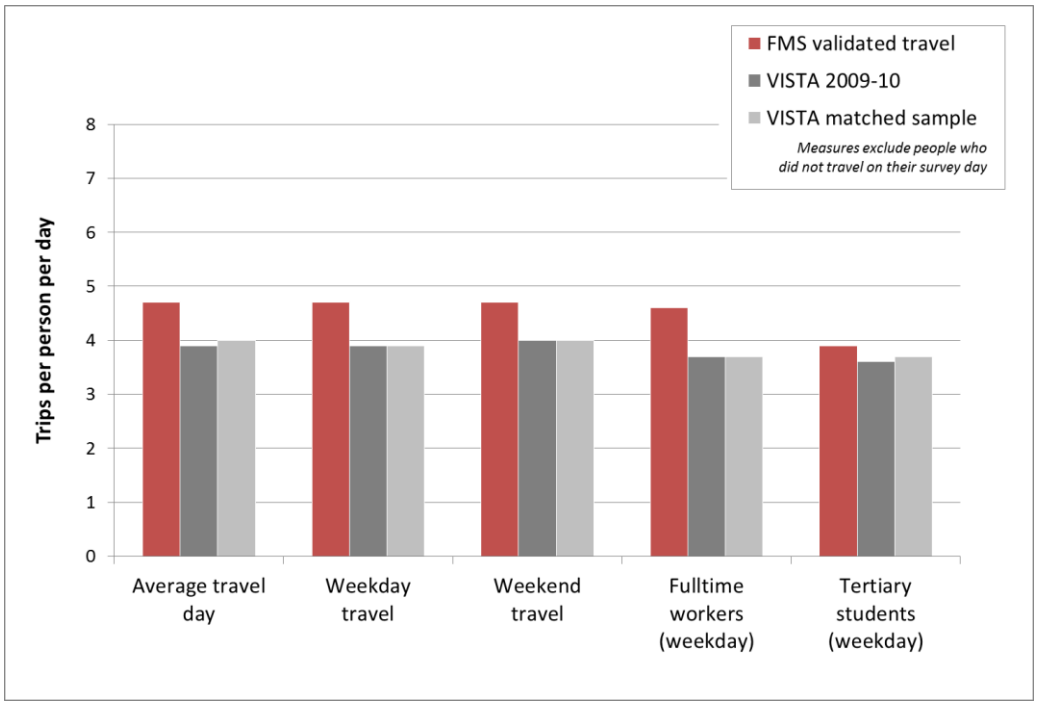


Figure 28 Comparison of trip-rates

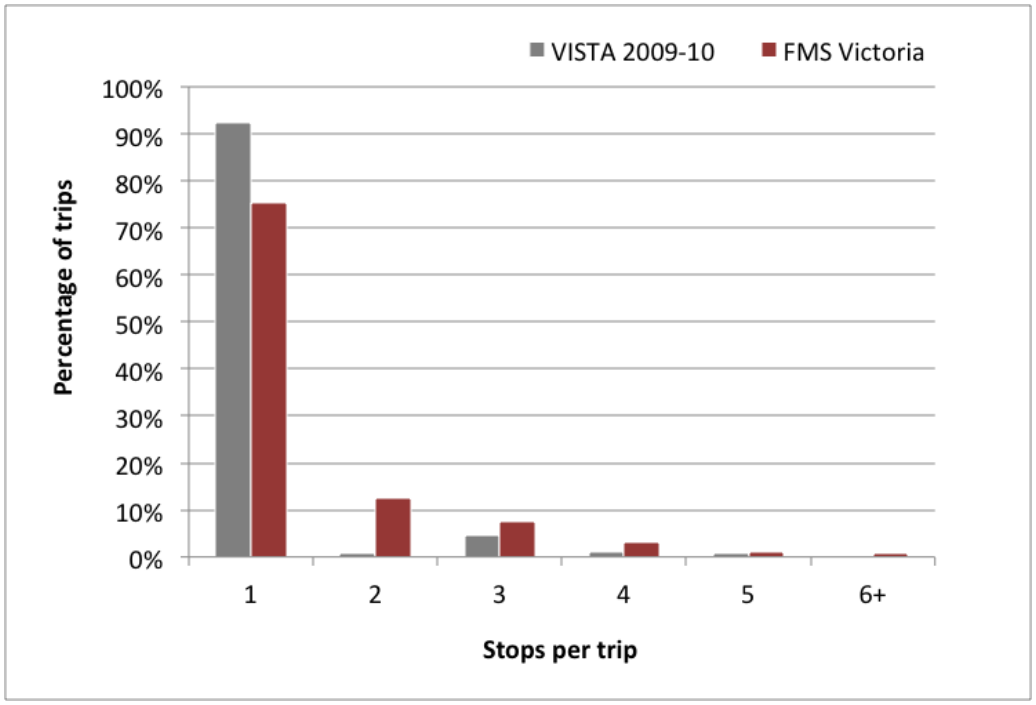


Figure 29 Comparison of stops per trip

7.3 Travel purpose

To understand the broader trip-rate discrepancies, an analysis of travel purposes is conducted (Figure 30).

Note: given the similarities in the main and matched VISTA samples (Table 3 and Table 4), just the main VISTA sample is used (again filtered on age group and home location). This maximises the sample size available to analyse trip purposes (e.g. the VISTA matched sample only contains 37 weekday trips for education) and simplifies the number of comparisons being made.

From FMS, only days in which all of the activities have been validated are included in the travel purpose analysis. This may include some stops that have not been validated en route.

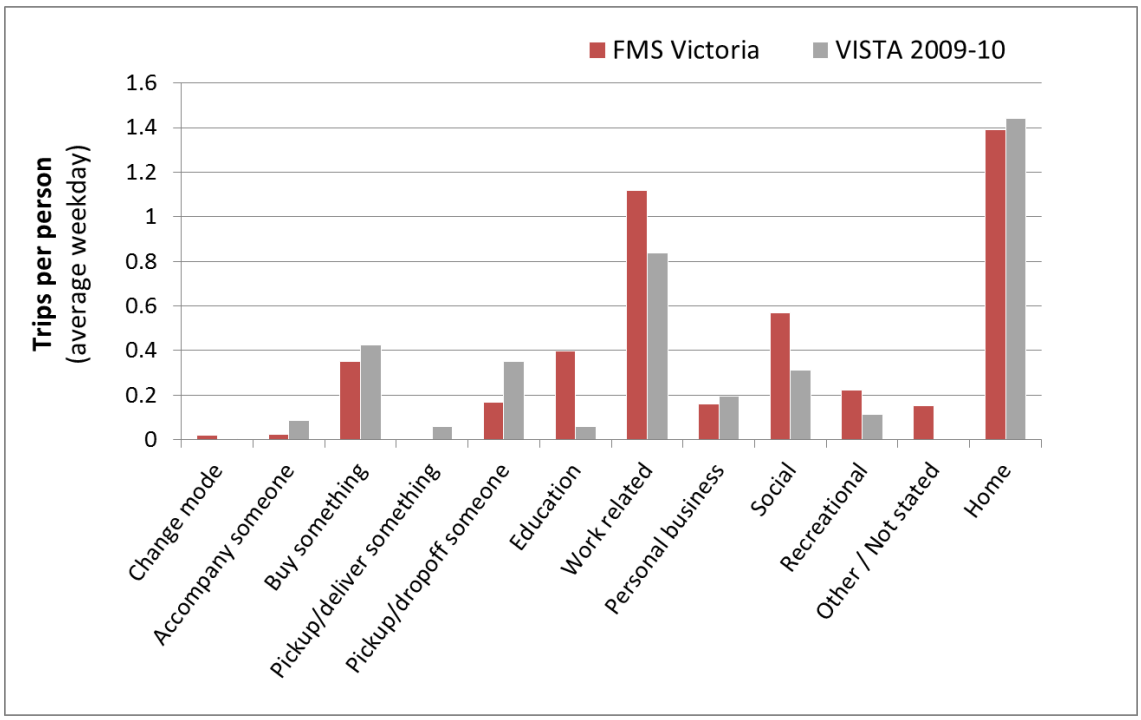


Figure 30 Purpose of travel - average weekday

As a useful starting point, the number of trips home each day is broadly comparable between FMS and VISTA. This indicates that any additional trips detected in FMS are being made as part of existing home-to-home trip-chains.

On an average weekday, more work-related trips and education related trips per person are being detected in the FMS. Similarly, social and recreational trips are also higher. Together, these may point to additional trips out from work and university during the day. VISTA is detecting greater number of pick-up/drop-off stops. This is expected in the current version of FMS, as very short stops (particularly with the same motorised mode before and after) are ignored (Zhao, Ghorpade, et al., 2015).

We could potentially expect a better match on weekend travel as there are fewer pivotal activities (e.g. work and education, potentially used as an overarching proxy of daily travel behaviour). Like weekday travel, there is a good match on trips back home on a weekend day, providing a stable context to analyse results (Figure 31). Shopping – a key weekend activity – also compares well between FMS and VISTA. The other main weekend activities - social and recreation trips – are more frequently reported in FMS.

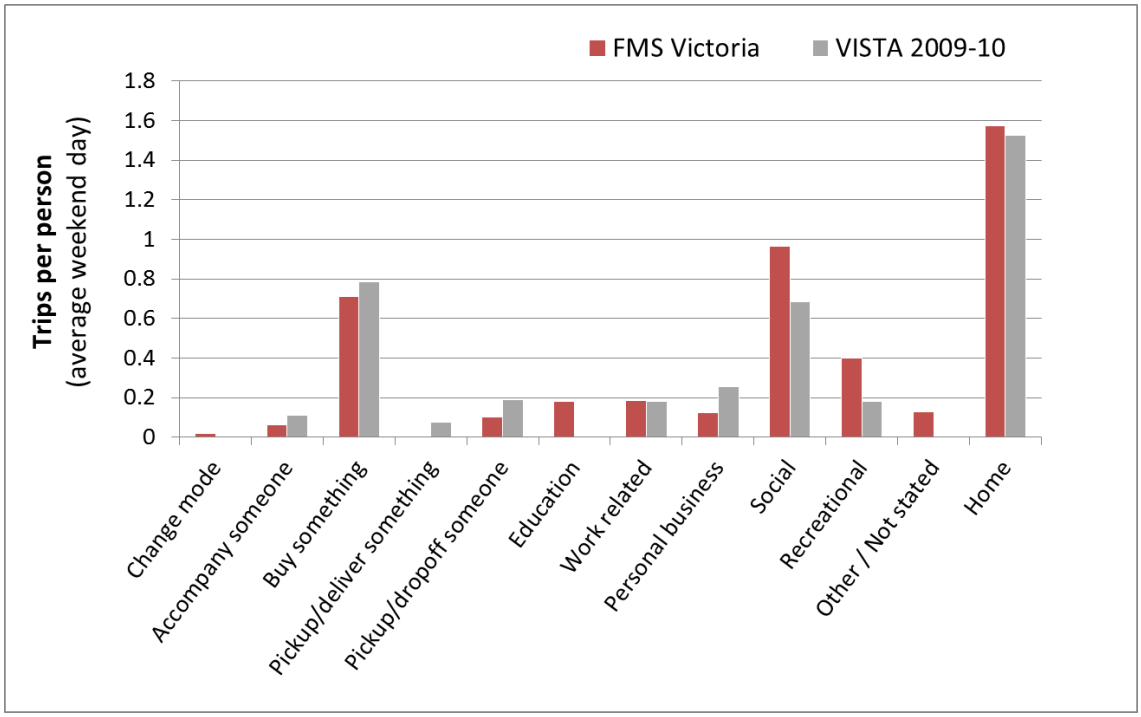


Figure 31 Purpose of travel - average weekend day

To partially control for variations in respondent demographics, the average weekday behaviour of fulltime workers and university students are both explored.

Full-time worker travel behaviour (Figure 32) reiterates the earlier finding for all weekday travel. From a comparable base of home-based trip chains, there are more work trips per person, as well as more social trips (which includes eating and drinking) and recreational trips. VISTA respondents report slightly more chauffeuring trips.

The student travel behaviour (Figure 33) chart reveals a likely participant bias. While overarching trip rates between FMS and VISTA are quite similar, there are a dramatically higher number of education trips being made by FMS students. The VISTA sample, on the other hand, shows a higher number of employment trips from the tertiary student cohort (including just full-time students). Given a likely difference in respondent demography, further detailed analysis of travel behaviour differences for this particular group may not be meaningful.

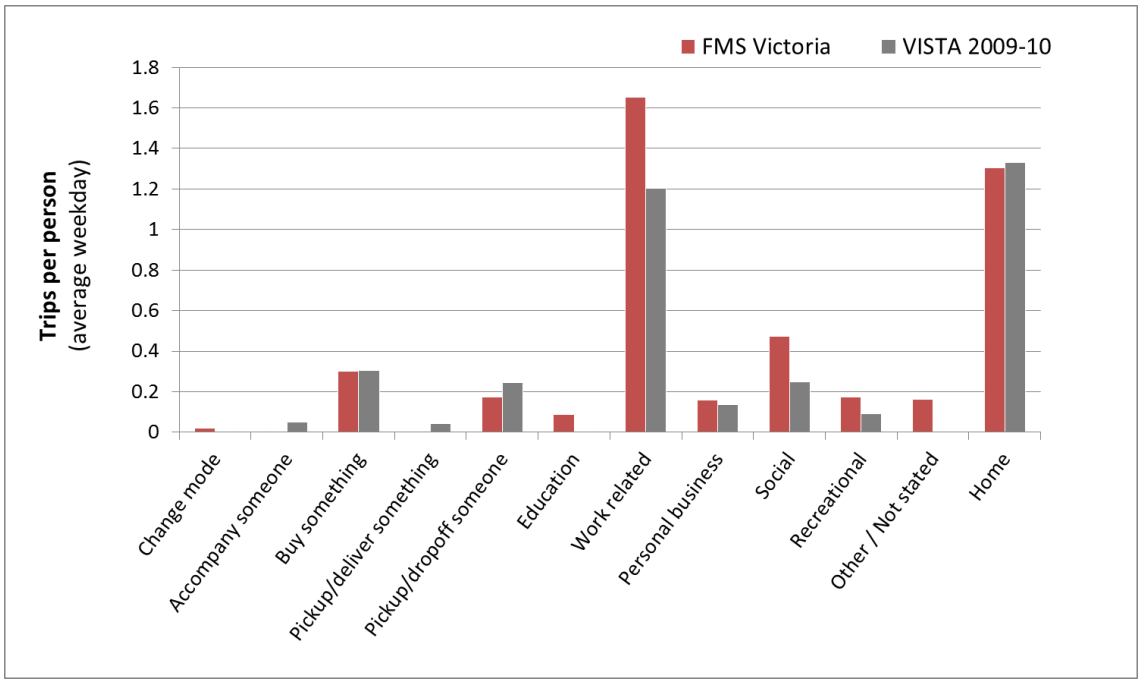


Figure 32 **Full-time worker weekday travel**

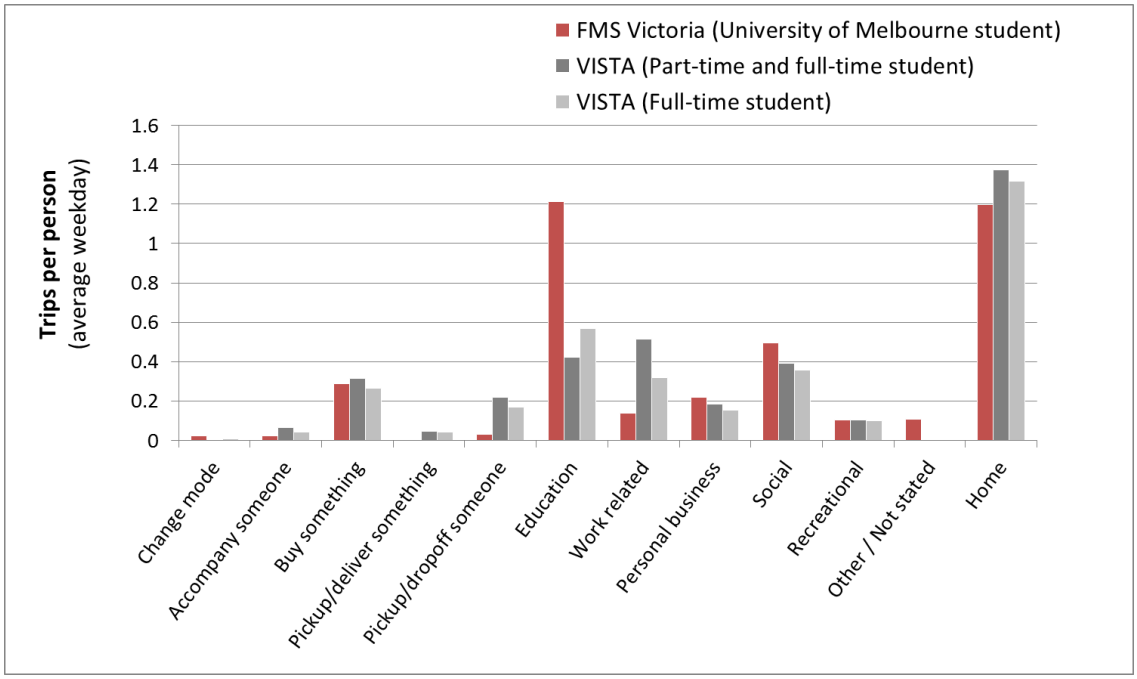


Figure 33 **Tertiary student weekday travel**

7.4 Travel times

Analysing weekday trip start time in 5 minute blocks (Figure 34) emphasises the typical reporting behaviour in a self-completion travel diary. Large spikes of travel are shown for VISTA trips each hour, and to a lesser degree each half hour, as people round their travel departure times. As expected, the use of FMS gives a smoother profile of when trips are occurring through the day.

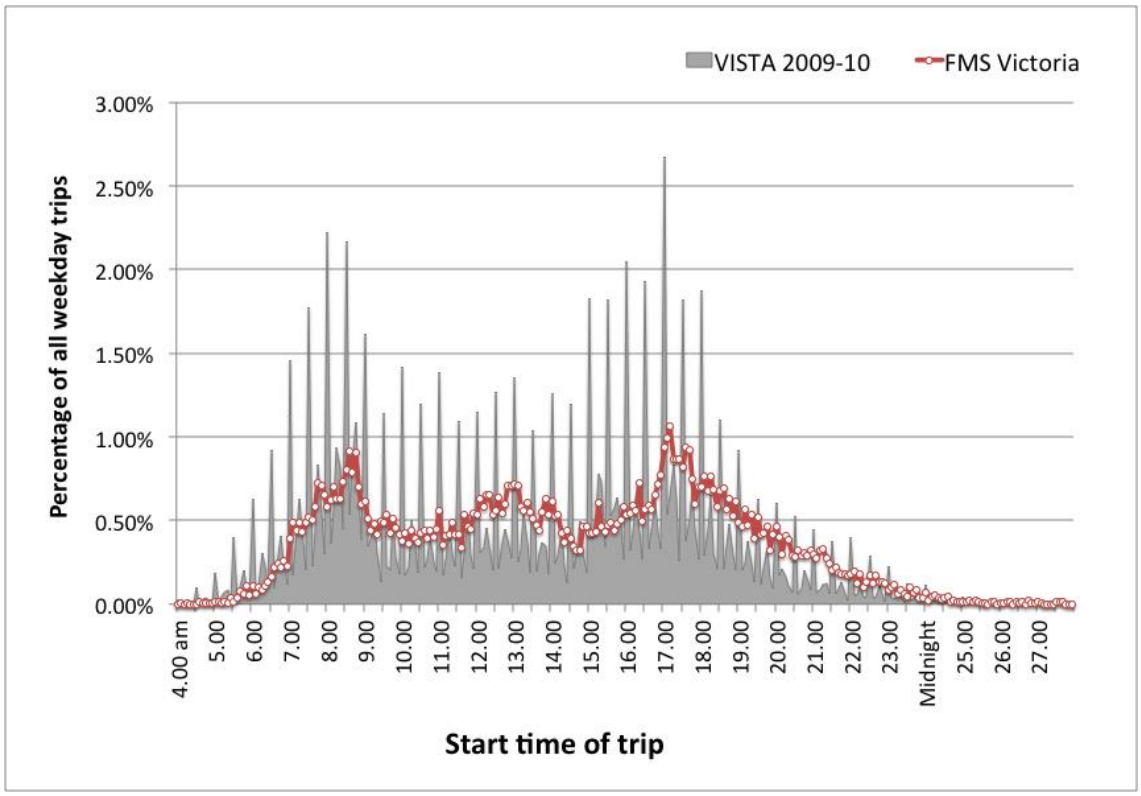


Figure 34 Weekday trip start time (clustered in 5-min ranges)

As well as the accuracy of the travel time reporting, FMS travel times point to broader trip making differences. Grouping trips by the starting hour of travel, FMS shows a higher proportion of trips being made at lunchtime (Figure 35). Less anticipated is the higher proportion of evening trips also being detected by the FMS. This may be a partial result of the additional pick-up / drop-off behaviour in VISTA (3pm to 4pm spike), but is worth examining further on a more closely matched sample.

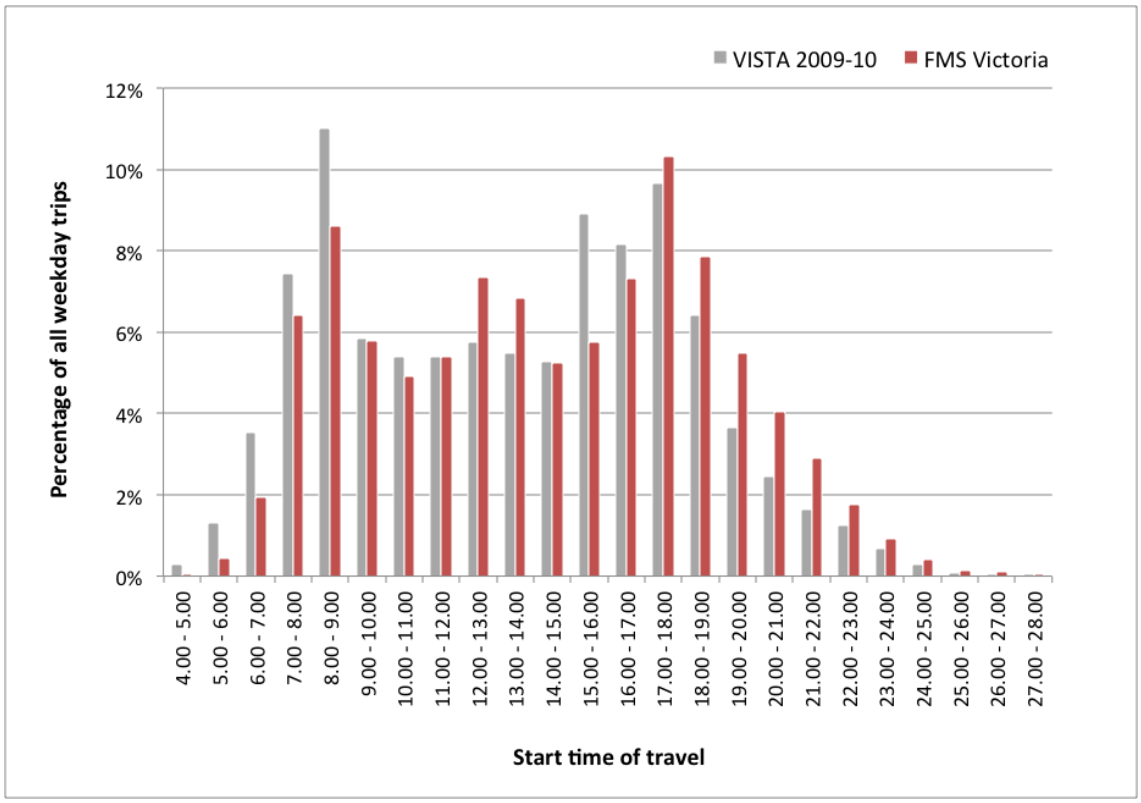


Figure 35 Weekday trip start time (clustered in 60-min ranges)

Weekend travel has a different overall profile, following a simpler bell-shaped distribution whereby most travel occurs in the middle of the day (Figure 36). As for weekday travel, trip starting times are clustered in hourly bands for VISTA respondents, and more evenly distributed for those using FMS.

The hourly snapshot of weekend travel suggests proportionally more FMS travel reported in the evenings (Figure 37). Of potential research interest is whether *some* participants in self-completion surveys such as VISTA believe they have reported 'enough' travel through the day, and subtly opt out of evening reporting to minimise survey burden. In this instance, the younger FMS Victoria sample (and higher associated likelihood of evening travel) is likely to be the main source of difference.

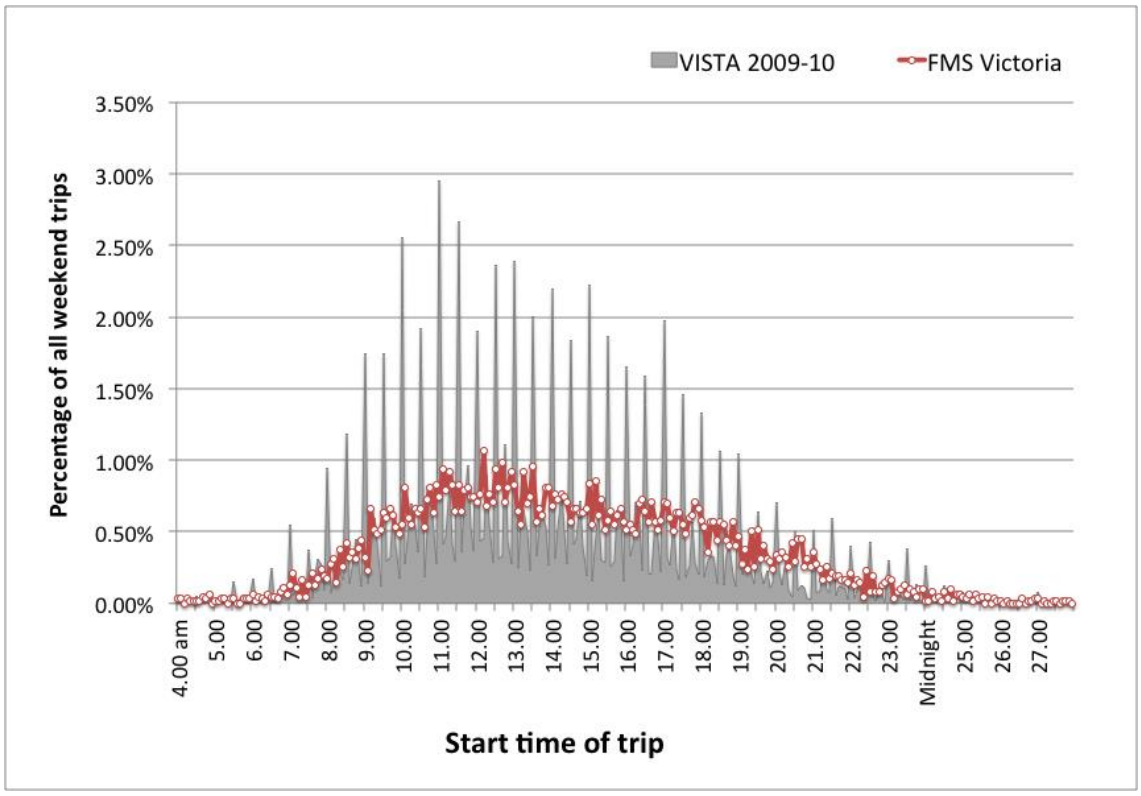


Figure 36 **Weekend trip start time (clustered in 5-min ranges)**

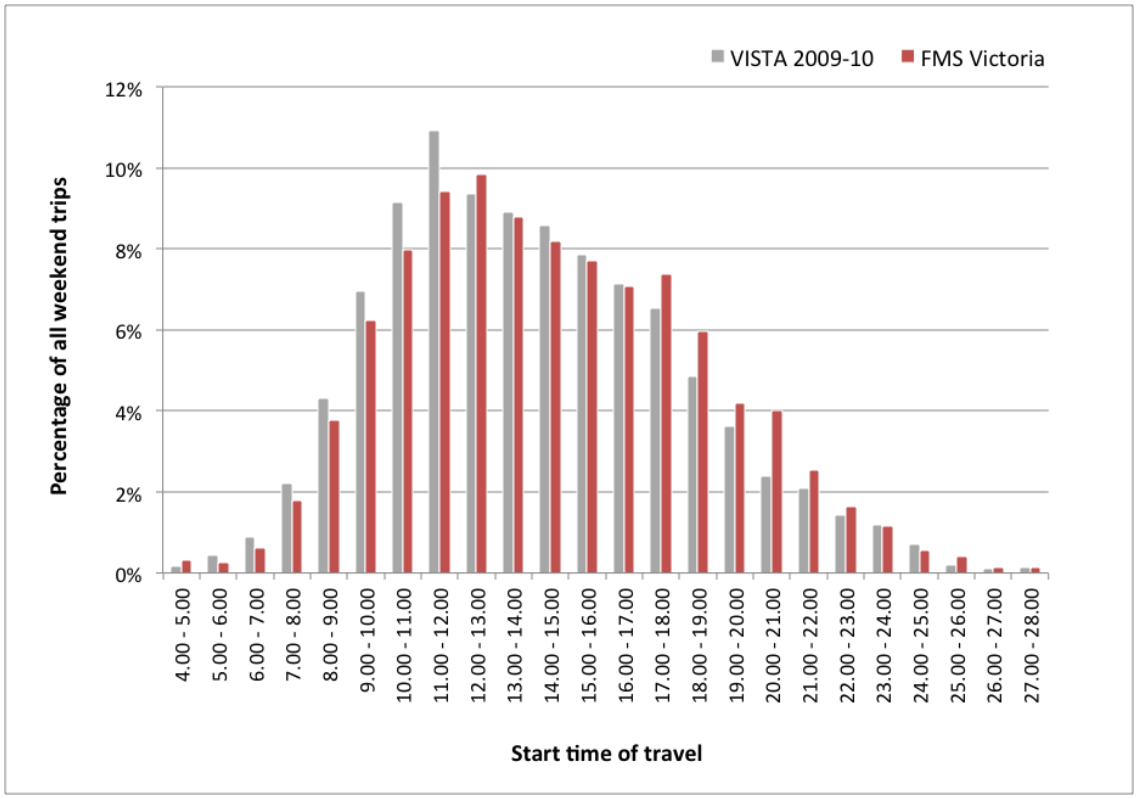


Figure 37 **Weekend trip start time (clustered in 5-min ranges)**

The corollary of more precise trip starting times is the collection of more precise travel times. While FMS demonstrates a smooth travel time distribution, a VISTA participant will generally report travel to the nearest 5, 10, 15, 30, 45 or 60 minutes (Figure 38).

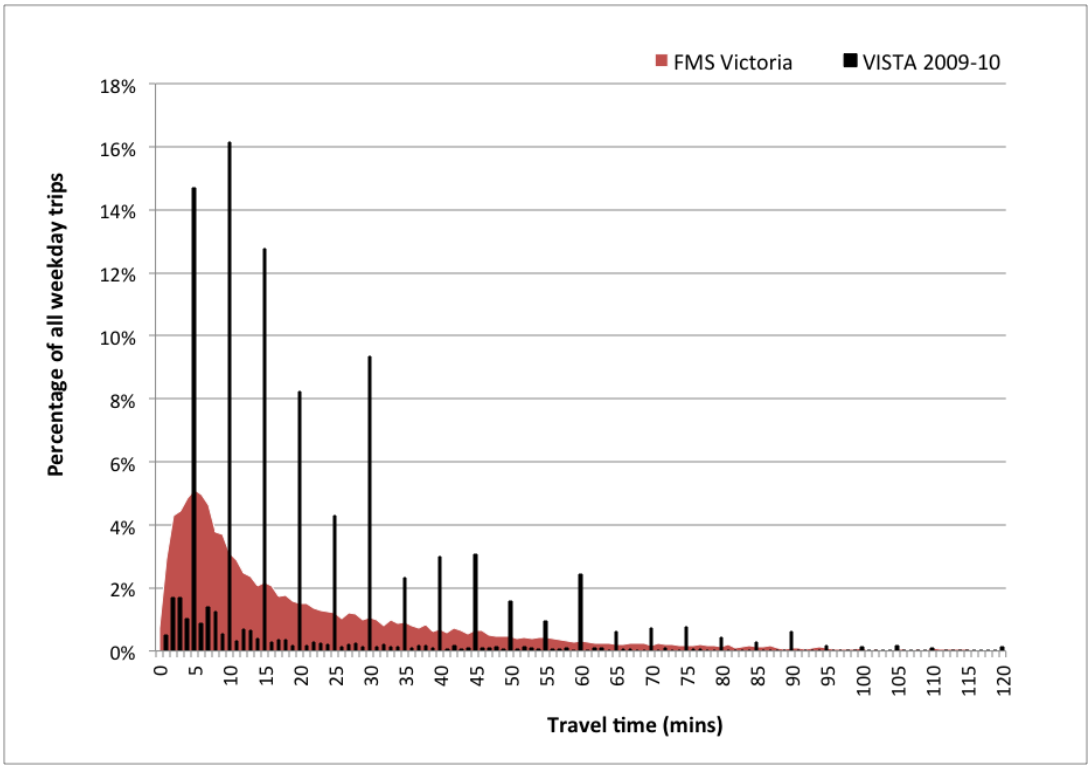


Figure 38 Weekday travel time distribution

7.5 Travel distances

While travel time reporting in VISTA carries a clear respondent bias, travel distance is a calculated field. The fixed rail network allows train distances to be precisely calculated in VISTA, with other modes typically adopting a shortest network distance. VISTA may also include some manual adjustments on outlier values; for example, the lack of a pedestrian underpass coded into a base GIS network may result in long and circuitous walking trips to access a train station.

Distances in FMS Victoria will typically represent the actual path travelled, calculated by GPS. In certain instances, FMS may return straight-line distances where:

- the app has been switched off
- phone battery is low
- satellite coverage is not available
- stop has been manually added by the participant.

Although FMS is detecting an actual, rather than shortest, path of travel, there are a greater proportion of short trip distances in FMS compared to VISTA (Figure 39). This may relate to the larger number of short socialising and recreational trips that are being picked up on FMS.

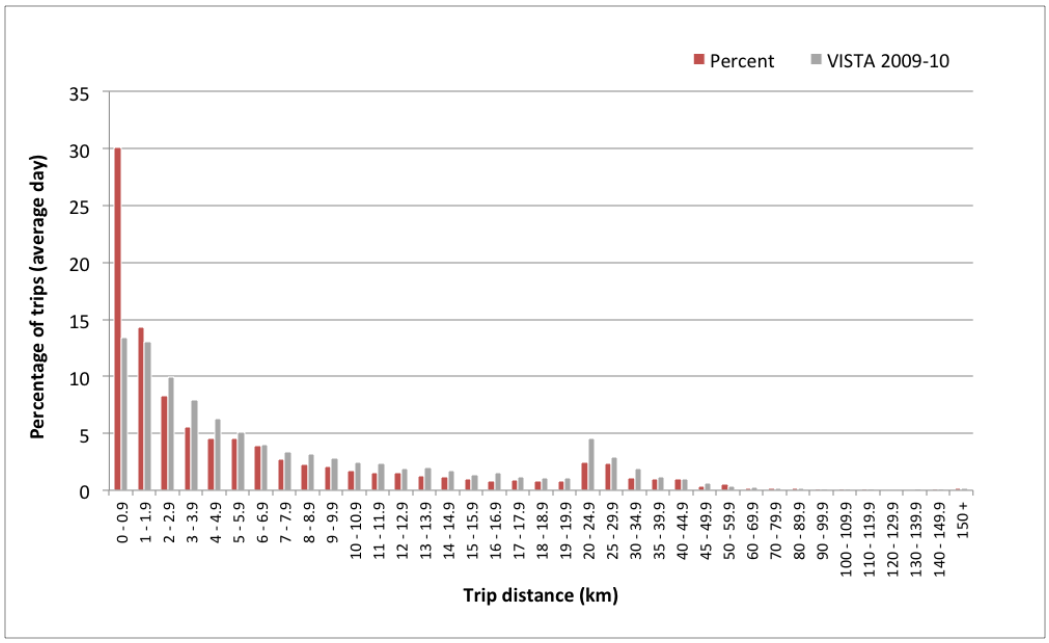


Figure 39 Trip distances (average day)

In contrast, using just validated trips, the average distance travelled on each mode is typically longer in FMS (Figure 40). The exception is a large number of VISTA train trips from outer Melbourne that are substantially longer than FMS. These, and the slightly longer bike trips, lead to a higher distance travelled per person per day (38.4km in VISTA compared to 35.7 kilometres in FMS). While train is somewhat understandable due to a limited outer suburban FMS sample, further investigation on bicycle differences is required to determine whether this is a particular type of bike trip that is not picked up adequately in FMS (e.g. weekend training rides); path selection (e.g. parkland shortcuts); or socio-demographic characteristics of the sample.

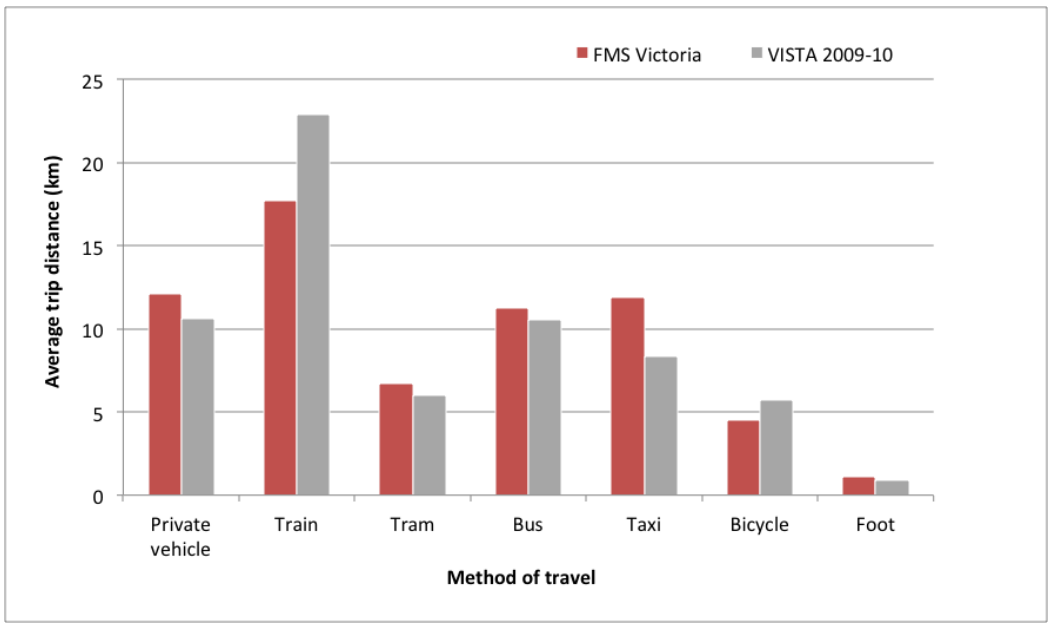


Figure 40 Trip distances by mode (average day)

7.6 Mode share

An advantage of VISTA-type surveys over traditional traffic and patronage counts is the ability to use the same methodology to compare different modes of travel. FMS allows for similar comparisons. Mode share is therefore a key output from household activity and travel surveys.

Mode share is often used to illustrate the overall transport task: kilometres travelled by each individual mode. The weekday and weekend transport task are both provided below (Figure 41 and Figure 42 respectively).

- The normal mode share pattern from VISTA is clearly demonstrated, with a large private vehicle usage (well over 80% of kilometres on an average weekday, and approximately 90% of weekend kilometres). Public transport accounts for the bulk of the remainder, with walking, cycling and other modes only delivering a small percentage of all kilometres travelled on an average day. This is again just the travel of those people aged 18 to 70, living in metropolitan Melbourne.
- Data from FMS paints a very different picture. Just over half of weekday kilometres are estimated to be travelled using private vehicle, with over a quarter made by public transport. Walking is shown to account for a remarkable 7% of all distance travelled on an average day.

To understand potential bias in the FMS mode share data due to the known clustering of respondents around the central city, FMS mode share was recalculated using a respondent home location filter (inner/middle/outer Melbourne) (Figure 43).

- It is positive to note that geographic differences do in fact emerge, suggesting that, although self-selecting, the FMS sample is not demonstrating homogeneous behaviour.
- Expected differences in mode share across different geographic areas *are* apparent, with more driving and less public transport and walking in outer areas of Melbourne. However, the substantial walk and public transport mode shares still hold**. This is a potentially critical difference between the surveys, with further research required to understand whether the source of the variance is behavioural or methodological.**

Data from FMS was also analysed across just one random day, to remove potential bias from a few respondents who may have validated a large amount of (largely repeated) travel, but the large discrepancy with VISTA remained.

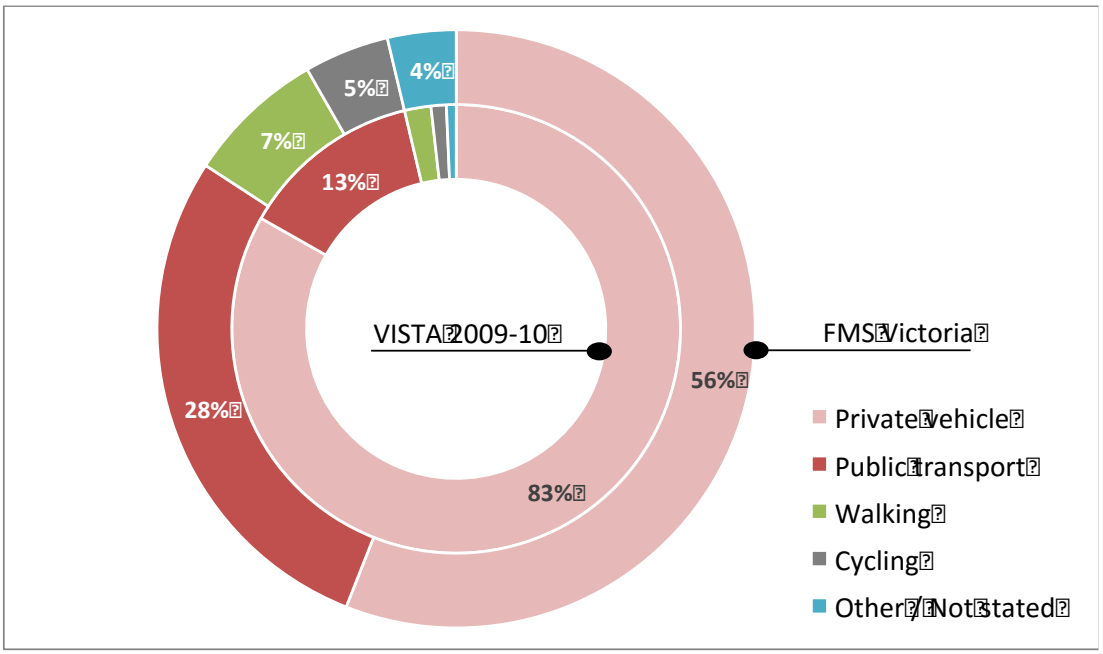


Figure 41 **Mode share by distance travelled (weekdays)**

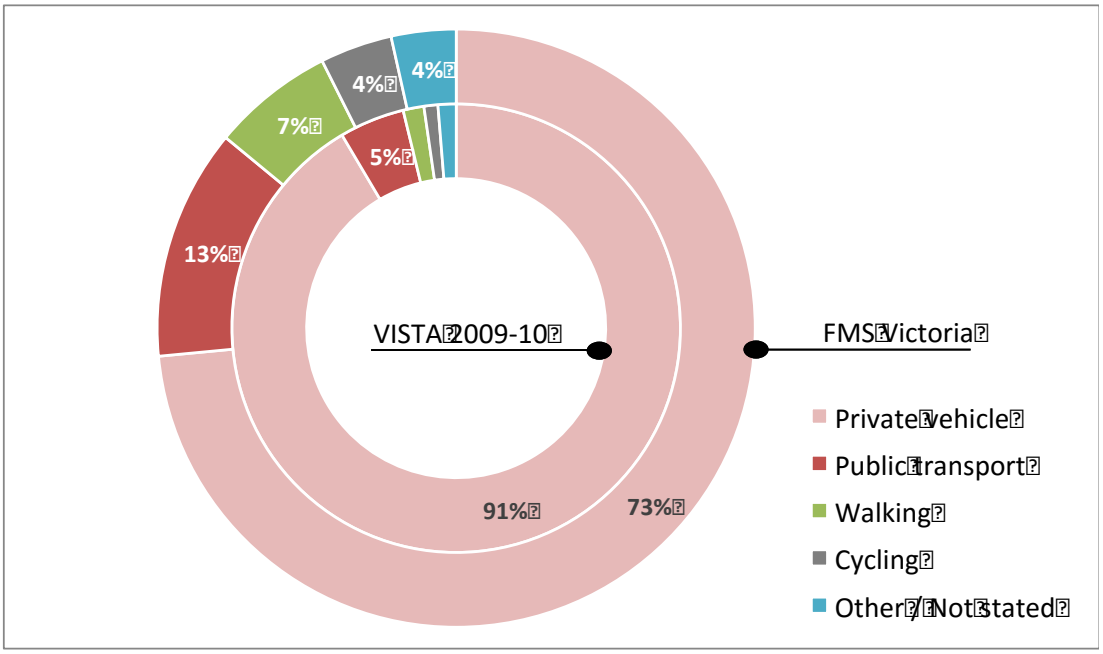


Figure 42 **Mode share by distance travelled (weekend)**

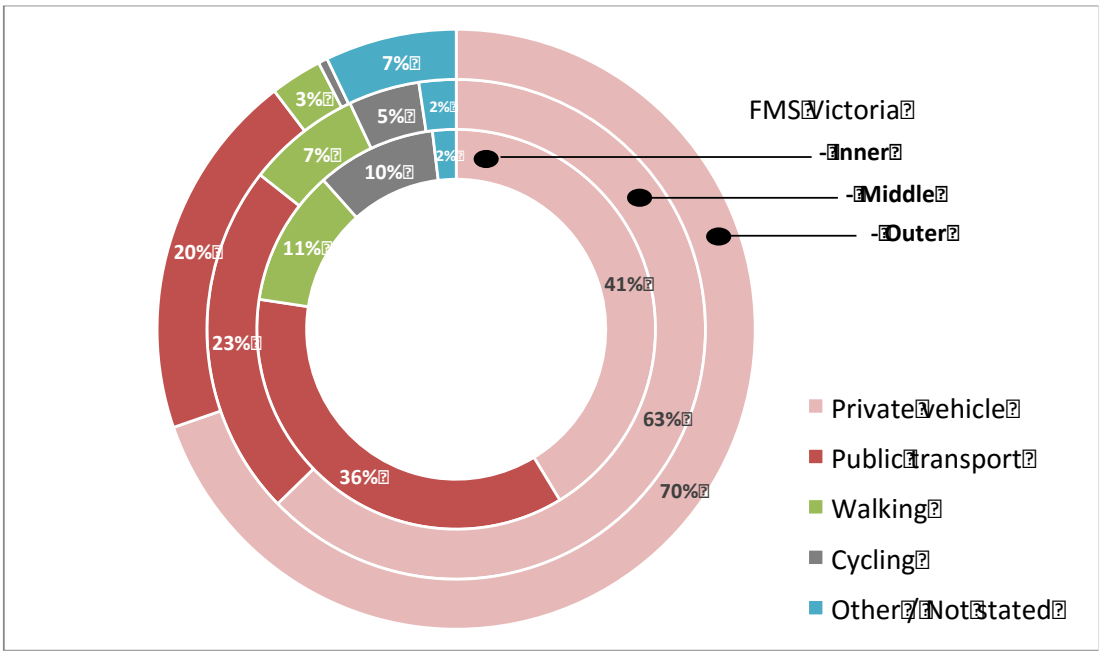


Figure 43 **FMS mode share by metropolitan Melbourne home location (average day)**

Appendix A – Media

RACV Royal Auto Magazine

– October 2015 Edition

RA | RACV MEMBER NEWS

BACKYARD BIRD COUNT AIMS TO HELP SAVE NATIVE SPECIES

RACV members are being asked to help preserve native birdlife by stepping in to their own backyard and taking part in the Aussie Backyard Bird Count 2015. It is part of National Bird Week, from 19-25 October.
RACV member Emily Scicluna, 21, a committee member of BirdLife Melbourne and student of Biological (Advanced) Science, will be taking part for a second time. Last year 800,000 birds were counted and this year's goal is one million. The project helps understand how urban birdlife is faring. "Last year we saw a lot of house sparrows and Indian mynas. It's important to learn about the distribution of these invasive species as well as the native ones," Emily said.
To participate all you need to do is find a "green patch" and spend 20 minutes a day for one week, recording the birds you know and looking up the ones you don't. To help data collection and bird identification go to aussiebirdcount.org.au where you can also download the new Aussie Bird Count app.
Story: Claire Sheed-Finck. Pictures: Shannon Morris

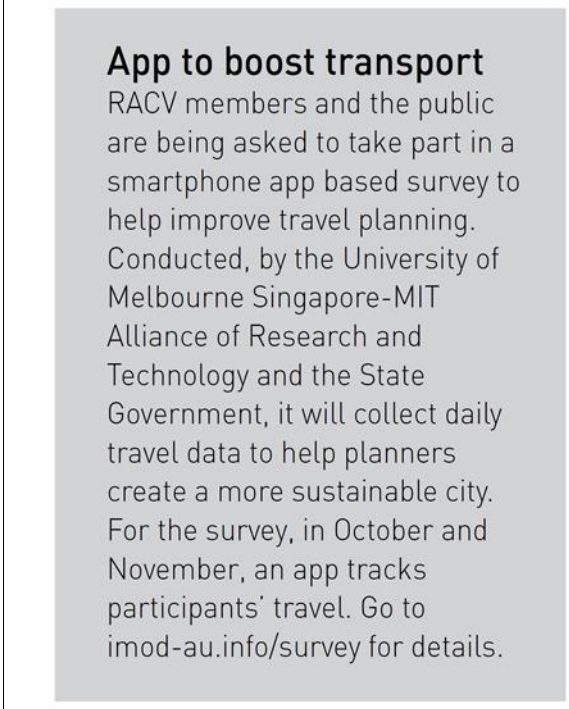
Solar record bid

Nature and technology conspired to defeat two RACV members' bid to cross the Simpson in solar-powered 4WDs and enter the Guinness Book of Records.
One vehicle, owned by Mark French, had a "catastrophic electrical controller" issue that meant it never left Melbourne. Instead, Mark helped Alan and Barbara Johnson in their bid. The trip from Melbourne to Mt Dare in SA saw Alan's 4WD Suzuki line up at the start line. A problem with the charging system showed up after the second charge and on day two it became serious when the panels failed to operate as expected. With bad weather approaching, it was decided to call off the attempt because of time. Then the front diff in Alan's support vehicle blew up and RACV Total Care was called to get the vehicle, Suzuki and trailer back to Melbourne.
Mark and Alan say the experience will help their renewed bid next year.

App to boost transport

RACV members and the public are being asked to take part in a smartphone app based survey to help improve travel planning. Conducted, by the University of Melbourne Singapore-MIT Alliance of Research and Technology and the State Government, it will collect daily travel data to help planners create a more sustainable city. For the survey, in October and November, an app tracks participants' travel. Go to imod-au.info/survey for details.

70 | OCT 2015 | royalauto.com.au



App to boost transport

RACV members and the public are being asked to take part in a smartphone app based survey to help improve travel planning. Conducted, by the University of Melbourne Singapore-MIT Alliance of Research and Technology and the State Government, it will collect daily travel data to help planners create a more sustainable city. For the survey, in October and November, an app tracks participants' travel. Go to imod-au.info/survey for details.

Ferntree Gully Belgrave Trader

– 13 October 2015

Box Hill moves in

Grand final blitz gets results

Uni wants to track residents

Uni wants to track residents

BELGRAVE residents are being targeted to take part in a trial to gather accurate travel and activity data.

The University of Melbourne has focused on the town to test a new smartphone application.

The Future Mobility Sensing (FMS) app is expected to provide more detailed information than traditional paper-based diaries.

Professor Stephan Winter said transport planners relied on surveys to understand how, where and when travel was made across the city.

The app simplifies data collection by automatically tracing user movements across the day.

By tapping into various smartphone sensors, such as GPS and accelerometer technology, detailed descriptions of routes can be constructed.

Further information about the trial, including pre-registering your interest to participate, can be found at the project website http://imod-au.info/survey.

ABC News Online

– 23 September 2015

http://www.abc.net.au/news/2015-09-23/melbourne-university-to-follow-volunteers%27-travel-movements/6797484


NEWS

Melbourne University to follow volunteers' travel movements in new smartphone tracking trial

Melbourne University is seeking people willing to have their movements tracked by their smartphone as they travel around Melbourne.

The Future Mobility Sensing (FMS) project aims to improve the data used by governments to make decisions about transport planning.

Volunteers would need to install a smartphone app developed by the Singapore-MIT Alliance for Research and Technology (SMART) onto their personal phones.

Melbourne University's Steve Roddis said the app would track the user's movements for two weeks, to give researchers invaluable data about their movements over time.

"What it gives us is a lot of fine-grained information about how people travel around Melbourne," Mr Roddis told 774 ABC Melbourne's Jon Faine.

Government agencies currently survey people on their travel using paper-based diaries, which Mr Roddis said were "cumbersome" and usually only captured a single day's travel.

"It is actually easier for people to give their data and participate in this kind of study," he said.

"It is not a cumbersome diary, they simply carry their smart phone around with them."

RELATED STORY: Flinders Street Station restoration works to begin next week

RELATED STORY: Melbourne rail tunnel to force hundreds from homes

MAP: University of Melbourne 3010

Keypoints

- Melbourne University will track the movements of volunteers across a two-week period
- All movements from cycling to drive, public transport and walking will be tracked using a volunteer's smartphone
- Data will be used to make government decisions on transport planning
- University has assured all data would be private

From cycling to walking the dog, app to track all movements

Along with surveys, researchers also rely on responses to Australian Census questions about travel to work and agencies such as VicRoads conduct counts of cars using roadways.

But each of those approaches only captured data about particular types of travel.

By contrast, Mr Roddis said the data collected in this trial would capture all the volunteer's movements including "going to the shops, going to the gym and walking the dog".

"What this [app] does is pick up walking, cycling, car, public transport —for any reason, at any time of the day," he said.

If the trial is successful researchers will be able to investigate questions such as whether people use the same routes every day in their travels around the city.

"We will be picking up two weeks of data through this app compared to, typically, one-day travel diaries," said Mr Roddis.

"We will get a sense of the dynamic of how people travel over a two-week period."

The trial will be run in partnership with SMART, the Victorian Government and Massachusetts Institute of Technology (MIT).

Researchers will compare the data gathered to that collected through traditional methods.

"It is really a proof of concept," Mr Roddis said.

"It will allow us to test the tool and see what opportunities there are to, incrementally, change the way that surveys are conducted on transport in Melbourne."

He said people who chose to take part in the trial could rest assured their personal travel details would not be made public.

"Privacy is the number one thing we will be pushing through this — all the data is secured," Mr Roddis said.

People interested in taking part in the trial can register at the FMS project website.

PHOTO: From cycling to public transport and even walking the dog, the Melbourne University trial aims to track all movements. (Nic MacBean: ABC News)

Topics: mobile-phones, urban-development-and-planning, research, university-of-melbourne-3010

Public transport posters

Placed November 2015 at Belgrave Station, Tecoma Station and in local buses servicing Belgrave

Appendix B – VISTA participant invitation

Email sent to VISTA participants by the Department of Economic Development, Jobs, Transport and Resources (8/10/15). Email addresses were restricted to those VISTA participants who had indicated an interest in participating in other government sponsored transport-related research.

Good morning,

Some time ago, you may recall participating in the Victorian Integrated Survey of Travel and Activity ('A survey of day-to-day travel'). This involved recording all of your travel for a single specified day. In your responses, you also indicated that you may be interested in participating in other government sponsored transport research.
This email is an invitation to participate in a new type of travel survey: the Future Mobility Sensing project.
The project is described below, and your participation is entirely voluntary.

---
* Future Mobility Sensing Project *

The Department of Economic Development, Jobs, Transport and Resources is co-sponsoring a trial in which personal travel data is automatically collected using a smartphone app. The app tracks your movement by using various sensors in the smartphone, including the GPS and accelerometer. Conducted by the University of Melbourne, the trial has the potential to collect more detailed travel data than previous paper based surveys. In total, participants are asked to provide two weeks of travel data by using the smartphone app and validating the data for accuracy. The trial will run from 1 October to 30 November.

As well as assisting with transport planning in your local area, if you complete the survey you may also be eligible to receive one of 500 WISH gift vouchers ($50 value each).

- To find out more information about the study, and register to participate, please go to http://imod-au.info/survey/
- To contact the project team at the University of Melbourne, please email info@imod-au.info
- The trial has recently been profiled on ABC News: http://www.abc.net.au/news/2015-09-23/melbourne-university-to-follow-volunteers-travel-movements/6797484

You are receiving this invitation as you provided your email address as part of the Victorian Integrated Survey of Travel and Activity. If you no longer wish to receive email invitations to participate in government sponsored transport research, please reply to this message with "Unsubscribe" included in the subject header.

Appendix C – Incentive eligibility

Eligibility to directly receive a $50 WISH gift voucher

Participants will be emailed a **$50 WISH gift voucher** at the conclusion of the trial if they meet all of the following conditions.

- They are one of the **first 450 respondents** (150 from each of the three study area groups) to complete the survey. The three study area groups are:
    - Residents of Belgrave (postcode 3160, including Tecoma)
    - Residents of Carlton (postcode 3053)
    - Staff and students of the University of Melbourne, Parkville campus (postcode 3010)
- They are **18 years of age or older** as of 1 October 2015.
- They own a smartphone, and are able to download the *FMS* survey app onto their smartphone. Only one registration per smartphone handset is permitted.
- They participate in the survey by logging into the *FMS* smartphone app and carrying their smartphone with them while they travel for a total of **fourteen-days** (including at least **seven continuous days**) before 1 December 2015.
- They validate the accuracy and completeness of the travel collected each day by the *FMS* app using an online survey tool. All travel days must be completed and validated by **Friday 4 December 2015**.

Note:

Participants should only take part in the study if they are comfortable in volunteering 14-days of travel and activity information. Respondents who don't report travel and activity because they have left the *FMS* app logged off for extensive periods will be ineligible for an incentive.

The $50 WISH gift card is sent electronically to the email address used to register for the survey. Please ensure this email address is up-to-date to ensure that the gift-card is received. University of Melbourne staff and students must use their current university email to be eligible to receive the gift card.

Participants will be advised by email of their eligibility to receive a gift-voucher no later than 1 December 2015. Those who miss out on the gift-voucher because they were not one of the first 450 respondents may still be eligible to enter the prize draw (see over page).

Details about the gift cards, and the stores where they can be redeemed, are available from: https://everydaygiftcards.com.au/gift-cards/wish-gift-cards

Eligibility to enter a prize draw for one of 50 WISH gift vouchers

All survey participants, except those from the three study areas who have already received a gift card (see above), will be entered into a prize draw for one of fifty WISH Gift Vouchers ($50 value each) if they meet the following conditions:

- They are **18 years of age or older** as of 1 October 2015.

- They are a Victorian resident.
- They own a smartphone, and are able to download the *FMS* survey app onto their smartphone. Only one registration per smartphone handset is permitted.
- They participate in the survey by logging into the *FMS* smartphone app and carrying their smartphone with them while they travel for a total of **fourteen-days** (including at least **seven continuous days**) before 1 December 2015.
- They validate the accuracy and completeness of the travel collected each day by the *FMS* app using an online survey tool. All travel days must be completed and validated by **Friday 4 December 2015**.

Note:

Participants should only take part in the study if they are comfortable in volunteering 14-days of travel and activity information. Respondents who don't report travel and activity because they have left the *FMS* app logged off for extensive periods will be ineligible to enter the prize draw.

The $50 WISH gift card is sent electronically to the email address used to register for the survey. Please ensure this email address is up-to-date to ensure that the gift-card is received.

The prize draw will take place at the Melbourne School of Engineering, University of Melbourne, on Friday 11 December 2015. Winners will be notified by email within 7 days of the draw.

Details about the gift cards, and the stores where they can be redeemed, are available from: https://everydaygiftcards.com.au/gift-cards/wish-gift-cards

Appendix D – Consent Form

Participants are automatically directed to a consent form screen following successful registration.

PROJECT: Victorian Future Mobility Sensing Project

INVESTIGATORS: Prof Stephan Winter, Dr Nicole Ronald, Prof Richard Sinnott, Prof Chris Leckie, Prof Russell Thompson, Dr Maria Vasardani, Stephen Roddis, Ronny Kutadinata in collaboration with DEDJTR, the Singapore-MIT Alliance for Research and Technology and the Massachusetts Institute of Technology under the umbrella of the Carlton Connect Initiative Fund

CONTACT US: Prof Stephan Winter, winter@unimelb.edu.au, (03) 8344 7875

Human Research Ethics Committee Project No.: 1543801.1

[Age] I am 18 years of age or over.

[Voluntary] I understand that my participation in this study is completely voluntary. Before or after registration I am free to withdraw from the project at any time without notice, explanation or prejudice.

[Purpose] I acknowledge that the project is for the purposes of research, and this research is for informing transport planning in Victoria and world-wide.

[Personal data / contact] I understand that my registration data is needed during the survey for communication, and at completion for payment (if I am eligible). I have been informed that my registration data will be stored securely, will be accessed only by the investigators in this project, and will be destroyed after the completion date of the survey (30 November 2015) if I choose not to stay on register for further surveys. It will never be linked to the research.

[Survey data] I have been informed that the raw survey data I provide will be safeguarded subject to any legal requirements, that the raw survey data will never be linked to my registration data, that only researchers in this project will be provided with access to the raw survey data, and that the raw survey data and all its derivatives will solely be used for the research in this project.

[Trip data] I have been informed that anonymous *processed* data (i.e., trip locations and purposes) will be shared with the Department of Economic Development, Jobs, Transport and Resources (the Victorian authority to collect individual travel and activity surveys) for their purposes of improving transport planning in Victoria.

[App] I have been informed that the application, when turned on, will track my mobility and upload this data to a server at the University of Melbourne for the purpose of the described research, that this application has a drain on the battery, and that I can log out of the app whenever I do not want to be tracked.

[Liability] I understand that the sole responsibility of this trial survey is with the University of Melbourne, on contract of the Department of Economic Development, Jobs, Transport and Resources.

[Device / charges] I understand that if I have chosen to use my own (or a third party) mobile device, and that I will not be reimbursed for any telecommunication charges (data or other) related to my participation.

[Payments] I understand that I will receive a $50 gift-voucher only if I have satisfied the specified eligibility criteria.

[I agree / I disagree]

This goes to the next page:

[Follow-up] I want to stay on register for follow-up surveys. In this case I agree that the registration data is shared with the Department of Economic Development, Jobs, Transport and Resources.

[I agree / I disagree]

THE UNIVERSITY OF MELBOURNE

Language ▾ Melbourne

Logout
Hello, SR_temp!

HOME DASHBOARD FREQUENT PLACES PRE-SURVEY FAQs SUPPORT CONTACTS

Consent Form

PROJECT: Victorian Future Mobility Sensing Project

INVESTIGATORS: Prof Stephan Winter, Dr Nicole Ronald, Prof Richard Sinnott, Prof Chris Leckie, Prof Russell Thompson, Dr Maria Vasardani, Stephen Roddis, Ronny Kutadinata in collaboration with DEDJTR, the Singapore-MIT Alliance for Research and Technology and the Massachusetts Institute of Technology under the umbrella of the Carlton Connect Initiative Fund

CONTACT US: Prof Stephan Winter, winter@unimelb.edu.au, (03) 8344 7875

Human Research Ethics Committee Project No.: 1543801.1

Please refer to the Plain Language Statement for detailed information about the project.

[Age] I am 18 years of age or over.

[Voluntary] I understand that my participation in this study is completely voluntary. Before or after registration I am free to withdraw from the project at any time without notice, explanation or prejudice.

[Purpose] I acknowledge that the project is for the purposes of research, and this research is for informing transport planning in Victoria and world-wide.

[Personal data / contact] I understand that my registration data is needed during the survey for communication, and at completion for payment (if I am eligible). I have been informed that my registration data will be stored securely, will be accessed only by the investigators in this project, and will be destroyed after the completion date of the survey (30 November 2015) if I choose not to stay on register for further surveys. It will never be linked to the research.

[Survey data] I have been informed that the raw survey data I provide will be safeguarded subject to any legal requirements, that the raw survey data will never be linked to my registration data, that only researchers in this project will be provided with access to the raw survey data, and that the raw survey data and all its derivatives will solely be used for the research in this project.

[Trip data] I have been informed that anonymous processed data (i.e., trip locations and purposes) will be shared with the Department of Economic Development, Jobs, Transport and Resources (the Victorian authority to collect individual travel and activity surveys) for their purposes of improving transport planning in Victoria.

[App] I have been informed that the application, when turned on, will track my mobility and upload this data to a server at the University of Melbourne for the purpose of the described research, that this application has a drain on the battery, and that I can log out of the app whenever I do not want to be tracked.

[Liability] I understand that the sole responsibility of this trial survey is with the University of Melbourne, on contract of the Department of Economic Development, Jobs, Transport and Resources.

[Device / charges] I understand that if I have chosen to use my own (or a third party) mobile device, and that I will not be reimbursed for any telecommunication charges (data or other) related to my participation.

[Payments] I understand that I will receive a $50 gift-voucher only if I have satisfied the specified eligibility criteria.

I agree *I disagree*

THE UNIVERSITY OF MELBOURNE

Language ▾ Melbourne

Logout
Hello, SR_temp!

HOME DASHBOARD FREQUENT PLACES PRE-SURVEY FAQs SUPPORT CONTACTS

[Follow-up]I would like to be invited to take part in other transport-related research conducted by the University of Melbourne. My email address will be kept on record for this purpose, and I understand I can opt out at any time.

(Agreeing to take part in other research is entirely voluntary, and does not affect your participation in this study)

I agree *I disagree*

Appendix E – Plain Language Statement

What is this project about?

The Victorian Future Mobility Sensing Project ('FMS Victoria') will trial a novel smartphone-based travel and activity survey, which seeks to provide more accurate and more detailed data than the current paper-based Victorian Integrated Survey of Travel and Activity (VISTA). VISTA has provided the government with travel and activity survey data for decades, and is an essential source for public transport planning, transport infrastructure investment, and urban planning in Victoria. Your voluntary participation in this trial will help to improve VISTA and the associated transport decision-making in Victoria.

For this trial the University of Melbourne (lead) is partnering with the Department of Economic Development, Jobs, Transport and Resources (the Victorian authority to collect individual travel and activity surveys), the Singapore-MIT Alliance for Research and Technology, and the Massachusetts Institute of Technology, who have developed the software you have in your hands.

The trial is run to address a range of research questions:

- comparing the survey results with the paper-based Victorian Integrated Survey of Travel and Activity (VISTA);
- comparing the travel demand in Melbourne, with the travel demand in Singapore, two cities with very different patterns of mobility;
- collecting the traveller's satisfaction with their chosen modes of transport; and
- studying the automatic interpretation of the collected travel and activity data, so as to reduce participant burden in completing future surveys.

The investigators of this project are:

- Prof Stephan Winter, Dr Nicole Ronald, Prof Richard Sinnott, Prof Chris Leckie, Prof Russell Thompson, Dr Maria Vasardani, Stephen Roddis, and Ronny Kutadinata from the University of Melbourne
- Prof Moshe Ben-Akiva (MIT, USA) and Dr Fang Zhao (SMART, Singapore)

The project is funded by the Carlton Connect Initiative of the University of Melbourne, with support of the Department of Economic Development, Jobs, Transport and Resources and in-kind contributions of the University of Melbourne, SMART and MIT.

Since this trial relies on volunteers sharing their travel data it has been designed according to the ethical standards laid out in the Declaration of Helsinki, which exceeds national legislation.

Invitation

We would like to invite you to participate in this exciting trial. It involves volunteering a small amount of your time and attention over a fortnight, and helps to contribute to a more sustainable and smarter city.

What will you be asked to do?

If you decide to volunteer your time and participate in this trial, then this is what you can expect:

- You will register for the trial at https://melbourne.fmsensing.com.
- During the registration process, you will be asked to complete a consent form, agreeing to participate in this survey and allowing the application (called 'app' in the following) to track your daily travel.
- You will then be asked to download the app to your smartphone, and login using your registration information (and until then this app does not collect any personal data).

- You are then ready to participate in the trial. We will ask you to start the app every morning when you leave your house and turn off the app when you come home (you can interrupt it anytime in between if you do not want to be tracked at particular locations). The app will automatically record your travel each day. This will not restrict you from using normal functions on your smartphone (such as calling, texting, or browsing the internet). The app may also allow you to comment on your satisfaction with your current mode of travelling. Once you finish your travel you can log out from your app.
- The study is interested in all travel outside the home, for any purpose. We therefore ask you to carry your phone in situations where you might normally leave it behind; e.g. taking an evening stroll; visiting a neighbour; walking the dog; etc.
- The app will drain your battery faster than normal usage, so be prepared to charge your phone during the day.
- Each day, log in to https://melbourne.fmsensing.com, look at your data and confirm that this represents the travel you made. We call this the data validation phase. On average, we estimate that participation in the survey will take you 5 minutes per day.
- Participants who meet the following conditions may be eligible to receive a $50 gift-voucher:

  you provide travel data for 14 days before 1 December 2015, including at least seven consecutive days, and validate the data by 4 December 2015;

  you are one of the first 450 respondents (150 from each of three target area groups) to complete the survey. The three target areas groups are:

  - residents of Belgrave (postcode 3160, including Tecoma)
  - residents of Carlton (postcode 3053)
  - staff or students of the University of Melbourne (Parkville campus);
- We appreciate the contributions of volunteers living elsewhere (all data is helpful), but the $50 incentive is specifically designed to encourage participation from nominated target areas. All other Victorian participants who complete the survey will be entered into a prize draw for one of fifty gift-vouchers ($50 value each).
- Full details of gift-voucher eligibility is available from the project website (http://imod-au.info/survey/)

How and what data is collected

The application collects precise information about the location and movement of your device using GPS, GSM, Wi-Fi, and accelerometer data. In addition, the application may collect certain information automatically, including: the type of mobile device on which you have downloaded the application; the unique ID of your mobile device; your mobile device's IP address; your mobile device's operating system; and information about the way you use the application.

How will my privacy be protected?

Your anonymity is our prime responsibility. All data will be kept secure on a server at the University of Melbourne. Your identity will not be revealed at any stage, and will not be linked to the research. The registration data will be kept separate from the travel data in order to preserve your privacy. Furthermore, to guarantee confidentiality of the information you have provided, access to the anonymized travel data will only be provided to project researchers, , with usage bound to the aims of the project. The data management follows strictly the University of Melbourne Policy on the Management of Research Data and Records, which is available at http://www.unimelb.edu.au/records/research.html, and which requests that we keep the travel data for five years after the last project publication appears.

The raw travel data will not be shared with any third party in any situation except when required by law. However, we will share interpreted, anonymous trip data with our project partner, the Department of Economic Development, Jobs, Transport and Resources, in order to fulfil the aims of the project. We will also publish de-identifiable findings of generalized, aggregate nature in scientific articles.

How will I receive feedback?

We will publish all our findings. You will find links to these publications on the project website once they come out.

Once your 14 days of travel data has been completed, and any incentive vouchers delivered, your registration data will be deleted for privacy purposes. We will therefore unable to provide direct feedback to you after the study unless you opt in to receive project updates.

What if I change my mind?

Your participation in this trial is completely voluntary. You may at any time opt-out from allowing us to have access to your travel data in three ways:

- Log out of the app via the "log out" screen. This will discontinue all data collection until such time as you log in again.
- Uninstall the app.
- Contact our team at info@imod-au.info to request removal of your data from the database. We will comply with all requests for data removal, except after payment.

In any case your registration data will be destroyed by default automatically by the end of the survey period. Your decision to participate or not, or to withdraw, will not affect your relationship with the University of Melbourne or the Victorian Government, and will not affect any services you may receive now or in the future.

Where can I get further information?

If you require any further information, or have any concerns, please do not hesitate to contact the lead investigator, Prof Stephan Winter, winter@unimelb.edu.au or (03) 8344 7875. Should you have any concerns about the conduct of the project, you are welcome to contact the Executive Officer, Human Research Ethics, The University of Melbourne, via phone: (03) 8344 2073, or fax: 9437 6739.

This project has been approved by the Ethics Committee of the School of Engineering, The University of Melbourne (Human Research Ethics Committee Project No.: 1543801.1).
PLS version 2.4, 25 September 2015

Appendix F – Registration questions

Demographic questions

- What is your age?
- What is your gender?
- What is your marital status?
- Which of the following best describes your current employment situation?
- Which category best describes your highest level of formal education?
- What is your country of birth?
- Last year, what was your total household income from all sources before tax?

Housing questions

- For how many years (to the nearest year) have you lived at your current address?
- Which of the following best describes the building in which you currently live?
- What is the ownership status of your current residence?
- Including yourself, how many people normally live in your household?

Mobility questions

- How many vehicles are owned, leased or regularly available to the members of your household?
    - Include cars, motorcycles, mopeds, trucks, vans, etc
    - Exclude vehicles available through a car share scheme
- How many adult bicycles, in working condition, are kept at this household?
- How many children's bicycles, in working condition, are kept at this household?
- Do you currently use or are you a member of the Melbourne Bike Share program?
- Do you currently hold a driver's license?
    - [Selected from] Full Car Licence; Probationary Car Licence; Car Learner's Permit; Motorcycle Licence; Other Licence; None of these
- Do you currently use or are you a member of a car sharing scheme?
- Do you have access to any of the following transport programs or passes?
    - [Selected from] Disabled Person's Parking Permit; Multi-Purpose Taxi Program; Scooter and Wheelchair Travel Pass Access; Travel Pass Vision Impaired Travel Pass; None of these; Prefer not to say

Mobility questions (screenshot over page)

- Please tell us about some of your frequently visited places. This will make it easier for us to interpret and for you to review your location data.
    - (As many frequent places can be added as you would like. Your home address is specifically needed to confirm whether you are eligible for a gift-voucher or prize draw entry).
- Select the primary activity type
- Enter/search for an address, location or place name
- Adjust temporary location marker in map by moving it if not accurately placed

Frequent Places

Please tell us about some of your frequently visited places. This will make it easier for us to interpret and for you to review your location data.

(As many frequent places can be added as you would like. Your home address is specifically needed to confirm whether you are eligible for a gift-voucher or prize draw entry).

1. Select the primary activity type: Home

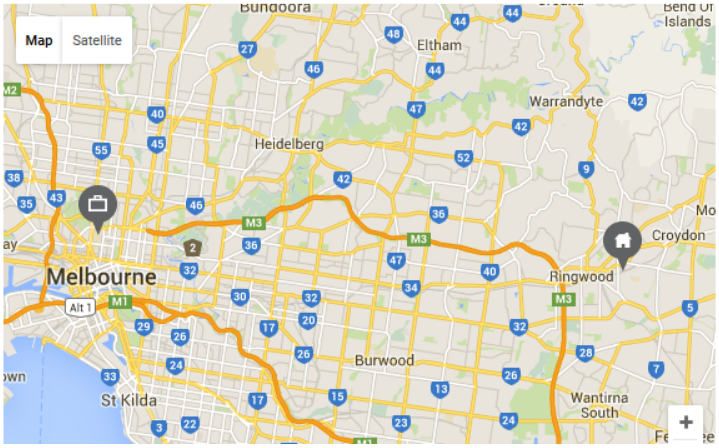
2. Enter/search for an address, location or place name:

Enter a location

3. Adjust temporary location marker in map by moving it if not accurately placed

Add frequent place

*To delete, right-click on an existing marker, or click on 'X' in the corresponding table row.



Activity type	Description
Home	Ringwood East, Victoria, Australia
Work	University of Melbourne, Parkville, Victoria, Australia

Appendix G – Conversion of Google Polyline code

```
def decode_line(encoded):
    """'decode_line' sourced from http://seewah.blogspot.com.au/2009/11/gpolyline-decoding-in-python.html
    Decodes a polyline that was encoded using the Google Maps method.
    See http://code.google.com/apis/maps/documentation/polylinealgorithm.html
    This is a Python port of Mark McClure's JavaScript polyline decoder
    (http://facstaff.unca.edu/mcmcclur/GoogleMaps/EncodePolyline/decode.js)
    and Peter Chng's PHP polyline decode
    (http://unitstep.net/blog/2008/08/02/decoding-google-maps-encoded-polylines-using-php/)"""
    encoded_len = len(encoded)
    index = 0
    array = []
    lat = 0
    lng = 0
    while index < encoded_len:
        for i in range (0,encoded_len):
            b = 0
            shift = 0
            result = 0
        while True:
            b = ord(encoded[index]) - 63
            index = index + 1
            result |= (b & 0x1f) << shift
            shift += 5
            if b < 0x20:
                break
        dlat = ~(result >> 1) if result & 1 else result >> 1
        lat += dlat
        shift = 0
        result = 0
        while True:
            b = ord(encoded[index]) - 63
            index = index + 1
            result |= (b & 0x1f) << shift
            shift += 5
            if b < 0x20:
                break
        dlng = ~(result >> 1) if result & 1 else result >> 1
        lng += dlng
        array.append((lat * 1e-5, str(lng * 1e-5)))
    return array

if __name__ == "__main__":
    with open('H:\\Documents\\FMS\\FINAL\\Databases\\2 Cleaned google polylines.csv') as inputfile:
    # import csv as inputfile
        with open('H:\\Documents\\FMS\\FINAL\\Databases\\Stop coordinate file.csv','w') as outputfile:
        # export data in an output.csv file

            for line in inputfile.readlines():
                parts=line.split(',')    # breaks up csv
                a=parts[3].strip()       # reads encoded string
                stopid=parts[1]          # stores stopid
                sequence=parts[2]        # stores sequence
                recnum=parts[0]
                print recnum
                latlngs = decode_line(a)     # pass string as argument to decoder function
                counter=0                    # counter used to order points
                for latlng in latlngs:
                    counter=counter+1
                    outputfile.write(stopid+","+sequence+","+str(counter)+","+str(latlng[0]) + "," + str(latlng[1])+'\n')
```

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