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An evaluation of bicycle passing distances in the ACT

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An evaluation of bicycle passing distances in the ACT

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ABSTRACT

To evaluate bicycle passing distances in the Australian Capital Territory (ACT), specialised passing distance measurement devices (PDMDs) were installed on a sample of 23 cyclists who ride in the ACT. Passing distance data and GPS data was collected by cyclists using the PDMDs for a four-week period, during a trial phase of a newly legislated minimum passing distance (MPD) rule. The MPD rule requires drivers to provide more than 1 metre of space when passing a cyclist on a road with a speed limit of 60 km/h or below, and 1.5 meters of space when passing a cyclist on a road with a speed limit above 60 km/h Analysis of the data collected in the study identified 16,476 passing events during 6,531 kilometres of cycling, over a period of 271 riding hours. Non-compliance with the MPD rule on roads zoned 60 km/h or less was 2.7% and the mean passing distance was 1.85 metres. On roads zoned greater than 60 km/h non-compliance was 11.2% and the mean passing distance was 1.97 metres. The degree of non-compliance varied considerably with road characteristics and location.

KEYWORDS

Minimum Passing Distance, Metre passing rule, Cyclist safety, Naturalistic cycling study

Summary

This report provides details on the ACT Road Safety Fund project ‘An evaluation of bicycle passing distances in the ACT’. The first stage of the project required the re-design of a passing distance measurement device to produce a more robust, compact, and accurate device. The accuracy of the new device was verified using a number of different assessments, which included on-road tests to ensure that the measured data was accurate, consistent, and that the device functioned consistently under various operating conditions.

Twenty three cyclists in the ACT volunteered to have a device attached to their bicycles and naturalistic cycling data was collected over a four-week period from mid-August to mid-September 2018. The study was undertaken in compliance with the requirements of the University of Adelaide’s Office of Research Ethics, Compliance and Integrity (approval number H-2018-056).

During the evaluation period, the ACT Government had a minimum passing distance (MPD) rule in place as part of a “Safer Cycling Reforms” trial that commenced in November 2015. The MPD rule required drivers of vehicles to overtake cyclists with a passing distance of at least one metre on roads zoned 60 km/h and below and 1.5 metres on roads zoned above 60 km/h. The primary purpose of this study was to evaluate the effectiveness of the MPD rule in the ACT. This study also enabled the identification and of circumstances and locations where there were differences in the average percentage of non-compliant passing events.

Analysis of recorded data showed that most drivers in the ACT provided a reasonable amount of space when passing cyclists on various parts of the road network. Over the data collection period a total of 6,531 kilometres and 271 hours of riding was undertaken by the volunteer cyclists. During this period, 16,476 passing events were detected, of which 1,502 were determined to be non-compliant with the MPD rule. On low speed roads, where the speed limit was 60 km/h or below, the proportion of drivers that were non-compliant with the MPD rule was 2.7%. For high speed roads, where the speed limit was greater than 60 km/h, the proportion of non-compliance was 11.2%.

Results from individual participants was found to vary quite considerably and is likely due to different cycling habits and riding styles, such as route selection and time of day of rides.

The presence of a bicycle lane on a road appeared to be associated with a lower proportion of non-compliant on both high speed and low speed roads. Interestingly, on low speed roads, the median passing distance was found to be lower in locations where there was a bicycle lane. This is likely due to bicycle lanes being implemented in dense urban areas where infrastructure and smaller lane widths reduce the space available for vehicles to pass.

The riding undertaken by the cyclists in this study was found to be reasonably distributed over the ACT road network and roads ranked higher in the functional road hierarchy had a higher number of journeys compared to lower ranked roads. The data collected was able to be processed and converted into various road ‘heat maps’ to show:

- number of journeys during the study,
- median passing distances, and
- mean non-compliant pass ratio (proportion of non-complaint passes out of all passes).

These maps may be useful to identify where road infrastructure may be resulting in high numbers of non-complaint passes. However, the data collected over a four-week period, from a small number of cyclists, may not necessarily be representative, so care is needed when interpreting the results.

Contents

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1 Introduction

For cyclists who ride on the road, being passed by a vehicle is a common occurrence. However, if the lateral distance between the cyclist and the passing vehicle is too small a fall or a collision can occur. Research has shown that crashes resulting from a vehicle passing a cyclist too closely are more likely to result in severe injuries compared to other types of crash between cyclists and vehicles (Stone & Broughton, 2003; Raslavičius et al., 2017).

Even without a physical collision, a vehicle passing too closely may cause a cyclist to become unstable and fall. Furthermore, the mere sensation of being passed by a vehicle too closely has been identified as one of the most uncomfortable experiences for a cyclist (Guthrie et al., 2001; Parkin et al., 2007; Heesch et al., 2011).

Active transport methods, such as cycling, are being heavily promoted and encouraged by most governments in the various jurisdictions around Australia. To assist with ensuring the safety of cyclists, most jurisdictions have also put in place laws requiring vehicles to pass or overtake bicyclists safely, nominating a passing distance of at least one metre on roads zoned at 60 km/h or less and at least 1.5 metres on roads zoned above 60 km/h. Drivers are usually also granted permission to cross the centreline of the road, when safe, in order to comply.

A minimum passing distance law was introduced within the Australian Capital Territory (ACT) in 2018 after the two-year “Safer Cycling Reforms” trial which commenced in November 2015.

While it seems logical that these laws will improve cyclist safety, it is not yet clear what effect they will have on passing distances. Indeed, Haworth & Schramm (2014) noted that there is limited knowledge regarding what affects the lateral distance at which a driver chooses to pass a cyclist and what effect the introduction of a one metre passing laws may have on this distance.

Several previous studies have investigated the distance at which bicycles are passed by vehicles (Walker, 2007; Duthie at al., 2010; Parkin & Meyers, 2010; Love et al., 2012; Savolainen et al., 2012; Chapman & Noyce, 2012; Chuang et al., 2013; Walker et al., 2014; Kay et al., 2014; Mehta et al., 2015; Llorca et al., 2017). These studies have investigated how passing distance is altered by factors such as the sex of the cyclist, the presence of a bike lane, the clothing of the cyclist, the lateral position of the bicycle, and the helmet use or non-use of the cyclist. However, many of these studies utilised an instrumented bicycle that was ridden by only one cyclist (Walker, 2007; Chapman & Noyce, 2012; Walker et al., 2014; Mehta et al., 2015; Llorca et al., 2017), or just a few cyclists (Parkin & Meyers, 2010; Love et al., 2012; Chuang et al., 2013). Additionally, several studies restricted data collection to a specific set of streets or routes where infrastructure details such as road width, bike lane presence, and bike lane width were known beforehand or could be determined by investigation (Duthie at al., 2010; Parkin & Meyers, 2010; Love et al., 2012; Chapman & Noyce, 2012; Chuang et al., 2013; Walker et al., 2014; Mehta et al., 2015; Llorca et al., 2017).

Because of these limitations, the results of such studies cannot claim to be representative of typical cyclists’ riding experience or crash risk. Cyclists provided with an instrumented bicycle are unlikely to ride in the same way that they would on their own bicycle (e.g. a cyclist who is used to a light weight racing bicycle may ride differently when provided with an instrumented bicycle that is heavy and less responsive). Furthermore, the routes that cyclists travel (and their familiarity with the route) will have an added effect on their riding style.

Naturalistic studies of vehicle-bicycle passing distances, in which cyclists ride their own bicycles and select their own routes, would provide results that are free from the bias of the earlier studies and provide mass data for improved statistical analysis. Indeed, recent implementations of naturalistic studies in

Australia (Schramm et al., 2016; Mackenzie et al., 2017; Beck et al., 2018) have shown promise, in collecting data that is highly relevant to the assessment of passing distances and in exploring the effectiveness of passing distance laws.

The Centre for Automotive Safety Research (CASR) has developed a passing distance measurement device (PDMD-Mk1) that is lightweight and able to be attached to any bicycle. The device is designed to be attached to a cyclist's personal bicycle and collect data while they ride their usual routes (i.e. a naturalistic setting). Algorithms were also developed that can quickly process the data collected by the PDMD-Mk1 and automatically identify passing events. The location of these events can then be plotted on a map such that hot-spots can be identified and the effectiveness of cycling infrastructure can be analysed.

A trial using the PDMD-Mk1 found that it was capable of collecting data suitable for analysing passing distances and was easy for cyclists to use (Mackenzie et al., 2017). However, several aspects of the PDMD-Mk1 were identified as requiring improvement before it could be considered suitable for deploying in a larger study.

The objective of this study was to develop an updated passing distance measurement device, and then deploy a number of units in the ACT, attached to the bicycles of volunteer cyclists, to collect data that would enable the assessment of compliance with the passing distance law, explore the circumstances that affect passing distances, and identify locations where close passing distances are more likely.

This report describes the methodology and results of the study. In Section 2 the process of re-designing the PDMD-Mk1 is described. Then, in Section 3, the capabilities of the newly designed PDMD-Mk2 are verified in several assessments. Activities completed in preparation for the deployment of the devices are described in Section 4. The description of a problem encountered during the initial deployment of the devices is provided in Section 5, along with a resolution. The volunteer cyclist recruitment process is described in Section 6. Then, in Section 7, the details of the data collection procedure are presented. The methods used to process the collected data are explored in Section 8. The results of analysing the collected passing distance data and the opinions of the cyclist participants are presented in Section 9 and Section 10 respectively. Finally, Section 11 provides some discussion regarding the outcomes of the project.

2 The Passing Distance Measurement Device

A previous study of bicycle passing distances in Victoria (Mackenzie, Thompson & Dutschke, 2017) utilised a passing distance measurement device (PDMD) that was developed by the Centre for Automotive Safety Research (CASR) called the PDMD-Mk1. In this previous study it was discovered that there were several aspects of the PDMD-Mk1 that required improvement before it was suitable for use in future studies. The aspects of the PDMD-Mk1 which required improvement are described below, followed by a description of a new device, the PDMD-Mk2.

2.1 PDMD-Mk1 limitations

The PDMD-Mk1, consisting of a main control box and front sensor box, is shown attached to a bicycle in Figure 2.1 below. The main control box houses a microcontroller, GPS receiver, battery, data logger, motion sensor, and one ultrasonic sensor. The main box was also fitted with a power button for controlling the device and an indicator LED which displays the current operating mode. The second ultrasonic sensor is housed in the front sensor box, which transmits data back to the main box via a cable connection.

No issues were found with the recorded lateral distance data from the pair of ultrasonic sensors utilised by the device. However, several cyclists who used the PDMD-Mk1 reported that the front ultrasonic sensor would interfere with their right knee while riding. This was due to positioning of the sensor and the shroud protruding out laterally (see Figure 2.3).

Figure 2.1
PDMD-Mk1 attached to a bicycle

Several users of the PDMD-Mk1 also stated that they felt the device was too large or bulky and did not like the way it looked on their bicycle. Additionally, the bulkiness and attachment mechanism of the PDMD-Mk1 resulted in the device twisting out of position and, in some cases, detaching from the bicycle.

The GPS data quality was poor and there were a significant number of signal interruptions in the data recorded during journeys. It is possible that the positioning of the main box (with GPS receiver) beneath the saddle of the bicycle may have degraded the GPS signal and caused the frequent interruptions. This type of effect was highlighted in a study of the effect of the human body on GPS performance by Rehman et al. (2007).

The PDMD-Mk1 also utilised a motion sensor, which was intended to start and stop data recording when movement was detected, so that users did not need to remember to switch the device on and off. Unfortunately, this sensor did not perform as expected and the PDMD-Mk1 frequently stopped logging data in the middle of journeys.

Finally, it was noted that the accuracy of the ultrasonic sensors in measuring passing distances from a moving bicycle should be validated.

2.2 PDMD-Mk2 development

2.2.1 Hardware

The PDMD-Mk2 was designed to improve upon the aspects that were found to be problematic in the earlier trial. The new device consists of a smaller main control box (housing a microcontroller, GPS receiver, battery, removable SD card, and power button) and two ultrasonic sensors in separate compact cases, as shown in Figure 2.2 below.

Figure 2.2
PDMD-Mk2 attached to a bicycle

The ultrasonic mounting cases were re-designed to be more compact and to minimise the amount by which the sensor shroud protruded laterally (see Figure 2.3). This eliminated the potential for interference with cyclists' knees when riding. The general size and aesthetic of the ultrasonic mounting cases and the main control box were also addressed, becoming smaller and sleeker. The reduction in bulkiness improved the rigidity of the mounting and eliminated any tendency for twisting or detachment.

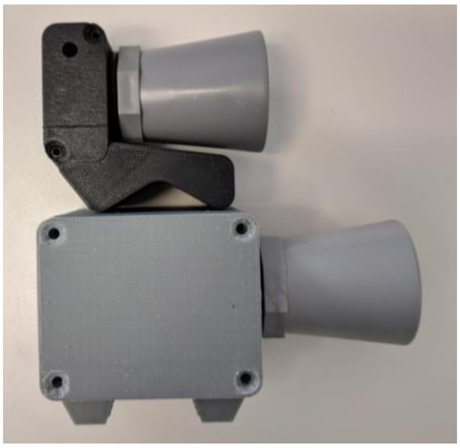

Figure 2.3
The PDMD-Mk2 ultrasonic mounting case (top), compared to the original PDMD-Mk1 version (bottom)

To address the issues with GPS signal reception, a superior receiver module was integrated into the main control box. The control box was also installed on the top tube behind the handlebars facing the sky and away from the cyclist's body.

The use of a motion sensor was abandoned such that the PDMD-Mk2 would require manual operation by the cyclist via a power button on top of the main control box. Manual operation of the device was something that the cyclists from the previous study (Mackenzie, Thompson & Dutschke, 2017) indicated they were willing to do.

In reducing the size of the device, a smaller battery was used. This resulted in a reduction in the operating time. However, the PDMD-Mk2 was designed so that it could be recharged easily by the cyclist when required. The PDMD-Mk2 main control box, a pair of ultrasonic mounting cases, and some examples of mounting adaptors can be seen in Figure 2.4 below. The adaptors were designed to enable different mounting configurations which would ensure secure attachment to different bicycle frame types or sizes.

Figure 2.4
The PDMD-Mk2 main control box (top), ultrasonic mounting cases (right side), and mounting adaptors (lower left)

2.2.2 Operation

Installation of the PDMD-Mk2 on most bicycles was a reasonably simple process. The main control box and ultrasonic sensor mounts were designed with slots such that they could be easily attached to most bicycles with cable ties. The main control box was attached to the top of the bicycle's top tube, while the front ultrasonic sensor was attached on either the underside of the top tube or the down tube (see Figure 2.2). The rear ultrasonic sensor could be attached to multiple locations: directly to the bicycle's seat post, to the bicycle's seat post using the long mounting adaptor (shown in Figure 2.4) or attached to the bicycle's saddle rails with the saddle rail mounting adaptor (also shown in Figure 2.4). The cables connecting the sensor cases to the main control box were wrapped and tied around the top tube and seat-post so they would not interfere with the rider. Each of the ultrasonic sensors were installed perpendicular to the longitudinal axis of the bicycle, to ensure lateral distances from the centre of the bicycle were measured.

Once installed on a bicycle, the PDMD-Mk2 was relatively simple to operate. When starting a journey, the cyclist would press the power button on the top of the main control box. This would activate the device, and it would immediately start acquiring a GPS signal. This process could take up to three minutes but was usually quicker. An LED integrated into the power button indicated the current status of the device via a sequence of flashes.

Once a GPS signal was acquired, the device would open a new logging file on the removable SD card and begin recording data. A GPS data point was recorded once every 2 seconds (0.5 Hz) and distance data from both ultrasonic sensors was recorded 20 times a second (20 Hz).

At the end of a journey the cyclist would press the power button again to deactivate the device. The would stop all recording and close the logging file.

Through this process, a unique log file would be created on the SD card for each individual journey taken by the cyclist. Once data collection was complete, the SD card could be removed and all the recorded data extracted for future analysis.

If required, the electronics within the device could be removed from the main control box mounting system and recharged away from the bicycle by plugging into a USB cable. A light inside the device indicated when the device was charging and when the battery was full.

3 Validation of PDMD-Mk2 measurements

As stated above, it was deemed important to verify that the data being recorded by the PDMD, while attached to a bicycle being ridden on a public road, is accurate.

Two prototype PDMD-Mk2 units were constructed, and a number of tests were undertaken in order to verify the accuracy and consistency of the data being recorded under different circumstances. The test methodology, and the outcomes, are described below. An assessment of the device's battery life and resistance to water is also described.

3.1 Temperature changes and air turbulence

The ultrasonic distance sensors operate by emitting a sound pulse and measuring the time it takes to reflect off an object and return to the sensor. The measured time is converted to a distance by accounting for the speed of sound through air. As the temperature of air changes, its density also changes, and this affects the speed at which sound travels through the air. The ultrasonic sensors are equipped with temperature compensation circuitry which is designed to account for changes in air density and maintain the accuracy of distance measurements. However, the speed at which this temperature compensation occurs is not clear.

There are several situations in which a sudden temperature change may be encountered by the PDMD (e.g. a blast of hot air from an exhaust) and it should maintain accuracy in these situations. It may also be possible that air turbulence could affect the natural passage of the sound pulse through the air.

The accuracy of the PDMD under turbulent temperature changes was tested by setting up an ultrasonic sensor facing towards a solid screen (as shown in Figure 3.1) and reading the distance measured while blowing hot air from different directions.

Using a heat gun, hot air was applied in three direction: between the sensor and the screen, over the screen towards the sensor, and over the sensor towards the screen (shown as 1, 2, and 3 in Figure 3.1 respectively). This procedure was conducted with the screen at a distance of 50 cm and at 100 cm.

The ultrasonic sensor recorded accurate readings from both the 50 cm and 100 cm distances. There was no discernible change in the reading when hot air was applied in direction 1 or 2. However, when hot air was applied in direction 3, there was a significant change in the distance reading.

These results show that the distance readings from the ultrasonic sensor are not affected by rapid temperature changes and air turbulence which travel across the face of the sensor or towards the sensor. This cannot be said for temperature changes that travel away from the sensor. However, this was considered to be an unlikely circumstance to encounter while riding as the hot air would need to be flowing past the body of the cyclist which would disperse the flow.

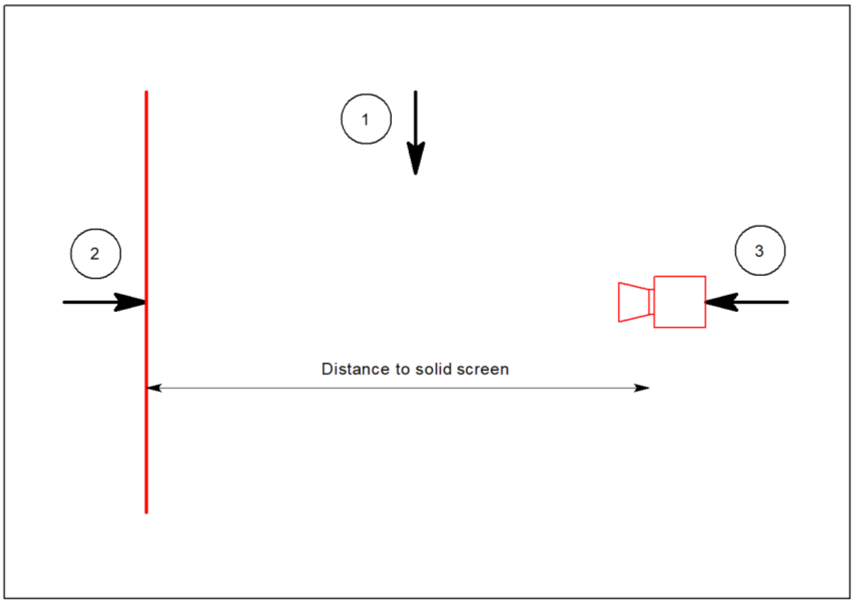

Figure 3.1
Top-down view of testing layout, with arrows showing the directions that hot air was applied using a heat gun

3.2 Sensor performance during on-road tests

The ultimate test of the PDMD is to measure the accuracy of the distance readings during a live on-road test. While the lab test of temperature changes and air turbulence described in Section 3.1 confirmed that the distance readings are robust during particular adverse conditions, there may be other factors which affect accuracy during real world cycling.

The accuracy of the PDMD during on-road cycling was tested during a number of passes by a vehicle equipped with a video overlay system (see Figure 3.2). After installing the video system on the test vehicle and calibrating with overlay (relative to the front left wheel), ten on-road passes were performed. Prior to each pass the driver ensured the traffic and road environment was safe, and then drove past the cyclist at a comfortable distance.

The recorded passing videos were viewed, and the overlay was utilised to note the distance of each passing event. These passing events were then matched to the recorded data from the PDMD

It should be noted that the resolution of the overlay system was around 0.05 metres. This resolution was considered acceptable given the dynamic and noisy environment that will be encountered by the PDMD during cycling journeys. That is, an accuracy greater than 0.05 metres is not expected by the PDMD in such an environment.

Figure 3.2
Video overlay system used to test the accuracy of the PDMD
(In this image the cyclist is observed to be passed at a distance of approximately 1.4 metres)

The results of comparing the distances measured by the video system and the PDMD during ten passing events is shown in Figure 3.3. The two measurement methods showed a good correlation (R^2 = 0.9338), with the PDMD detecting slightly shorter distances on average. This small difference in the distance (approximately 3 cm) is within the 5 cm accuracy limits. It was speculated that the difference in measured distances may be a result of the vehicle body (door panels) extending further laterally than the wheels, which the video system was calibrated against.

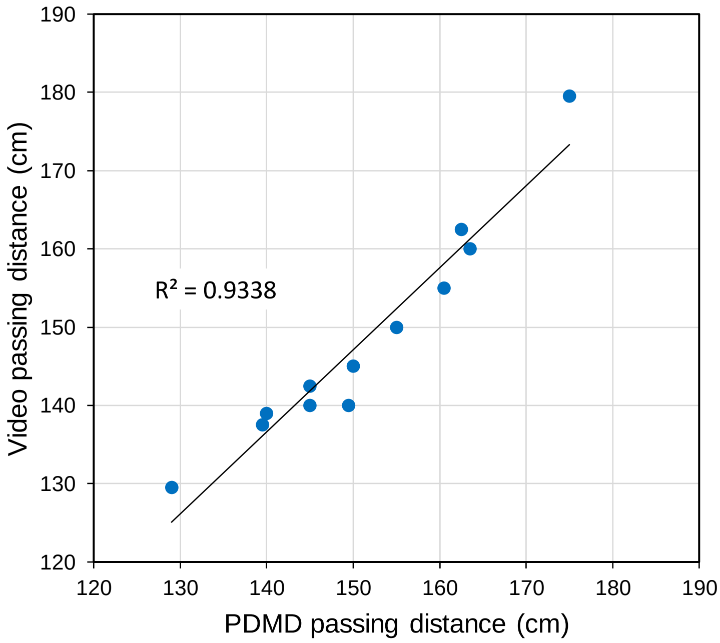

Figure 3.3
Correlation between PDMD recorded distance and video recorded distance

In Figure 3.4, an example of the distance data recorded by the front and rear ultrasonic sensors of the PDMD during a passing event is shown. It can be observed that the rear sensor detects the vehicle initially, followed by the front sensor. As the vehicle passes, both sensors agree on the minimum distance (around 140 cm). Finally, the vehicle leaves the detection zone of the rear sensor first and then front sensor soon after.

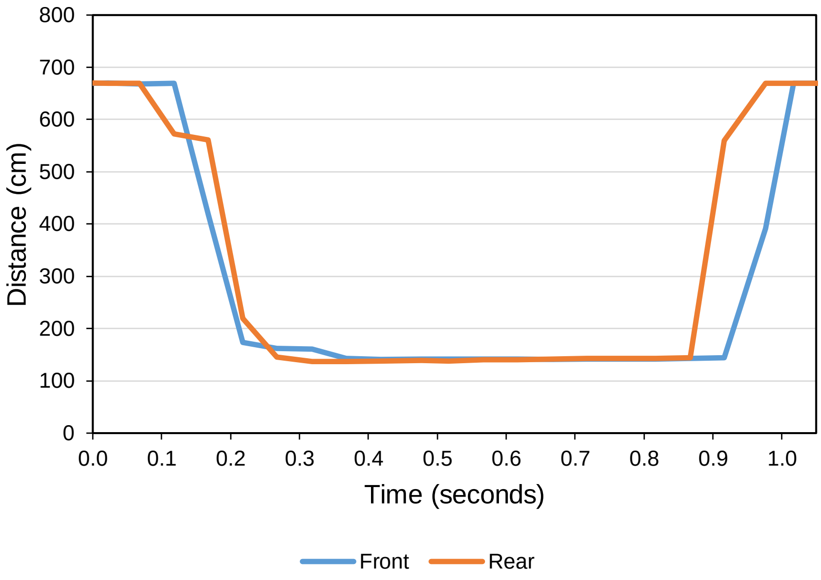

Figure 3.4
Distance data recorded by the PDMD during a passing event

Based on the results of this testing, it was deemed that the distance sensors were functioning correctly and were able to detect the passing of a vehicle. The accuracy of this detection capability was around 5 cm, which is acceptable for the investigation of passing distances.

3.3 GPS location and speed data

One of the aspects of the PDMD-Mk1 that required improvement was the reliability and accuracy of the GPS data. Without constant and accurate location data it would not be possible to reliably associate passing distances with roadway infrastructure.

The implementation of an improved GPS receiver module, and the removal of the motion sensor that was used in the PDMD-Mk1, resulted in an improvement in the recorded location data. Furthermore, no instances of signal loss or drop-out were observed during any of the test journeys that were performed around Adelaide during a two-week trial period of three PDMD-Mk2 units.

These improvements have resulted in cleaner and clearer GPS data, as shown in Figure 3.5 below.

Figure 3.5
GPS track of an example journey, shown in yellow
(Top: entire ride, Bottom: detail)

3.4 Battery life

As noted above, the re-design of the PDMD resulted in a smaller device (as intended). However, this also reduced the size of battery that could be integrated. The PDMD-Mk2 is fitted with a 1,000 mAh battery, compared to 6,000 mAh on the PDMD-Mk1. To compensate for this reduced battery capacity, the PDMD-Mk2 was designed to be easily rechargeable.

For the current study the PDMD-Mk2 is intended to be deployed with volunteer cyclists for a period of four weeks. It should have an appropriate battery capacity that will enable a significant amount of data to be collected before the device requires recharging.

The battery life of the device was tested by recharging to maximum capacity and then leaving it switched on in a safe place until the unit lost power. The internal memory of the unit was then checked to determine the time between activation and power loss.

This procedure was conducted for two situations: with the device inside (without a GPS signal), and with the device outside (where a GPS signal was available). The results of the two tests were an 18.5 hour battery life when inside, and a 19.1 hour battery life when outside.

A battery life of 18 hours would provide enough power for two 27-minute rides each weekday for four weeks. This was deemed to be a sufficient amount of riding between battery charging.

3.5 Water resistance

The 3D printed enclosure used to house the PDMD was not designed to be water-proof but should be resistant to water. That is, it should resist ingress of water when attached to a bicycle that is being ridden in light rain.

The water resistance of the enclosures was tested by removing all the electronics from the enclosure, stuffing the enclosure with absorbent material (tissues), sealing and mounting the enclosure in the usual manner, and then exposing it to water. The enclosure was sprayed with water from several directions to the point that liquid was observed to be pooling on the surface and dripping down the sides.

The outside of the enclosure was allowed to dry and then it was opened. The absorbent material was then inspected carefully for any signs of moisture, particularly near the edges of the enclosure when water would be expected to enter.

No obvious signs of moisture were discovered, and the enclosure was deemed to be resistant to light water exposure.

4 Deployment preparation

Once the PDMD-Mk2 was validated and deemed suitable for data collection, a number of steps were taken in preparation for deployment with volunteer cyclists in the ACT.

4.1 Ethics approval

As this research study involved volunteer cyclists, a human research ethics application was submitted to the University of Adelaide's Office of Research Ethics, Compliance and Integrity on 8th February 2018. The application was approved, with amendments, on 3rd April 2018. The human ethics approval number is H-2018-056.

The approved ethics application listed the following major requirements for the study:

- There will be no identification of individual cyclist participants or their individual riding data during the study or in the reporting of the results;
- Participants will have the study explained to them and provided with an information sheet and consent form;
- Participants will have the option to withdraw from the study at any time and this will be explained to them;
- Participants will be told that their journeys will be tracked by GPS but will have the option to switch off the device if they do not want particular journeys to be recorded;
- Participants will be able to remove their devices if they feel it poses a risk to their safety while riding; and
- Participants will be provided with contact details of researchers and can make contact at any time for support.

4.2 PDMD-Mk2 construction

The goal of this study was to collect data from 20 volunteer cyclists. In order to insure against the possibility that some devices may be faulty, stolen, or damaged, a total of 22 units were constructed. This was in addition to the two prototype units that were built for use during the validation process.

Each unit was tested by verifying that distance and GPS data was being recorded, along with a check to ensure that the recharging circuitry was working.

4.3 Data collection planning activities

In addition to the construction of the passing distance measure measurement devices, several planning actives were undertaken in order to ensure a smooth deployment, including:

- Preparing recruitment materials such as device instructions, participant information sheets, consent forms, and survey materials,
- Preparing information to be sent to participants as reminders during the data collection period,
- Organising travel to and from Canberra for researchers,
- Organising transport to and from Canberra for the PDMD units and other materials, and
- Preparation of tools and techniques for the efficient attachment and removal of PDMD units.

5 Data corruption problem

Once the construction of the PDMD-Mk2 units was complete, a number of cyclist participants were recruited, and the passing distance measurement devices were deployed in the ACT for a period of four weeks. However, after recovering the devices, it was discovered that the majority of recorded journey data had corrupt GPS coordinates. While lateral distance data was recorded successfully, the absence of GPS data meant there was no location or travel speed context for the participants' journeys during the data collection period. Unfortunately, this rendered the entirety of the recorded data unusable for the study and a secondary data collection phase was required. Each of the original cyclist participants were notified of the situation.

For the sake of completeness (in describing all activities undertaken during this project), and to acknowledge the contributions of the volunteer cyclist participants, assisting organisations, and research assistants, the original unsuccessful data collection phase is briefly described below. Then, the outcomes of an investigation into the cause of the data corruption problem are provided, followed by a description of how the problem was overcome in preparation for the secondary data collection phase.

Section 6 and Section 7 below describe the recruitment of participants and data collection activities for the secondary data collection phase. All data analysed and presented in the results was recorded exclusively during this secondary data collection phase

5.1 Unsuccessful data collection phase

The research team approached Pedal Power ACT for assistance with the recruitment of cyclists for the study. Pedal Power ACT advertised the study in their weekly "News Wheel" e-newsletter and on their Facebook page. Both advertisements were linked to an eligibility survey that was used to screen interested cyclists.

There was a good response to the advertisements and there were more potential candidates than devices available. Therefore, a set of criteria were used to select the cyclists who would be most suitable for participation in the study. The 21 selected cyclists were contacted and reconfirmed their desire to take part in the study. These participants were then provided with a participant information sheet, a study consent form, and invited to attend device fitting sessions. At the fitting sessions, each participant was provided with a participant information sheet and had the study explained to them again by one of the researchers. The participants confirmed their understanding and desire to take part in the study by signing a consent form. A passing distance measurement device was then attached to their bicycle and the operation of the device was explained.

At the conclusion of the data collection period the participants were invited to attend a device recovery session, where the PDMD was removed from their bicycle. Once all the devices were collected, each unit was opened and the microSD card was removed to extract the recorded data. After reviewing the recorded data, it became clear that there was an issue with corrupted GPS coordinates.

5.2 Identification of the cause

After informing the participants of the problem, an investigation was conducted to ascertain the cause and identify a solution.

It was discovered that there was an issue with the way that GPS signal data was being handled internally by the device's software. The devices were programmed in such a way that raw GPS data was being acquired and then converted “on-the-fly" to a more useable GPS format (time, date, latitude, longitude, heading, and speed). It appears that an issue occurred when an incomplete or 'bad' GPS message was acquired. In this circumstance, the conversion process failed in a manner that resulted in the most recent successfully converted GPS data being recorded over and over for the remainder of that journey. An incomplete GPS message is a relatively frequent occurrence, particularly when a GPS receiver is first switched on and acquiring a signal. This meant that the recorded data had consistently corrupt GPS information.

For unknown reasons this issue was not observed during any testing of the devices in Adelaide.

5.3 Resolution of the problem

After identifying the problem, the devices were reprogrammed so that the raw GPS signal data was recorded directly without any conversion. This solution required the recorded data to be post-processed, but this was a relatively minor task and provided confidence in the quality of the data being collected.

After updating the software on all the devices, they were tested to confirm that all GPS data was being recorded successfully, including any incomplete messages and all subsequent valid messages. These updated devices were then deployed in the secondary data collection phase described below.

6 Recruitment of participants

6.1 Advertisement and identification of cyclists

Once it was known that a secondary data collection phase was required, an invitation was sent to all the original participants, asking whether they would be willing to be involved in another round of data collection. Of the original 21 participants, 12 agreed to take part in the secondary data collection.

In order to recruit additional participants, Pedal Power ACT (the largest cycling organisation in the ACT) kindly advertised the study (for a second time) via their "News Wheel" e-newsletter (Figure 6.1), which has a mailing list of over 10,000 cyclists, and on their Facebook page (Figure 6.2). Both advertisements were linked to an eligibility survey, hosted online by SurveyMonkey (shown in Appendix A). The eligibility survey provided a description of the study and the criteria for participation. The survey then requested details that were used to filter out unsuitable candidates (who did not meet the participation criteria) and, further, to identify the most suitable cyclists from those that were suitable (see Section 6.2 below).

Within a 24-hour period, 26 cyclists had registered their interest by completing the eligibility survey and the recruitment was closed.

Figure 6.1
Pedal Power ACT e-newsletter promotion

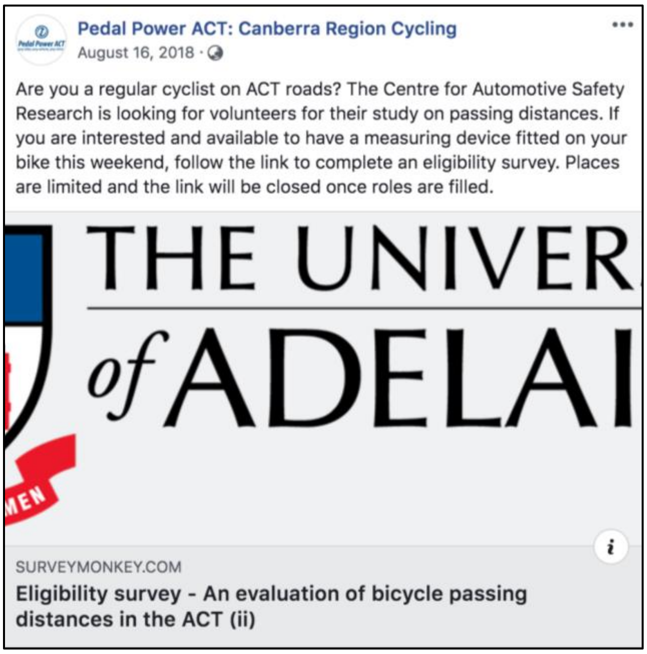

Figure 6.2
Pedal Power ACT Facebook promotion

6.2 Selection of participants

Two additional passing distance measurement devices were available for the secondary deployment, resulting in a total of 23 units. As such, 11 more participants were required in addition to the 12 original participants who had agreed to take part a second time.

The 26 cyclists who filled out the eligibility survey were prioritised based on three criteria to select the most suitable. The first criterion was to achieve a representative distribution of gender based on the National Cycling Participation survey for the ACT (Munro, 2017), which indicated that approximately 40% of riders were female. Next, was to seek an even distribution of riding around the state by selecting an equal number of participants who resided to the North and South of Canberra, based on reported postcode of residence. Finally, the candidates who reported travelling the highest average number of kilometres per week were given preference to maximise the amount of data collected.

After applying these criteria, the final group of 23 selected cyclists consisted of 8 females (35%) and 15 males (65%). There were 5 female cyclists who reported that they lived in the North (63%), with the remaining 3 reported as living in the South (37%). For the male cyclists, there were only 4 who reported that they lived in the North (27%), while 11 reported they lived in the South (73%).

The female riders reported average weekly riding distances of between 80 km and 300 km, with an average of 145 km. The male riders reported average weekly riding distances of between 50 km and 250 km, with an average of 150 km.

The final selected cyclists were contacted to reconfirm their desire to participate in the study and were then sent a participant information sheet, a study consent form, and details of upcoming device fitting sessions (see Section 7.1).

An additional five cyclists, who had not been selected but were the next most suitable, were also contacted to remain on standby in case of withdrawal by one of the participants. However, none of these standby cyclists were required.

7 Data collection

Data collection consisted of fitting the passing distance measurement devices to participants' bicycles, sending reminders and providing support during the 4 week data collection period, and then removing the devices.

The data collection period occurred between the weekend of 18/19 August and ended on the weekend of 15/16 September. This period was chosen in order to avoid school holidays and other major events, which may have affected driver behaviour or the amount of traffic on the roads in the ACT.

During this period there were 7 days of rain, as recorded in Canberra by the Bureau of Meteorology. There were three days with less than 1 mm of rain, two days with between 1 mm and 10 mm of rain, and two days with more than 10 mm of rain. The minimum and maximum temperature on each day of the data collection period, as recorded in Canberra by the Bureau of Meteorology, is shown in Figure 7.1.

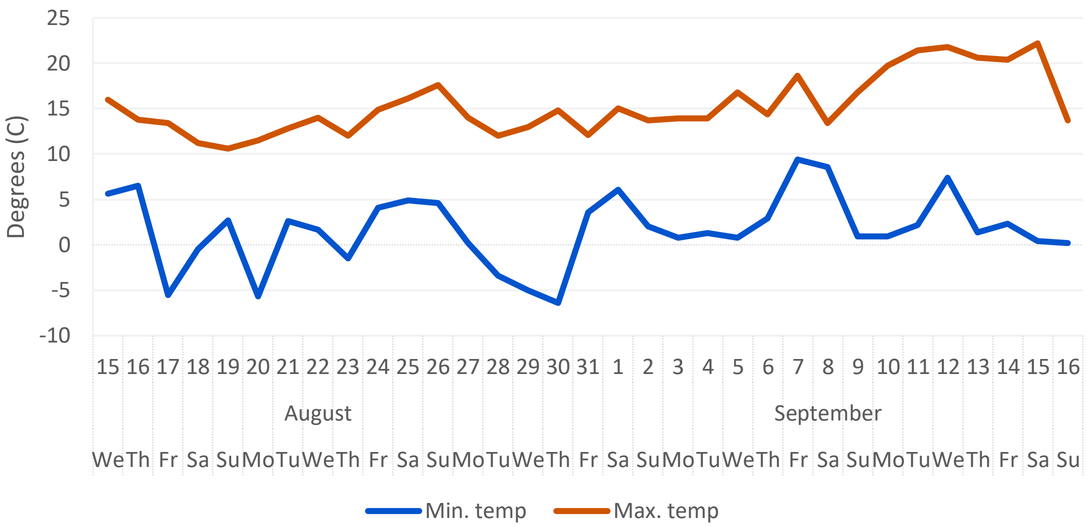

Figure 7.1
Minimum and maximum temperatures in Canberra during the data collection period

7.1 Fitting sessions

The 23 participants were invited to attend one of three fitting sessions on Saturday 18th August 2018 or three fitting sessions on Sunday 19th August 2018. The fitting session locations are shown below in Figure 7.2. Note that the Dickson Collage Carpark location was included in the earlier data collection but not for the secondary phase – it has been included in Figure 7.2 for completeness. Two of the previous participants were not able to come to a fitting session, so were sent a device to install themselves. These participants sent photos to the researchers to ensure they had correctly installed the device.

At the fitting sessions, each participant was provided with a participant information sheet and had the study explained to them by one of the researchers. The participant confirmed their understanding and desire to take part in the study by signing a consent form. A passing distance measurement device was then attached to their bicycle and the operation of the device was explained.

Each device was tested individually during the fitting sessions, to ensure meaningful data was being recorded. Some participants went for a short ride, and the recorded data was reviewed. No issues were detected.

Information on handle bar widths, bicycle type, self-reported cyclist type, participant age and number of years riding was also collected at the time of device installation.

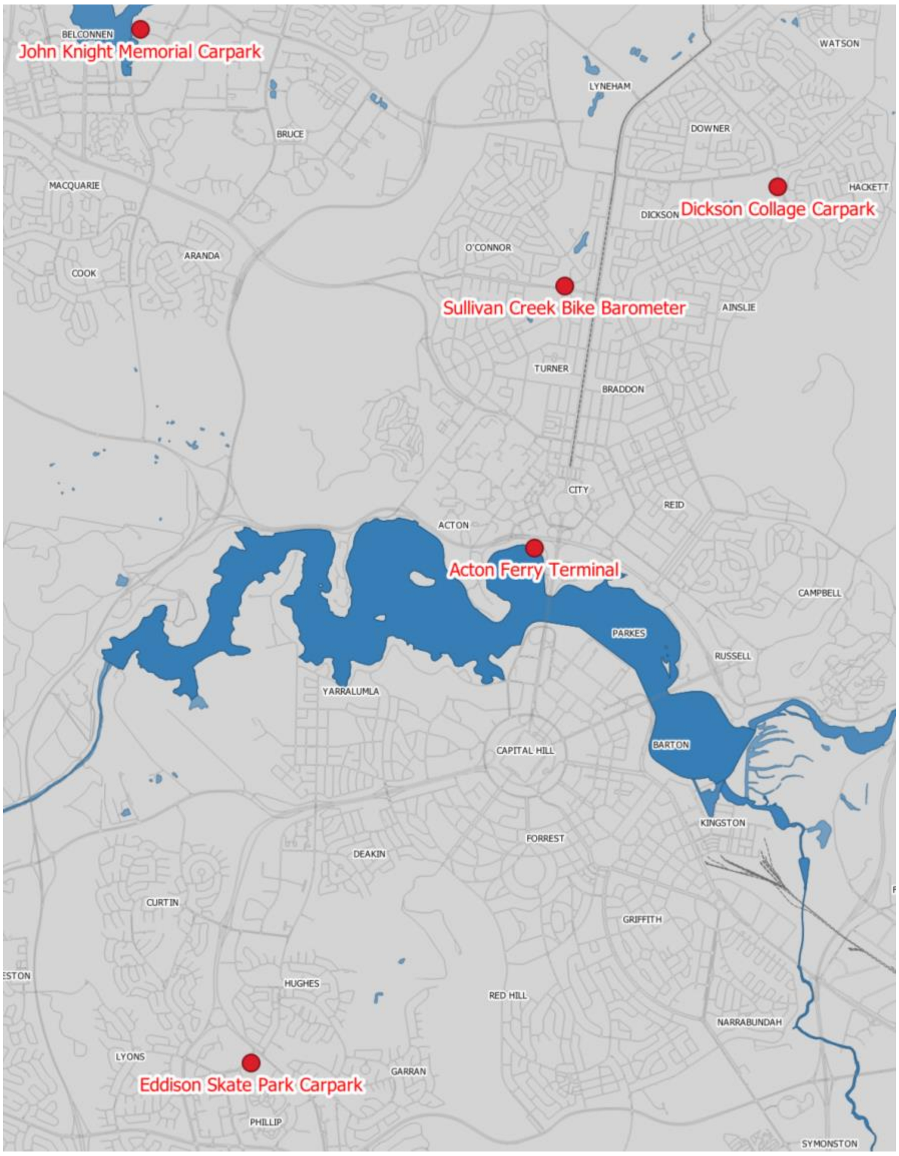

Figure 7.2
Location of PDMD fitting sessions

7.2 Participant reminders and support

At the start of each week of the study period, participants were contacted to remind them about the study, to switch the device on before each ride and switch the device off after each ride (to conserve battery life) as well as reminding participants to re-charge the device if required.

Only one participant reported a problem with their device. After some investigation it was discovered that the microSD card installed in their device was corrupt, and the participant was sent a replacement card with instructions on how to replace the card.

A few participants reported during the study period that temporary illnesses had limited their riding. Additionally, one participant reported sustaining a personal injury which halted their data collection 4 days. None of the participants withdrew from the study.

7.3 Device recovery

A final notification was sent to participants in the final week of the study period to remind them that the data collection phase was coming to an end and notifying them of the device collection sessions occurring on Saturday 15th and Sunday 16th of September 2018. The locations and time periods were consistent with the device deployment locations and times.

Some of the participants, who could not attend a device removal session, agreed to remove their devices themselves and return them to the Pedal Power ACT office. These devices were then posted back to the researchers in Adelaide. One participant, who was visiting Adelaide, brought their device back one week before the study ended. Ultimately, all 23 devices were recovered from the participants.

Eighteen participants agreed to fill-in an anonymous post-study survey (see Appendix B), which requested information on their cycling habits, cycling experiences, opinions on the metre passing laws, and experiences during this study. An analysis of the survey results is presented in Section 10.2.

Each of the 23 devices was opened, the microSD card was removed, and the recorded data was extracted for processing.

8 Data processing methods

8.1 Data storage

A custom SQLite database was designed to store the recorded GPS and passing distance data. Scripts were written in Python 3 to interact with the database.

The data from each of the deployed PDMD units were inserted into the database. Each data point was catalogued with a participant ID (anonymised) and a journey ID (i.e. a unique identifier for each separate trip made by the participant).

After filtering out unnecessary journeys, two processing streams were then undertaken: one using the GPS data (see Section 8.3), and one using the passing distance data (see Section 8.4).

8.2 Journey filtering

Some journeys were recorded while the device was charging, the device was accidently switched on when not moving, or in which no GPS data was collected. These journeys were automatically filtered by removing any instances in which there was no valid GPS data, or in which the diagonal distance of the box bounding the extent of the journey was less than 400 metres.

The remaining journeys were then individually reviewed manually. Journeys which were not captured by the automatic methodology, but were clearly not legitimate or did not have a good GPS signal, were discarded.

Journeys for which the distance sensors were reporting abnormal data were also manually removed from the database. Reasons for the reporting of abnormal data include faulty electrical connections between the distance sensors and the microprocessor, misalignment of the distance sensor (i.e. pointing the wrong way), or the distance sensor being covered or obscured. Notably, this process removed all journeys from two participants, who appear to have been provided with devices that developed a faulty connection between one of the distance measurement sensors and the microprocessor.

8.3 GPS data processing

8.3.1 Matching to roads

Raw GPS data have an accuracy of approximately 5 metres, and this is often degraded further by interference from nearby objects such as buildings or trees. As such, the latitude and longitude data reported by a GPS receiver will often drift from the true position by several metres. For example, a GPS receiver that was driven along a road may record a path that drifts to either side of the road throughout the journey.

Fortunately, with the knowledge that the GPS module was travelling along a road, the path can be corrected using digital map data. This is done by applying route analysis algorithms, commonly used in GPS navigation systems, to match or ‘snap’ the GPS data to the appropriate road or path section. The matching process involves identifying roads that are nearby the original GPS point, and running in the same direction as the GPS coordinates at the time that the data was recorded.

For each journey in the database, the GPS data was processed by a local installation of the Open Source Routing Machine (OSRM) route matching service (Project OSRM, 2019). The OSRM matching service outputs a new set of slightly shifted GPS data points that have been snapped to roads which are included in the Open Street Map (OSM) database (Open Street Map, 2019). This process enables the identification of the roads on which the cyclist was travelling during each journey.

The returned data also includes Open Street Map road identification numbers, which were utilised for determining road characteristics (see Section 8.3.4).

Not all GPS data could be matched to a road. There are two main reasons why the matching process may fail. First, that the cyclist was travelling on a road that was not contained within the Open Street Map database. Secondly, that the recorded GPS data point had simply drifted too far to be associated with the correct road.

GPS data (and the associated passing distance data) that could not be matched was not included in further analysis or the calculations of travel distance and travel time described below. At this stage, data that was recorded outside of the ACT was also removed from the analysis.

8.3.2 Estimating the travel distance

The travel distance between each matched GPS point was estimated using the Haversine function. For consistency with the data obtained for passing events (see Section 8.4.2), distances were only calculated where the travel speed was greater than 4 km/h. The total travel distance during a particular journey, or for a particular participant, was calculated by summing the estimate travel distances between all the relevant GPS points.

8.3.3 Estimating travel time

The travel time between consecutive matched GPS points was estimated as the difference in the timestamps contained within the GPS data. For consistency with the data obtained for passing events, time travelled was calculated only where the travel speed was greater than 4 km/h (see Section 8.4.2). The total travel time during a particular journey, or for a particular participant, was calculated by summing the estimated travel time between all the relevant GPS points.

8.3.4 Identifying road characteristics

The Open Street Map database stores road centreline data using line segments called 'Ways' which are made up of a number of nodes (GPS coordinates). A road may consist of one Way, which defines the entire length, or several Ways, that define separate segments. There is no specification for the length of a Way, which may be as short as a few metres or as long as several kilometres.

Each Way has a unique identification number and has a set of characteristics associated with it, including speed limit, road type, and the presence of a bicycle lane.

The output from the road matching process associates a Way identification number to each GPS point. This Way identification number can then be used to identify the road characteristics found at a particular GPS point. Using this process, the road details at each point (where matched data is available) along the recorded cyclist journeys can be explored.

8.3.5 Description of road characteristics

The Open Street Map database, and the road characteristic details contained within, are maintained and updated by an online community of contributors on a voluntary basis (crowdsourced). The database is only complete where contributors have provided data. Additionally, while there is an effort to check and monitor the accuracy of contributions, there is no guarantee that the information in the database provides a true representation of the real world.

The Open Street Map database provides a number of standardised categories that can be used to describe road characteristics. In this study, the highway, cycleway, and speed limit characteristics are utilised. The sections below describe each of these characteristics, along with the standardised categories and what they represent.

Road type

The highway characteristic describes the type of roadway using a hierarchical convention. A motorway is the highest class of road and is normally a restricted access major freeway. The road hierarchy then proceeds through trunk, primary, secondary, tertiary, residential, unclassified and service. Each road type also has an associated 'link road' which are allocated to the connecting sections between roads. For example, an off-ramp to a freeway would be represented by a motorway link. Figure 8.1 shows the highway classifications for the roads that were ridden during the study.

The Open Street Map Australian Tagging Guidelines (2019) describe how the various road types should be applied in an Australian context as shown in Table 8.1.

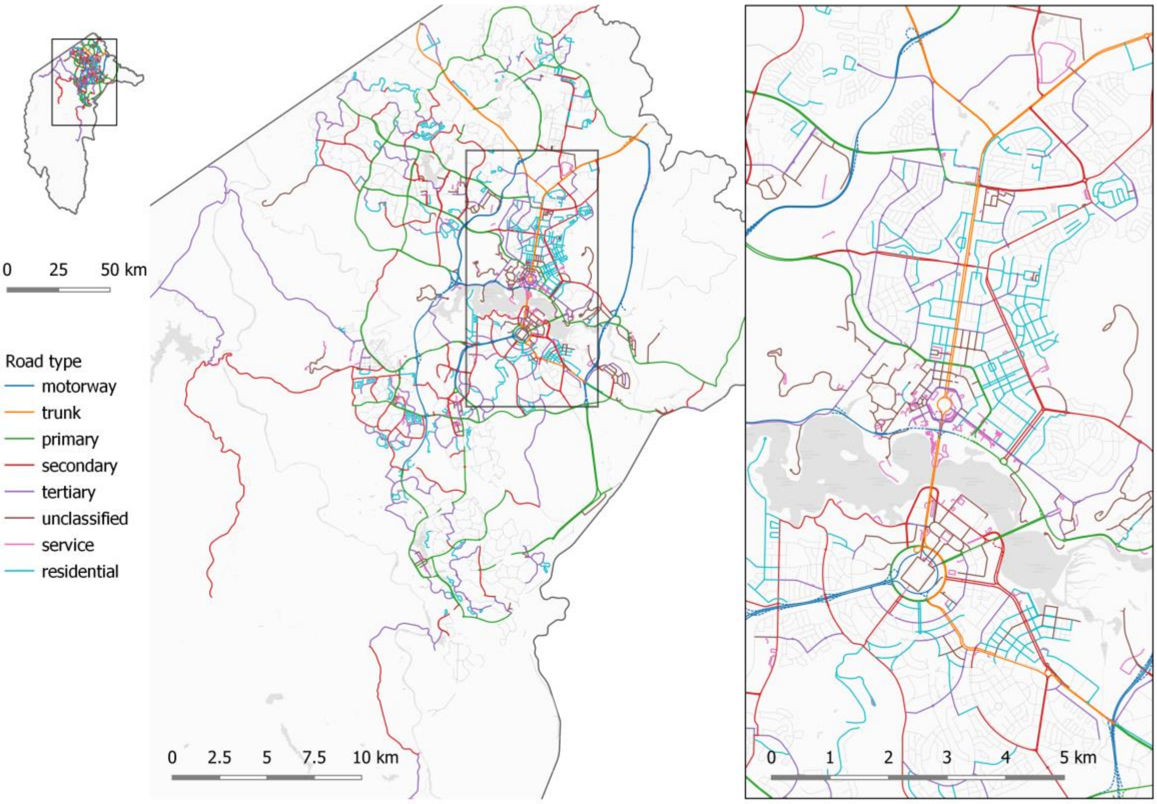

Figure 8.1
Highway classifications of roads in the Open Street Map database where GPS data was recorded (link roads shown as dashed lines)

Table 8.1
Open Street Map road type definitions according to the Australian Tagging Guidelines (2019)

Open Street Map road type	Australian Tagging Guidelines	
	Urban areas	Rural areas
Motorway	The metropolitan motorway network. 'M' classified roads in cities where they exist.	Motorways, freeways, and freeway-like roads. Divided roads with 2 or 3 lanes in each direction, limited access via interchanges, no traffic lights. Generally, 100 or 110 km/h speed limit. In states with the Alphanumeric system, these are 'M' roads if they are of freeway standard.
Trunk	"Met-roads" or 'A' classified roads in the cities where they exist, or other similar cross-city trunk routes in cities where they do not.	National highways connecting major population centres. In states with the Alphanumeric system, these are 'A' roads. 'M' roads which aren't of freeway standard are also classified as a trunk road. In other states, these are signposted with a white National Road shield, or a Green National Highway shield.
Primary	Other main cross city and arterial routes. 'B' classified roads in cities where they exist. Major connecting roads in larger rural cities.	State maintained roads linking major population centres to each other and to the trunk network. In states with the Alphanumeric system, these are 'B' roads. In other states, these are generally State routes signposted with blue shields.
Secondary	Major through routes within a local area, often connecting neighbouring suburbs.	District roads that are generally council maintained roads linking smaller population centres to each other and to the primary network. In states with the Alphanumeric system, these are 'C' roads.
Tertiary	Minor through routes within a local area, often feeders to residential streets.	Other roads linking towns, villages and Points of Interest to each other and the secondary network.
Residential	Residential streets.	Local streets found in and around cities, suburbs and towns as well as in rural areas.
Unclassified	Other streets. Not generally through routes.	Other named minor roads.
Service	Service and access roads, typically unnamed. Also used for small rear-access lanes.	Unnamed access roads. e.g. Entranceways and roads in parks, government properties, beach access etc

Bicycle lane

The presence of a bicycle lane was identified using the cycleway characteristic in the Open Street Map database. The convention for indicating the absence of a bicycle lane in Open Street Maps is to leave the cycleway characteristic blank. However, this presents some ambiguity, as it is unclear whether a contributor has reviewed the road and the cycleway characteristic has been deliberately left blank, or the road has simply not been reviewed. Despite this limitation, a bicycle lane was assumed to be absent on any road where the cycleway characteristic was blank. In some cases, the absence of a bicycle lane was explicitly indicated. The cycleway classifications for the roads that were ridden during the study are shown in Figure 8.2.

Figure 8.2
Cycleway classifications of roads in the Open Street Map database where GPS data was recorded

Speed limit

The speed limit characteristic indicates the maximum speed, in km/h, that vehicles can legally travel on the road. A number of roads do not have a speed limit listed in the database. Inspection of the roads that did not have a listed speed limit found they were predominantly secondary level highways or below, and are therefore likely to have speed limits of 50 km/h or 60 km/h. The speed limits on the roads that were ridden during the study are shown in Figure 8.3 below.

Figure 8.3
Speed limits on roads in the Open Street Map database where GPS data was recorded

8.4 Distance data processing

8.4.1 Filtering distance data

This study was predominantly interested in passing events from the lane directly adjacent to the cyclist. As such, recorded distances above 300 cm (a little less than a standard lane width) were filtered out prior to analysis. While it is acknowledged that some vehicles may elect to pass a cyclist at a distance greater than 300 cm, this circumstance would not necessarily be distinguishable from a vehicle travelling past a cyclist in an outside lane.

8.4.2 Identifying passing events

An algorithm, first used by Makenzie et al. (2017), was adapted to identify passing events in the data obtained during this study. A potential passing event was deemed to have occurred if the following criteria were met:

- The bicycle was moving faster than 4 km/h.
- The front and rear sensor reported the same constant value, within +/- 10 cm for at least three consecutive readings.
- There was no reading from either sensor for 0.5 seconds before and after the series of constant readings (i.e. the passing object appears and then disappears).

Consecutive passing events that were detected within 1 second of each other were combined into a single event.

The location of each potential passing event was obtained by matching it to its closest collected GPS data point. If this GPS data point had been matched to a road the passing event was processed further. Where the GPS data point had not been able to be matched, the passing event was excluded from further analysis.

The potential passing events were then classified as being either a legitimate event of interest, in which the cyclist was being passed by a vehicle, or an instance in which the cyclist was riding past a vehicle (usually when a vehicle was stopped in traffic or at an intersection).

By performing a cross correlation of all distance data collected between 2 seconds either side of the potential passing event, the phase difference between the data measured by the rear sensor and the front sensor could be measured. Through this process, the identification of which sensor first detected an object can be explored.

Three outcomes were possible as a result of the cross correlation. The first was a front-sensor-first phase difference which indicated that the cyclist was passing a vehicle. As these events were not of interest to the study, they were not analysed further. The second outcome was a rear-sensor-first phase difference, which indicated that the cyclist was being passed by a vehicle. These events were deemed to be legitimate passing events. Finally, the outcome of a nil phase difference could occur which indicated that both sensors detected the passing object at the same time. This outcome was usually the result of a cyclists being passed quite quickly and so were also included as legitimate passing events.

The passing distance of each of the legitimate events was then calculated by subtracting the cyclists' handlebar half-width (centre of bicycle to edge of handle bar) from the minimum distance measured by the sensors during the event.

8.4.3 Identifying non-complaint passing events

As the study was seeking to explore the prevalence and characteristics of passing events that were not compliant with the one metre passing rule, non-complaint passing events were explicitly identified.

All passing events were disaggregated by those that occurred on roads with a speed limit above 60 km/h (high speed roads) and those that occurred on roads with a speed limit of 60 km/h or below (low speed roads). A number of passing events occurred on roads where the speed limit was unknown. However, a review of these roads revealed they were predominately secondary level highways or below, and thus likely to have a speed limit of 50 km/h or 60 km/h. Therefore, passing events on roads where the speed limit was unknown were considered to have occurred on low speed roads.

A non-compliant passing event was determined to have occurred when the passing distance was less than 150 cm on high speed roads and when the passing distance was less than 100 cm on low speed roads.

9 Results - Participant passing distance data

There were 21 participants who recorded data which was deemed to be legitimate; that is, data showing that the device they were provided with was functioning correctly for at least one journey within the ACT.

In total, the participants recorded 465 journeys over the 4 week data collection period. The median number of journeys per participant was 17. The spatial distribution and frequency of journeys throughout the ACT road network is shown in Figure 9.1. There are several roads in the Canberra city centre that were traversed quite frequently (shown in red), while a number of local roads were traversed only once (shown in pale yellow).

Across all the journeys (where there was legitimate data and the bicycle was travelling faster than 4 km/h) the participants rode a total of 6,531 km over a total period of 271 hours. The median distance ridden per participant was 213 km and the median time spent riding per participant was 9.4 hours.

The travel distance and travel time for each participant is shown in Figure 9.2, along with the number of recorded journeys, as indicated by the size of the circular marker. It can be seen that there is a roughly linear relationship between travel distance and travel time (as would be expected), with a reasonable spread in the quantity of riding. When considering travel distance and number of journeys, it can be observed that there was also a spread in the length of journeys (i.e. a mix of some shorter and longer journeys).

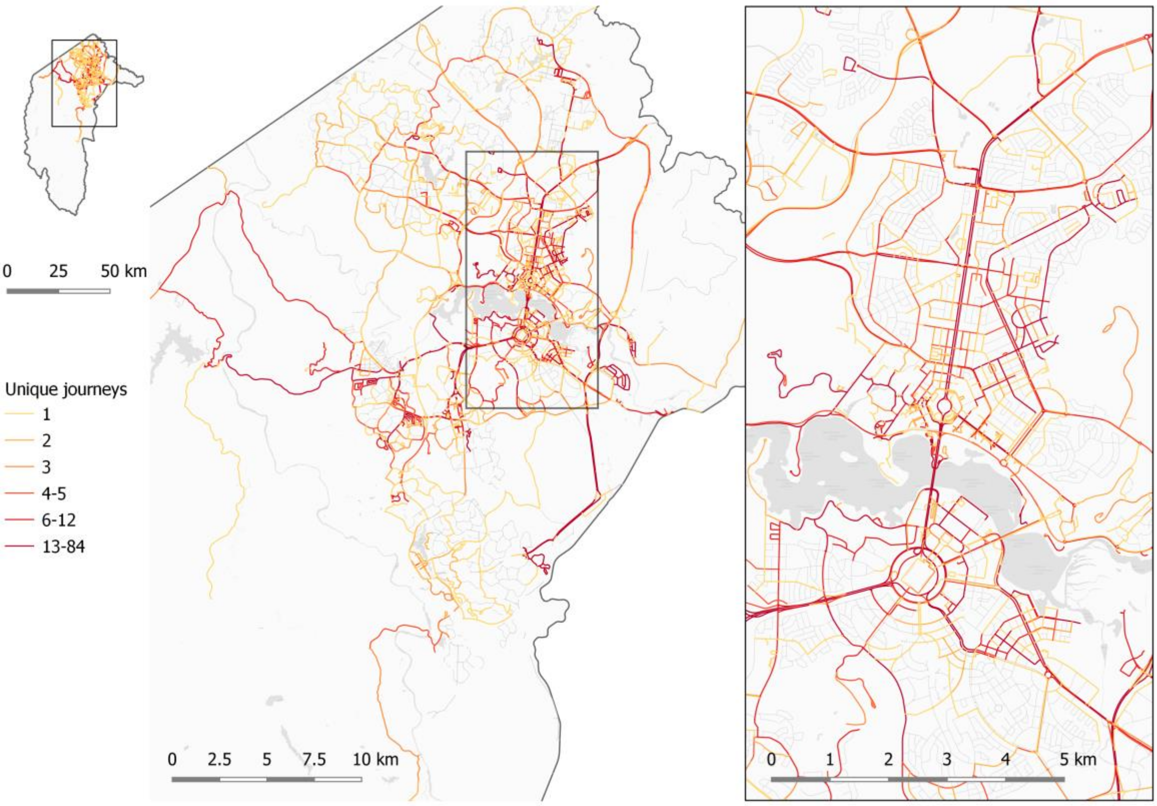

Figure 9.1
Number of journeys on roads in the ACT where data was recorded

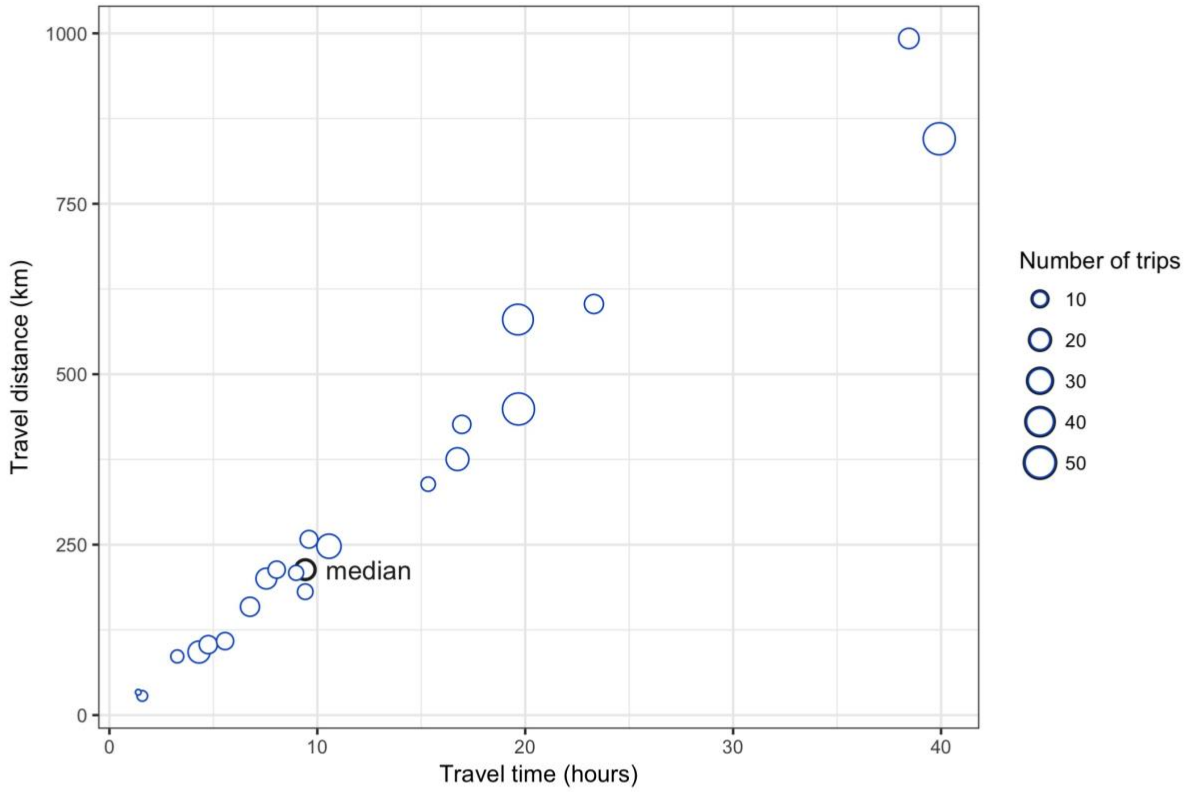

Figure 9.2
Travel distance, travel time, and number of journeys for each participant

The sections below present analyses of the passing events both overall and disaggregated by various categories. The median passing distance and the mean proportion of passing events that are less than 1.5 metres on high speed roads and less than 1 metres on low speed roads are presented. An individual road segment analysis, showing median passing distances and the mean non-compliance ratio across the parts of the ACT road network that were ridden during the study, is also presented.

9.1 Overall

During the 465 journeys there were 16,476 passing events identified. A histogram of the recorded passing distances, separated into those on high speed roads and low speed roads, is shown in Figure 9.3. Passing events that were not compliant with the ACT minimum passing distance law are highlighted in red. It is clear that the majority of passing interactions between cyclists and vehicles were compliant.

Overall, 1,502 of the recorded passing events were non-compliant. On high speed roads there were 1,349 non-compliant passing events. For low speed roads, there were 153 non-compliant passing events. Despite the larger proportion of non-compliant passing events detected on high speed roads (where the required passing distance is 150 cm), the majority of the passes were still at distances greater than 100 cm. This may be indicative that drivers are not aware of the requirements to provide a greater distance when passing cyclists on high speed roads.

It was encouraging to note that only a small number of passing events were detected at very close distances (less than 50 cm).

A summary of overall passing distances is shown in Figure 9.4. This figure and the subsequent figures below are presented in the following way. Vertically, the figure is divided to shown data from high speed roads and low speed roads separately. Horizontally, the figure is divided into two panels. The left panel shows a box plot, generated from the mean passing distance of all relevant journeys (the number of relevant journeys is shown to the left side of the panel). The thick vertical line indicates the median passing distance, the box indicates the extent of the interquartile range, the whiskers display the extent of the data within 1.5 times the interquartile range, and the crosses indicate data points considered to be outliers. The right panel shows the mean non-compliant pass ratio as a black dot, calculated from the mean non-compliant pass ratio of all relevant journeys. The extent of the relevant journey data from the 5th percentile to the 95th percentile is shown by the blue line.

In Figure 9.4, the median passing distance is shown to be 197 cm on high speed roads and 185 cm on low speed roads. There were 328 and 400 relevant journeys on these roads respectively. The mean non-compliant passing ratio was 11.2% on high speed roads and 2.7% on low speed roads. There was a large variance in the measured non-compliant passing ratios from the individual journeys, particularly for those on high speed roads.

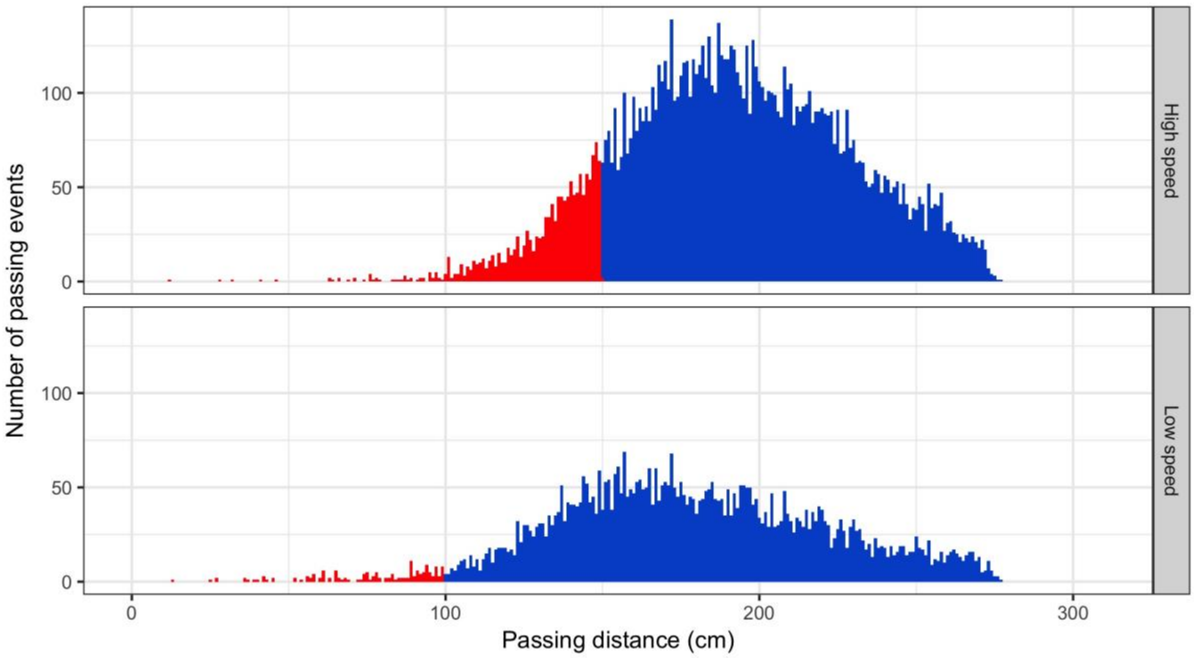

Figure 9.3
Histogram of passing distances for all passing events (non-compliant passing events shown in red)

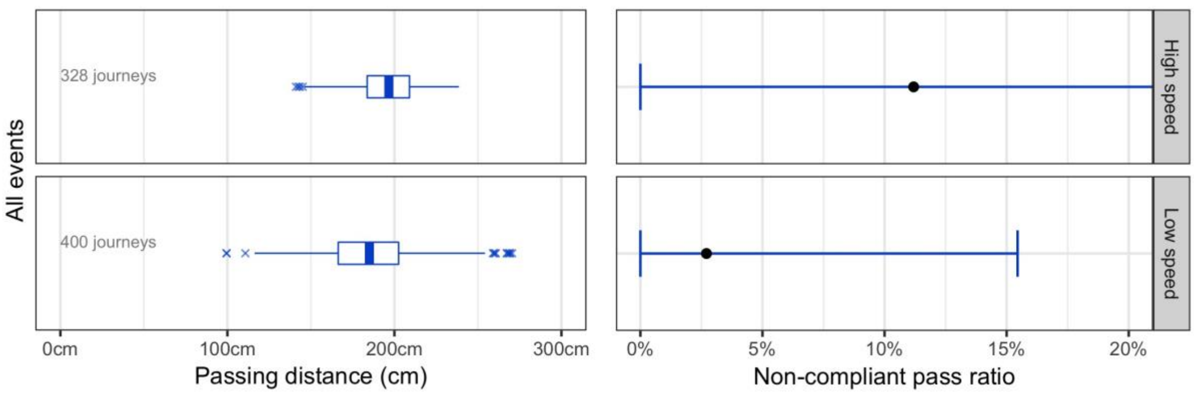

Figure 9.4
Passing distance summary for all passing events

9.2 By participant

A summary of the passing distances experienced by each participant is shown in Figure 9.5. It is clear that there is considerable variation between the participants. There is a significant spread in the number of journeys undertaken by each participant, the median passing distance experienced during those journeys, and the mean proportion of non-compliant passes experienced. The median passing distance ranged from a minimum of 178 cm to a maximum of 221 cm on high speed roads, and a minimum of 159 cm to a maximum of 233 cm on low speed roads. On high speed roads the proportion of non-compliant passes ranged from a minimum of 2.2% up to a maximum of 26.2%. On low speed roads the maximum non-compliant pass ratio was 7.9%, while there were several participants who did not experience any passing events within 100 cm.

This large spread in the experiences of the participants is likely to be a result of both their individual riding styles and characteristics, as well as the roads and routes they chose to travel during the study.

9.3 By road type

A summary of passing distances, split by road type, is shown in Figure 9.6. On high speed roads, those classified as motorways, motorway links, and secondary roads were found to have the furthest median passing distance, at around 206 cm. Trunk roads had the lowest median passing distance on high speed roads, at 182 cm. Trunk roads were also found to have the lowest median passing distance on low speed roads, at 160 cm. Low speed primary and secondary roads had greater median passing distances of 179 cm and 186 cm respectively. Even greater median passing distances, ranging between 192 cm and 200 cm, were found for low speed tertiary, unclassified, residential, and service roads.

On high speed roads, the mean non-compliant pass ratio was lowest on motorways, followed by primary and secondary roads. High speed trunk roads had the highest mean non-compliant pass ratio. The mean non-complaint pass ratio was generally similar on low speed trunk, secondary, and tertiary roads, but higher on primary roads.

It was not feasible to exhaustively review all the roads where data was collected in this study, but it is presumed that there are significant differences in the infrastructure and traffic flows on each road type which account for the differences in the median passing distances and proportion of non-compliant passes. Motorways and primary roads may provide greater lateral space for cyclists to position themselves away from the traffic or enable vehicles to provide a greater distance when overtaking. The lateral space on trunk, secondary, and tertiary roads may be constrained by urban infrastructure like sidewalks and buildings. Additionally, high traffic density may decrease the lateral separation between vehicles which can result in a reduction in the space provided to cyclists when passing.

9.4 By presence of bicycle lane

Passing distances in the presence or absence of a bicycle lane are summarised in Figure 9.7. On high speed roads bicycle lanes appeared to increase the median passing distance to 197 cm, compared with 191 cm on roads without bicycle lanes. On low speed roads the opposite was observed, with the median passing distance on roads without a bicycle lane decreasing from 189 cm to 178 cm on roads with a bicycle lane. Bicycle lanes on both high speed and low speed roads appeared to be associated with a decrease in the mean non-compliant pass ratio.

The lower median passing distance for bicycle lanes on low speed roads is likely to be due to narrower lanes in built up urban areas, forcing cyclists and vehicles to travel more closely. Despite this, it was encouraging to note that the mean non-compliant pass ratio was lower where there were bicycle lanes.

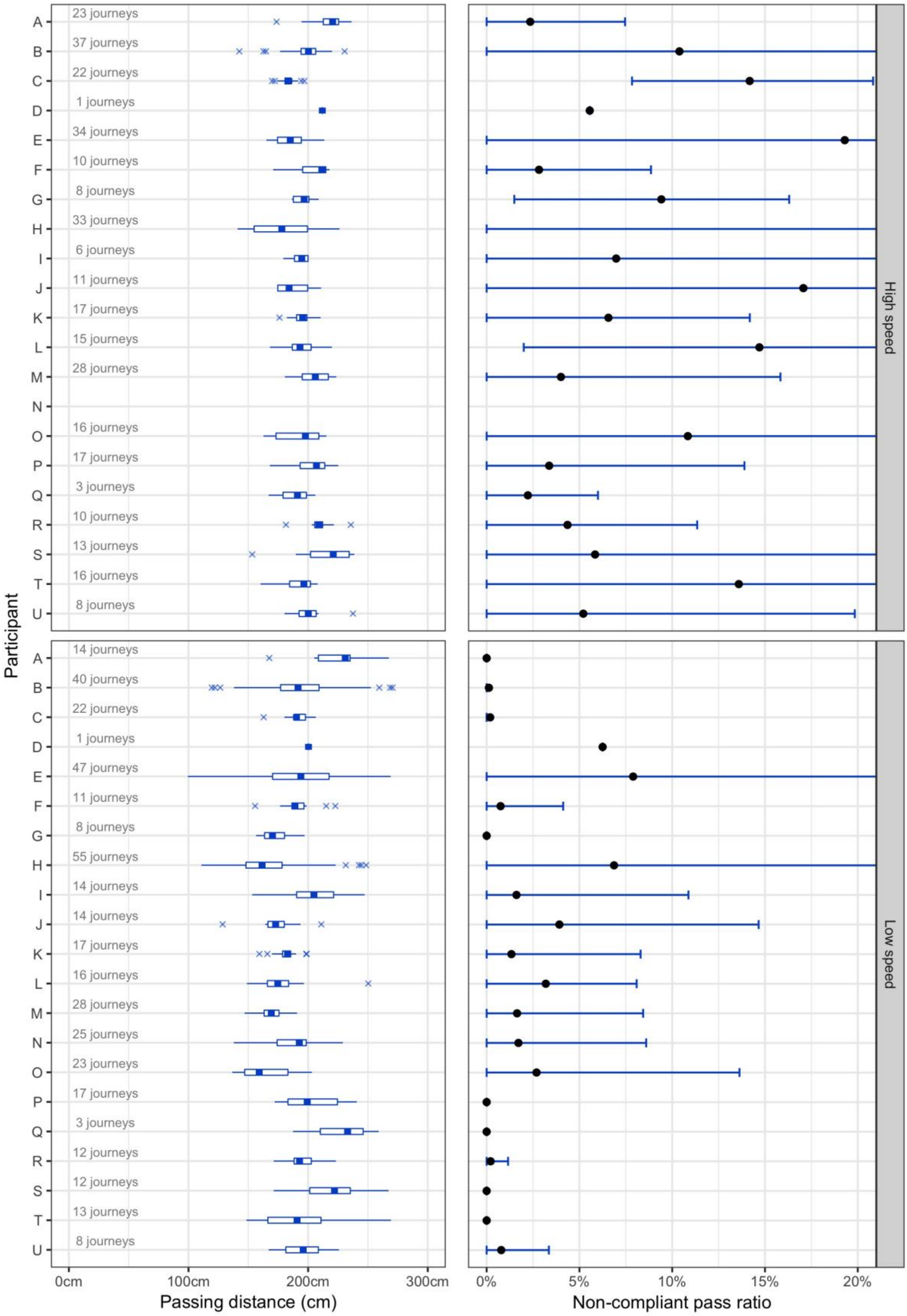

Figure 9.5
Passing distance summary, disaggregated by participant

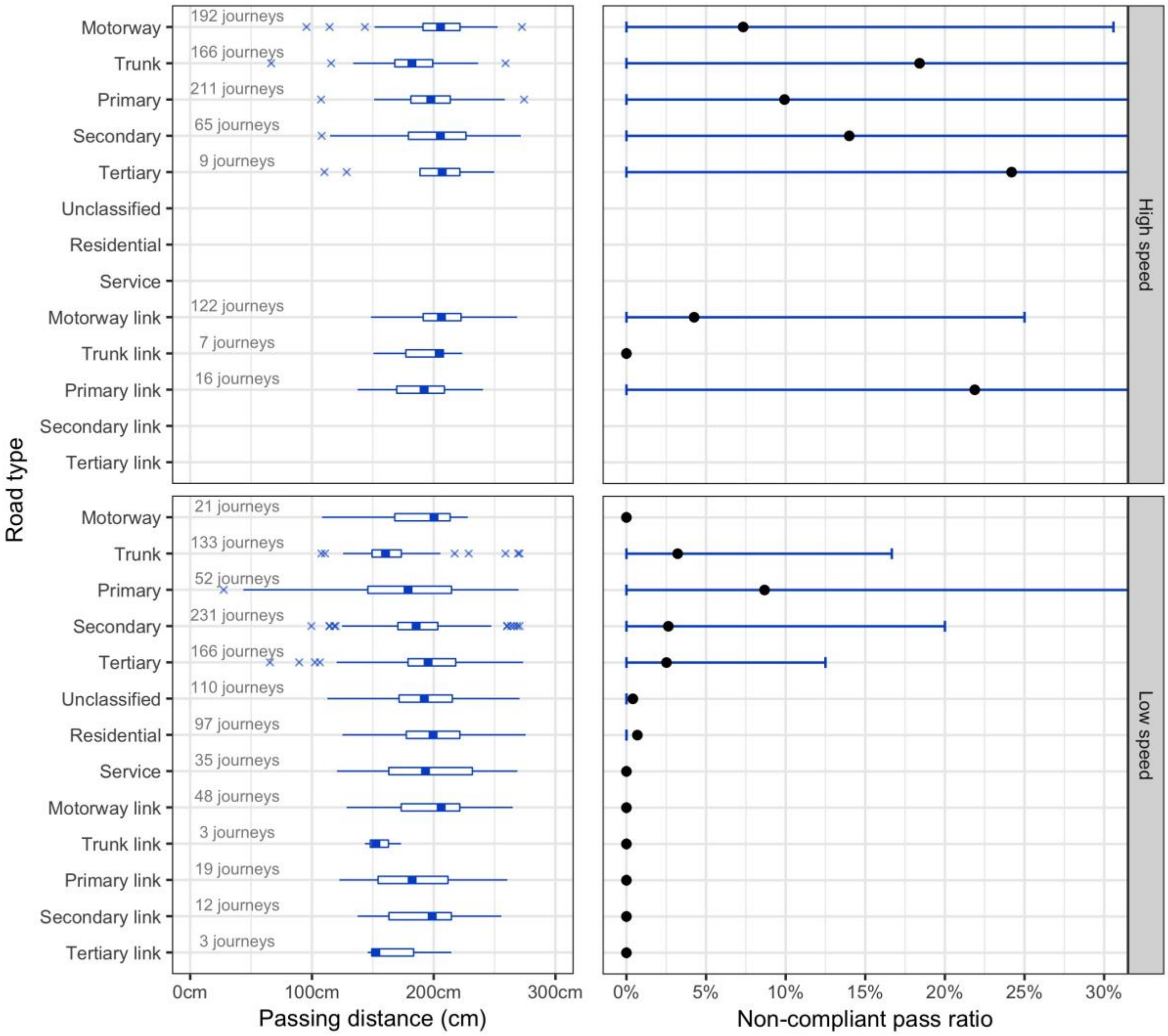

Figure 9.6
Passing distance summary, disaggregated by road type

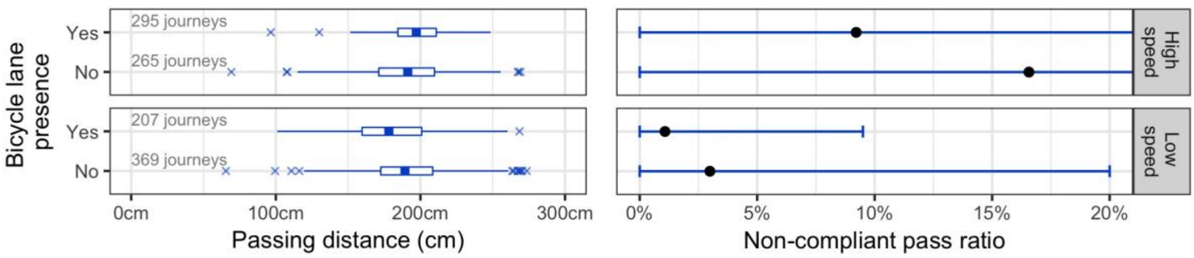

Figure 9.7
Passing distance summary, disaggregated by bicycle lane

9.5 By speed limit

A summary of the passing distances recorded on roads with various speed limits is shown in Figure 9.8. On high speed roads, the median passing distance tended to increase for higher speed limits. The lowest median passing distance was 180 cm on 70 km/h roads. On low speed roads the lowest median passing distance was 177 cm on 60 km/h roads. Roads with a speed limit of 50 km/h or less were found to have a median passing distance in excess of 210 cm. The mean non-compliant pass ratio tender to be higher on roads where the median passing distance was lower and vice versa. Although there was a large variance in the mean non-compliant pass ratio for each of the individual journeys.

9.6 By day of week and time of day

The passing distance summary for days of the week, shown in Figure 9.9, reveals that there is little difference in the median passing distance observed on each day. However, on low speed roads there was a tendency for the median passing distance to be higher (and the mean non-compliance ratio to be lower) on weekends compared to weekdays.

A summary of the passing distances recorded during riding at different hours of the day is shown in Figure 9.10. There was a tendency for the median passing distance to be lower during times associated with peak volumes of traffic particularly during the morning and afternoon commuting periods.

9.7 By location

The median passing distance detected along the various segments of the ACT road network that were ridden along during the data collection period is shown in Figure 9.11 with coloured lines. Only road segments upon which at least 5 unique journeys were ridden have been shown to ensure more confidence in the calculated median passing distance. The median passing distance for high speed roads and low sped roads have been identified separately.

In general, median passing distances were relatively high across the ACT network, with many segments calculated to have a median distance of greater than 160 cm. However, there were a number of segments with lower median passing distances, particularly within the Canberra CBD area. Several road segments were identified with a median passing distance of less than 160 cm (red, orange, and dark blue lines).

In Figure 9.12 the calculated mean non-compliant pass ratio throughout the ACT road network is shown with coloured lines. Again, to ensure some confidence in the results, only road segments upon which at least 5 unique journeys had been ridden were shown. The mean non-compliance pass ratio is displayed separately for high speed roads and low speed roads.

The majority of road segments were determined to have a mean non-compliance ratio that was relatively low; less than 5% on high speed roads or less than 2% on low speed roads. Higher non-compliance ratios were identified on a small number of road segments. A few of these segments had alarmingly high non-compliance ratios; greater than 10% on high speed roads (orange and red lines) and greater than 4% on low speed roads (dark blue or purple lines). However, it is likely that there was a large variance in the experience of cyclists who rode these road segments, and these findings should be interpreted with care.

Tables 9.1 and 9.2 present the ten road segments with the lowest median passing distance and highest mean non-compliant pass ratio respectively.

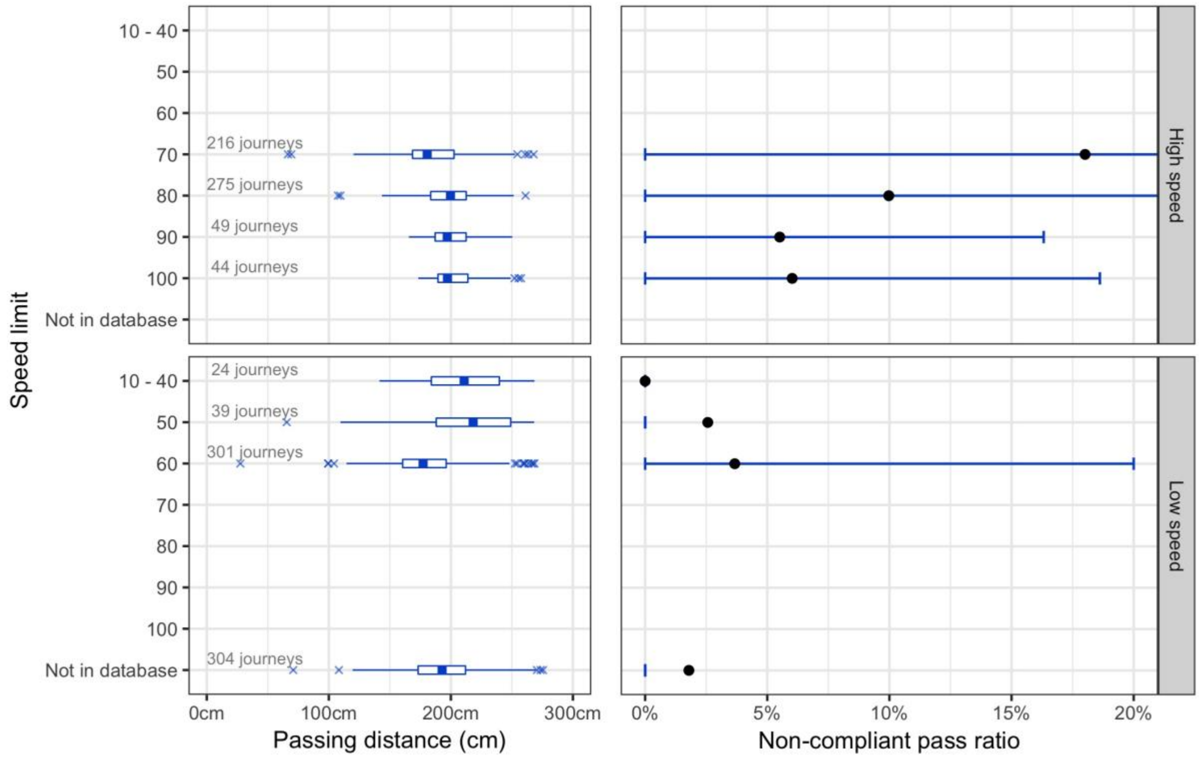

Figure 9.8
Passing distance summary, disaggregated by speed limit

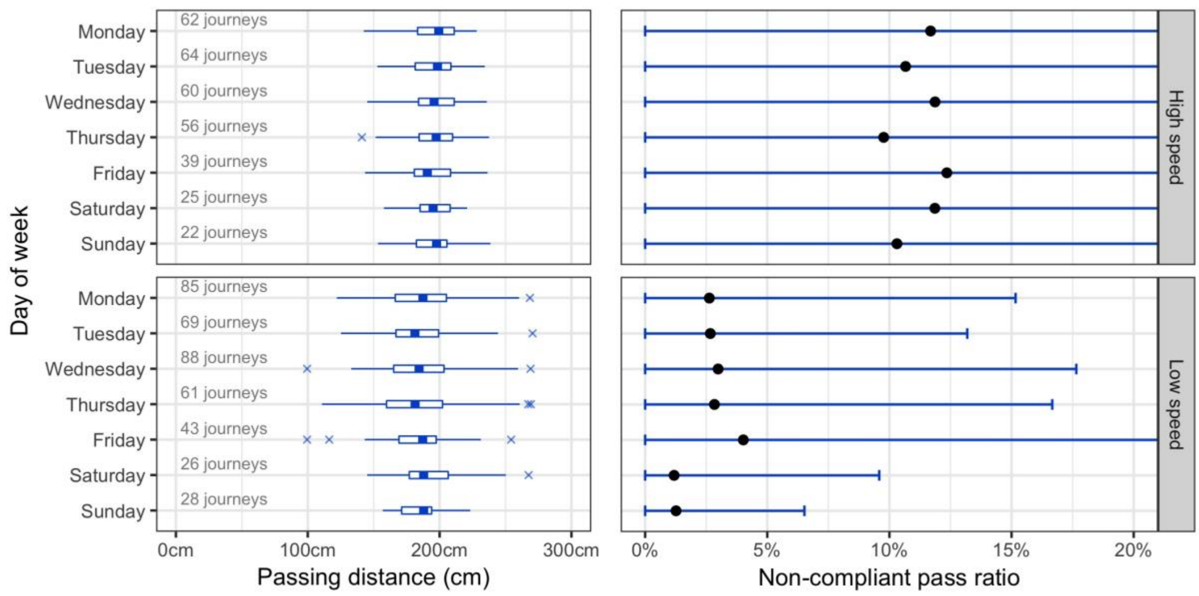

Figure 9.9
Passing distance summary, disaggregated by day of week

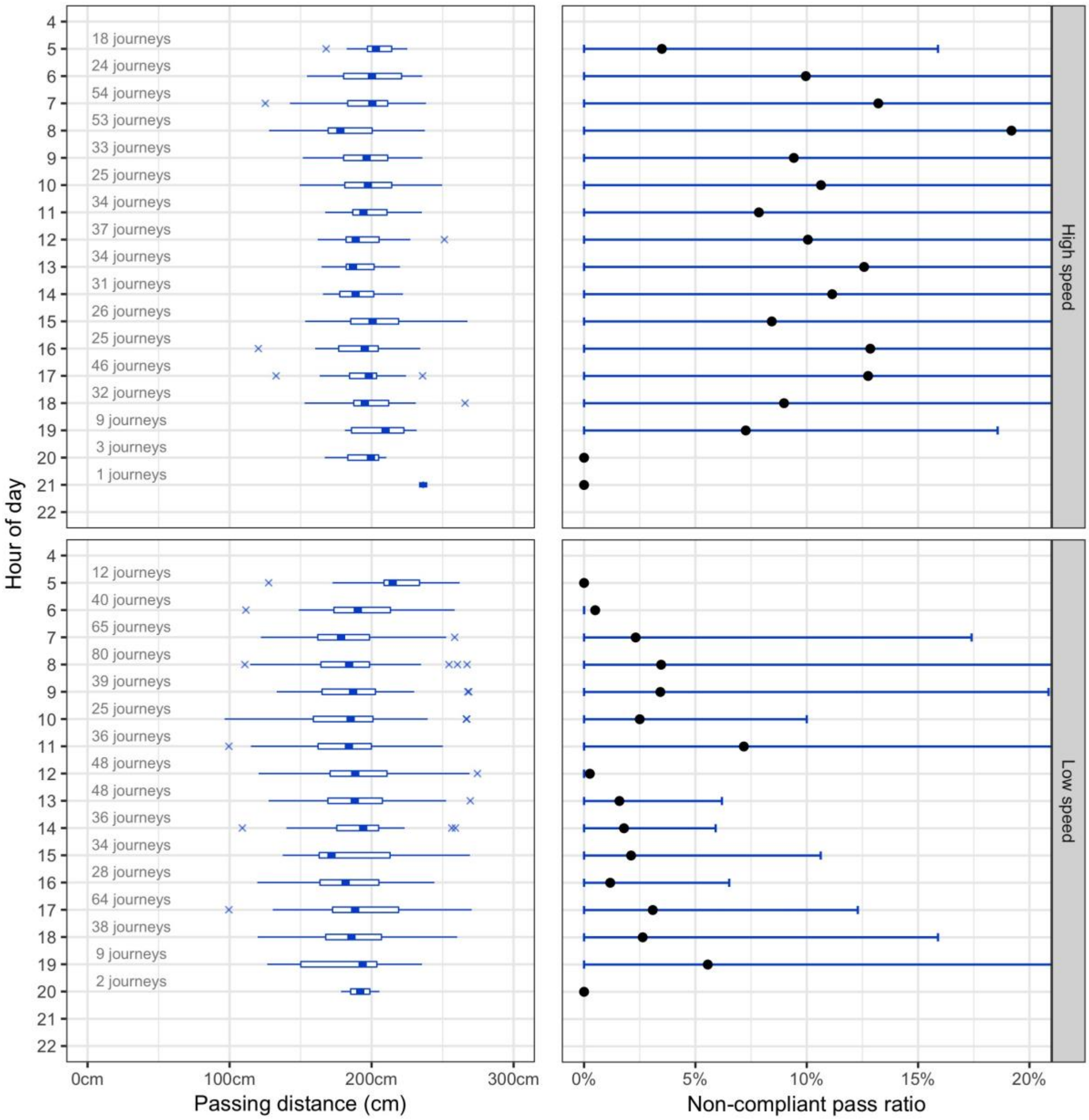

Figure 9.10
Passing distance summary, disaggregated by hour of day

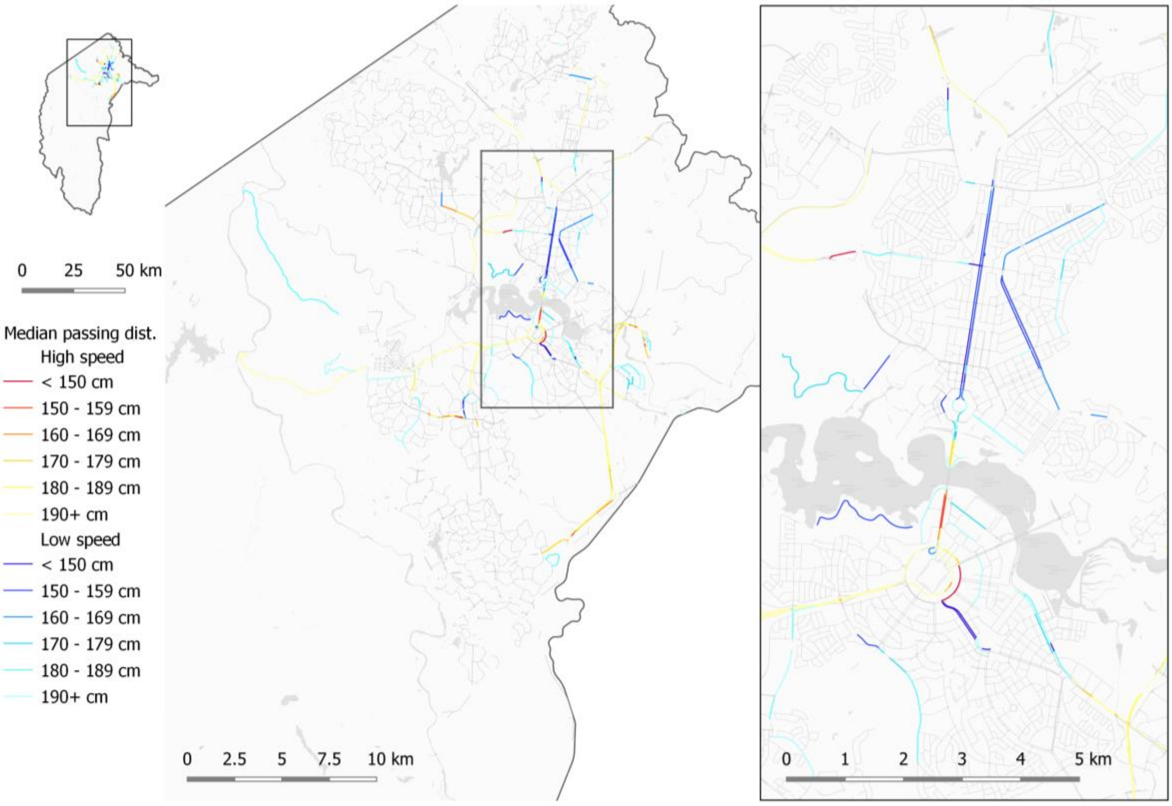

Figure 9.11
Median passing distance at locations with data from 5 or more journeys

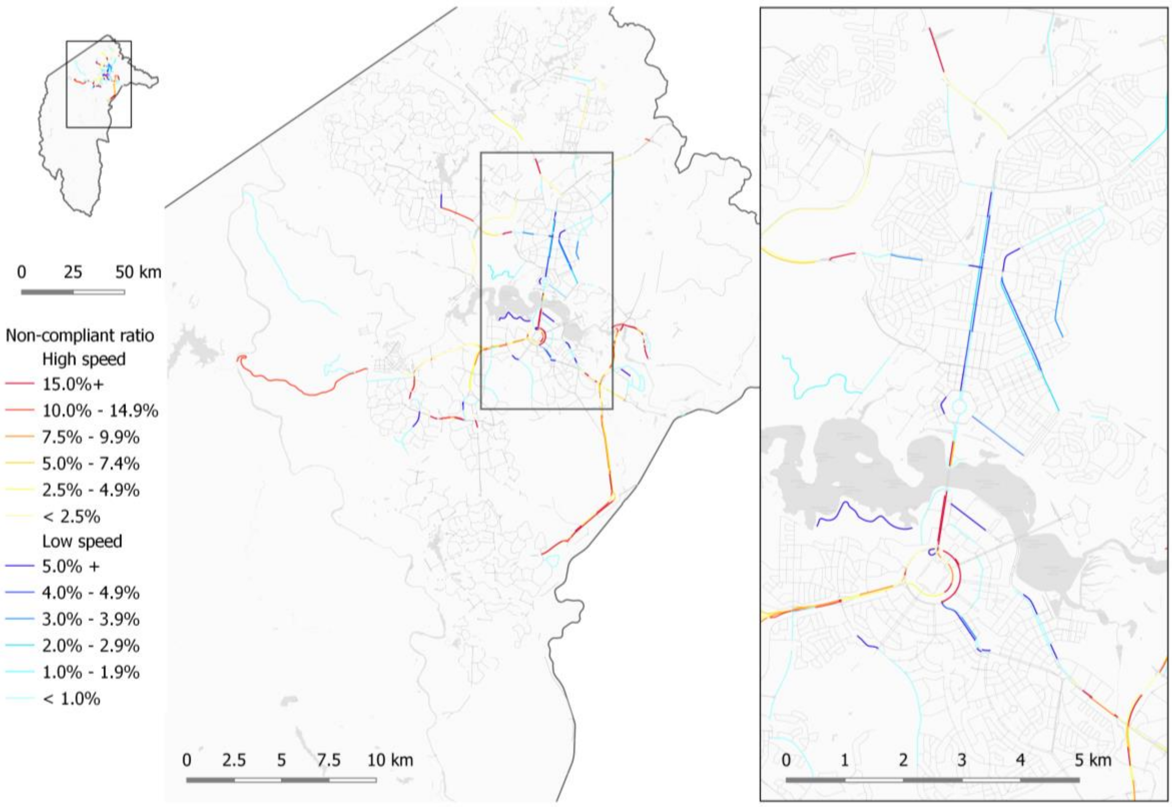

Figure 9.12
Mean non-compliant pass ratio at locations with data from more than 5 journeys

Table 9.1
Road segments with the closest median passing distance, with data from more than 5 journeys

Rank	Median passing distance (cm)	Road segment name	Road segment description
1	78	Canberra Avenue	Eastbound past Manuka Oval
2	106	Northbourne Avenue	Northbound for 10m past Rudd St.
3	117	State Circle	Eastbound between Canberra Ave. and Sydney Ave.
4	128	Canberra Avenue	Northbound between Manuka Circle and Dominion Circuit
5	137	Northbourne Avenue	Northbound between Alinga St. and Rudd St.
6	138	Melrose Drive	Northbound for 100m from Worgan St. onward
7	139	Canberra Avenue	Eastbound between State Circle and National Circuit
8	139	Northbourne Avenue	Northbound between Barry Drive and Elouera St.
9	140	Wentworth Avenue	Southbound between Cunningham St. and Burke Crescent
10	141	Melrose Drive	Northbound between Worgan St. and Launceston St.

Table 9.2
Road segments with the highest mean non-compliant pass ratio, with data from more than 5 journeys

Rank	Mean non-compliant pass ratio	Road segment name	Road segment description
1	75.9%	State Circle	Eastbound between Canberra Ave. and Sydney Ave.
2	75.0%	Canberra Avenue	Eastbound past Manuka Oval
3	70.0%	Hindmarsh Drive	Eastbound between Eggleston Crescent and Melrose Dr.
4	56.3%	State Circle	Northbound between Sydney Ave. and Brisbane Ave.
5	56.3%	Pialligo Avenue	Westbound for 100m approaching Beltana Rd.
6	51.7%	Fairfax Street	Westbound between Dryandra St. and Barry Dr.
7	51.1%	Commonwealth Avenue	Northbound between Kaye St. and Flynn Dr.
8	47.9%	Hindmarsh Drive	Westbound for 200m approaching Eggleston Crescent
9	47.6%	Northbourne Avenue	Northbound for 10m past Rudd St.
10	45.2%	State Circle	Northbound between Brisbane Ave. and Kings Ave.

10 Results – Participant survey data

An analysis of the participant data collected during the study is presented below in two parts. First, the demographic details collected from the 23 participants are provided. This data enables an understanding of the types of cyclists who took part in the study. The second part presents the responses to the post-study survey which was filled out by 18 of the participants. These responses outline the participants' experiences with riding, their thoughts on passing distances and passing laws, their riding and close passing experiences during the study period, and any opinions on the device that was attached to their bicycle.

10.1 Demographic data

Participants reported riding between 50 and 300 kilometres per week, with the average around 150 kilometres per week (*SD* = 57.0). Of the 23 respondents who gave their age, the youngest was 31 and the oldest 69 years of age, with a mean age of 49 years (*SD* = 9.9). There were 19 participants who stated they rode road bikes, with three riding flat-bar road bikes, and one a mountain bike. The type of cyclist each of the participants identified as (work commuter, weekend/recreational, or exercise) is shown in Figure 8.1 below.

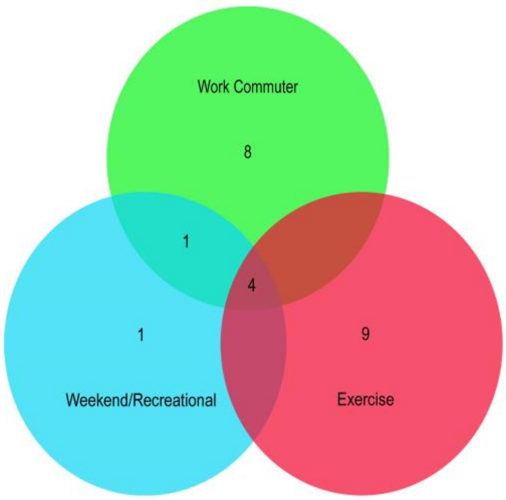

Figure 8.1
Participant self-reported cycling type

10.2 Post-study survey

10.2.1 Cycling habits and experience

Figure 8.2 shows that most participants had high levels of confidence when riding on roads with traffic (17 responses).

Most of the participants indicated they generally wore 'cycling clothes' when riding and one indicated they wore 'sport clothes'. Eleven participants stated they wore high visibility clothing whenever riding, compared to seven who stated they did not. All participants reported that they had lights on their bikes (one had rear lights only), with fourteen cyclists indicating they have them operating day and night, while four only activated their lights at night (two of whom did not wear high visibility clothing either).

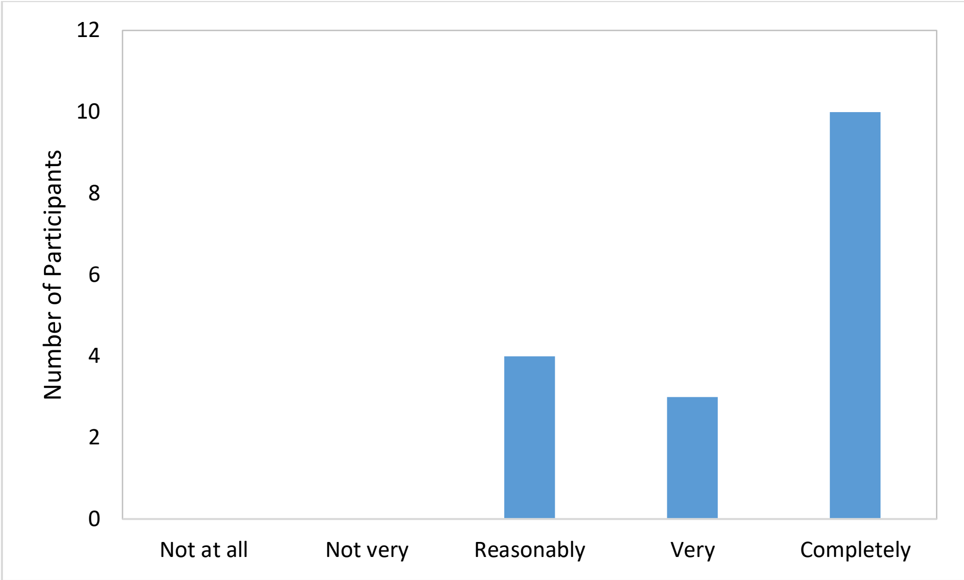

Figure 8.2
Perceived level of confidence when riding on roads with traffic

When asked "how safe do you feel when you ride your bike", most cyclists indicated they generally felt safe (as shown in Figure 8.3) but acknowledged that there were times when they felt unsafe. All respondents gave examples where they felt unsafe, particularly:

- On narrow roads with no shoulder or verge (especially high speed, country roads),
- On roads without bike lanes,
- On roads with high traffic volumes,
- In situations where aggressive drivers are deliberately being intimidating,
- When cars pass too closely,
- Encountering vehicles turning left in front, and
- Encountering vehicles parked in bike lanes.

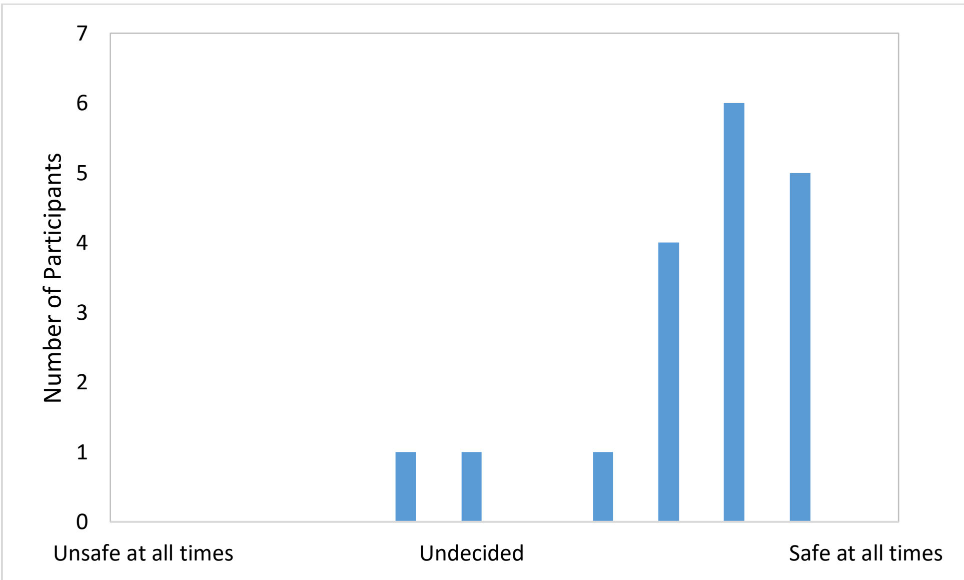

Figure 8.3
Perceived level of safety when participants ride their bikes

10.2.2 Passing distances

Participants generally had a medium level of concern about the distance at which motorist pass them when cycling, with most indicating that it 'sometimes' concerns them. Most also indicated 'sometimes' or 'rarely' for how often vehicles pass too close to cyclists, as shown in Table 8.1.

Table 8.1
Responses (number of participants) to statements about passing distances

Question	Never	Rarely	Sometimes	Often	Always
The distance at which motorists pass me when cycling concerns me.	0	3	12	3	0
How often do you perceive that vehicles pass too close to cyclists?	0	6	8	4	0

When asked if there were particular types of vehicles that regularly pass too close, the following responses were given:

- Generally, buses were noted as being most problematic (8 mentions)
- Trucks or large vehicles were also mentioned frequently (5 mentions)
- Trade workers/utility drivers (5 mentions)

Participants were also asked to specify how much distance they provide when passing cyclists and they reported the following:

- 0.5 metres to 1 metre, depending on their confidence (1 mention)
- At least 1 metre or more (3 mentions)
- At least 1.5 metres or more (7 mentions)
- At least 2 metres or more (6 mentions)
- Rarely drive, but give lots of space (1 mention)

10.2.3 Bicycle passing laws

In terms of the participants' attitudes towards bicycle passing laws, Table 8.2 shows that most liked the idea. However, twice as many participants thought further measures were also needed compared to those who thought passing laws would address the issue. Opinions were divided as to whether one-metre was adequate. Half of the participants thought a distance of one-metre was adequate, while the other half thought one-metre was still too close. All participants thought that these laws would make riding safer for cyclists and indicated that they personally would feel safer. However, twice as many participants thought it would be difficult to enforce bicycle passing laws compared to those who felt that it would not be difficult to enforce.

Table 8.2
Agreement (number of participants) with statements about bicycle passing laws

Question	Strongly disagree	Disagree	Agree	Strongly agree
I like the idea of bicycle passing laws	0	0	1	17
Bicycle passing laws would not address the issue, other or further measures are needed*	0	6	10	2
A one-metre passing distance is still too close	0	9	7	2
Bicycle passing laws would make riding safer for bicyclists	0	0	10	8
I would personally feel safer because of bicycle passing laws	0	0	11	7
I think it would be difficult to enforce bicycle passing laws	2	4	9	3

* One participant added that more enforcement was required because there are no consequences

The twelve participants who agreed or strongly agreed that the laws would be difficult to enforce were asked to specify why. They provided the following responses:

- As a cyclist you have to provide evidence.
- Cyclists need evidence and police are rarely around or equipped to prove an infraction.
- Effort with a bike + car/delay to enforcement.
- Hard to monitor.
- Hard to objectively measure.
- I have heard that many police are not interested in protecting cyclists and would rather them not on the road. Incidents occur quickly and are difficult for police to detect. Passing distances are only estimates made by people therefore not likely to be held up in court.
- I've never heard of anyone being booked for passing too close.
- It is his word over my word.
- It seems like it would be difficult to capture proof of bicycle passing distance and it may not even be apparent to police from the perspective of their vehicles.
- Police just need to do their jobs.
- Requires police to be observing cyclists.
- Very few police on the roads.

10.2.4 Riding frequency or behavioural change as a result of the study

Eleven participants indicated they rode the same amount as normal, although one participant had a week long break. Seven participants indicated they rode less than normal, mainly due to illnesses, and one participant sustained an injury resulting in only 4 days of data being collected. Most participants indicated that they rode the same routes as normal, with two indicating they rode different routes because of training reasons, and one stating they deliberately rode different routes to collect data for the study.

Twelve participants indicated that their riding behaviour did not change because of the study. Four participants indicated they rode more on roads than they normally would and two indicated they had an increased awareness of cars passing them. One cyclist indicated that waiting for a GPS lock on the device delayed their ride start time each time.

10.2.5 Self-reported number of close passes

One of the questions presented to the participants at device collection was “Number of perceived close passes during the study”. Only two people self-reported no close passes, nine participants reported being passed closely between one and five times, four reported being passed too close five to ten times. One person indicated they were passed too close 20 times, one indicated they were passed too close on every ride they went on, and one participant just indicated that the Northbourne Ave Road works led to many close pass events (did not specify a number).

10.2.6 Troublesome or annoying issues with the device and suggested improvements

Table 8.3 summarises the experience riders had with the device.

Table 8.3
Participants' agreement (number of participants) with statements about their experiences in the study

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The device was annoying	9	9	0	0	0
The device was distracting	13	5	0	0	0
The device interfered with the normal riding my bike	12	5	0	2	1
The device was user friendly	0	1	1	8	8

Eleven of the participants who responded to the survey indicated they had no issues with the device. Three participants indicated they felt the GPS lock took too long and one of those participants also indicated that the charging process was not intuitive. One participant indicated they had to charge it twice and one indicated that the device took up space on their bike meaning they had less space for food and a saddlebag. One participant felt the sensor could not be attached tight enough (self-installed) and the sensor kept moving and one participant thought 15 second delays between LED flashing was too long.

Eight of the participants made suggestions for improvement to the device. Suggestions proposed to improve the device included:

- Longer battery life, make it charge like a "normal" device (no need to turn on to charge).
- Improve installation: less cable ties, adjustable cable lengths, different mounting locations.
- Automatic on/off.
- Improve GPS lock times.
- Provide a 'beep' when on, decrease GPS heart beat delay (from 15 seconds to 3 to 5 seconds).
- Make it water proof.

11 Discussion

This study consisted of several elements: the further development and validation of a passing distance measurement device (PDMD-Mk2) as well as the recruitment of cyclists to participate in a study to collect naturalistic cycling data to evaluate bicycle passing distances in the ACT. Furthermore, this research also enabled the improvement of algorithms to automatically process the data collected and the generation of very interesting results.

The goal of developing a passing distance measurement device, capable of recording accurate and relevant data while attached to the personal bicycle of volunteer cyclists, in a naturalistic real-world setting, has been achieved. While an issue with GPS data corruption was encountered, the cause of corruption was quickly identified, resolved and the data collection was repeated.

As part of this study a cohort of ideal candidate cyclists were identified through a pre-selection on-line survey, and then optimal candidates based on residential distribution, gender representativeness (according to gender cycling participation in the ACT) and sufficient cycling exposure in the ACT were finally selected as participants. The attachment of the data collection devices to participants' bicycles was under-taken in a safe and convenient manner and on-going support of participants during the data collection period was offered. No adverse events were reported or noted, and the removal of the data collection devices and collection of survey data was undertaken without issues. Each of the above processes and procedures were conducted in a way that ensured the anonymity of the cyclist participants and met the requirements of ethics approval from the University of Adelaide's Office of Research Ethics, Compliance and Integrity.

The GPS location and passing distance data collected by 23 participants in the ACT over a four-week period was processed in a manner suitable to meet the goals of identifying the general compliance with the minimum passing distance (MPD) rule and to highlight circumstances and locations where there were differences in the frequency of close passing events.

The results of the data analysis found that, overall, most drivers in the ACT provide a reasonable amount of space when passing cyclists on the road network. There were 16,476 passing events detected with 1,502 found to be non-compliant with the MPD rule. On roads where the speed limit was known to be 60 km/h or below, the proportion of drivers not complying with the MPD rule (passing events less than 1 metre) was 2.7%. For roads where the speed limit was known to be greater than 60 km/h, the proportion of non-compliance with the MPD rule (passing events less than 1.5 metres) was 11.2%.

In comparison, a study conducted in Victoria by Beck et al. (2018), which utilised bicycle mounted devices for data collection in a similar way to the current study, found that 6% of passing events were less than 1 metre. This difference in the proportion of passing events less than 1 metre may be the result of several factors. While drivers are still required to pass cyclists safely, the state of Victoria does not currently have a minimum passing distance law. This may have contributed to a higher proportion of close passes in the Victorian data. Additionally, the characteristics of the roads on which data was collected may also have affected the results. Melbourne has more urban roads with higher traffic density compared with Canberra. A larger amount of data collected on this type of road would likely increase the proportion of close passes. Finally, there may well be fundamental differences in the way that drivers and cyclists interact in the ACT compared with Victoria, or in the type of road infrastructure that exists in each region.

This study had a reasonable distribution of journeys across the road network in the ACT, with roads ranked higher in the functional hierarchy having a higher number of journeys compared to lower ranked roads. The nature of the journeys, of multiple cyclists traversing the same roads, allowed the generation (to some degree) of heat-maps indicating particular roads with a lower than average median passing distance or higher mean non-compliant pass ratio. These maps could, in theory, be used as a starting point to investigate road infrastructure that may be resulting in higher proportions of non-complaint passing events. Safety audits could be undertaken to investigate infrastructure differences at locations with high frequencies of non-complaint passes compared to those with lower, or no, non-complaint passes. These audits may be useful to develop strategies for 'best practice' engineering solutions to help reduce the incidence of risky cyclist-vehicle interactions on problematic roads. However, further or ongoing data collection might be needed to ensure the 'hot-spots' revealed in this study did not occur by chance.

There was considerable variation in results from individual participants. This is likely to be a reflection of different cycling habits, route selection, riding style, and time of day of rides.

Bicycle lane presence increased the median passing distance on high speed roads but reduced the median passing distance on low speed roads. This effect may be due to narrower bicycle lanes being installed on low speed roads in locations where lateral space is limited by urban infrastructure and on-street parking considerations. Despite this result, the presence of a bicycle lane still appeared to decrease the mean non-compliance pass ratio for both high speed and low speed roads.

The finding that compliance with the MPD rule was greater on low speed roads compared with high speed roads may suggest that there is a need to promote the passing distance requirements more clearly, or more frequently, to improve compliance and help motorists better understand the context of their application across different speed limits. Additionally, on roads with a speed limit of 70 km/h, where there is significant non-compliance with the 1.5 m rule but good compliance with a 1 m rule, thought could be given to lowering the speed limit to 60 km/h.

While care has been taken to the collection and processing of the data during this study, there are a number of limitations that should be acknowledged. First, there is some scope for errors in the methodology used to identify passing events. The ultrasonic sensors used to record passing data operate at a frequency of 20 Hz which may be too slow to detect vehicles which pass very quickly. The algorithm used to identify passing events in the distance data that is recorded has not been exhaustively validated. As such, it is not possible to be certain that the algorithm has identified exclusively events where a vehicle has passed a cyclist. Nor is it possible to be certain the algorithm has not missed identifying passing events.

The GPS road matching process that was utilised could also have resulted in errors. For example, in a situation where a cyclist was riding along an off-road bicycle lane which runs adjacent to a road, there is the potential that the road matching process could have miss-allocated that part of the journey to the roadway.

Finally, the accuracy and quality of the road characteristic data obtained from the Open Street Map database is unknown. This road characteristics data has enabled the disaggregation of the passing distance data in the interests of analysis, but there is some potential for this to have resulted in erroneous conclusions.

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- Ian English
- Marleen Sommariva
- Martin Elsegood

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Appendix A – Online eligibility survey

<Opening page on survey monkey>

The Centre for Automotive Safety Research (CASR) at the University of Adelaide, is conducting 'An evaluation of bicycle passing distances in the ACT' using a bicycle mounted device that measures the passing distance between cyclists and road vehicles. This project has been made possible with assistance from the ACT Road Safety Fund and has been approved by The University of Adelaide's Human Ethics Review Committee, approval number H-2018-056.

To be eligible to participate in this study you need to be a regular bicycle rider in the ACT, who rides predominantly on the road network. You should be comfortable with using technology, and you need to be willing to have the small electronic device (as shown on the bicycle below) mounted on your bicycle for a period of up to 4 weeks.

The device has a GPS that logs your speed, your location and the lateral passing distance of vehicles that overtake your bicycle.

All data collected by the device will be confidential.

1. Are you interested in being involved with this study based on the above information?

Yes No

Response <No>

Unfortunately, you are not eligible to participate in this study, thank you for your time.

Response <Yes>

Thank you, you may be eligible to participate in this study.

This is a research study, where your participation is completely voluntary. The following information is provided so you are fully informed about the study. Once you have read this information, and you still wish to participate, click 'next' at the bottom of the page.

If you are eligible to participate, the trial will involve mounting a small device on your bicycle that will automatically measure vehicle passing distances, your riding speed and your location. The trial will run for a period of four weeks. The data collected by the device will be logged internally and there will be no visual display of passing distance or any other data. There will be no requirement for participants to adjust the device. However, there may be a need to recharge the battery, and instructions will provided on how to do this.

The device should not affect your bicycle or interfere with your normal riding in any way. Additionally, the trial will not require you to change your riding patterns at all; the idea is that you ride your bicycle in your usual manner. If you own more than one bicycle, the device will be mounted to the bicycle you use most frequently. You will also be asked to complete two brief surveys (each taking around 10 minutes to complete) regarding your general cycling patterns, your attitudes to passing distances and your experiences during the trial (one before and one after).

Researchers from CASR will visit you at a predetermined date and location to mount the device on your bicycle, provide you with the initial survey and answer any queries about the trial or the device. After the trial is complete, researchers from CASR will return to retrieve the device and provide you with the second survey.

Participation in this trial is entirely voluntary and, even if you agree to participate, you are free to withdraw from the trial at any time.

A report will be prepared for the ACT Road Safety Fund and a research publication may also be produced. Only, aggregated data will be reported, and your individual results will not be identifiable. Your individual route maps may be reported, but only for short, interesting segments where events occurred, and will not be reported for entire journeys. Your association with any reported route maps will not be known. All personal information such as your name and contact details will remain completely confidential.

If you have any questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should contact the Principal Investigator, Dr Jamie Mackenzie on (08) 8313 5997 during business hours or by email to jamie@casr.adelaide.edu.au. You can contact the Human Research Ethics Committee's Secretariat on phone (08) 8313 6028 or by email to hrec@adelaide.edu.au if you wish to speak with an independent person regarding concerns or a complaint, the University's policy on research involving human participants, or your rights as a participant. Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

2. Are you willing to participate in the trial and have a small electronic device mounted on your bicycle for a period of up to four weeks?

Yes No

3. Are you willing to have your regular cycling trips monitored for this period? This includes information regarding your speed and location, which is obtained through the device's GPS (although it will be possible to turn the device off if you do not wish to have a particular trip monitored).

Yes No

4. Do you ride on a regular basis (i.e. commute to/from work most days or take a long ride on the weekend)?

Yes No

5. Approximately, how many kilometres do you ride per week?

__________ km

6. Is a significant amount of your riding on the road (including bike lanes)?

Yes No

7. Do you store your bike in a secure place (i.e. within your home or office, rather than chained up in a public place)?

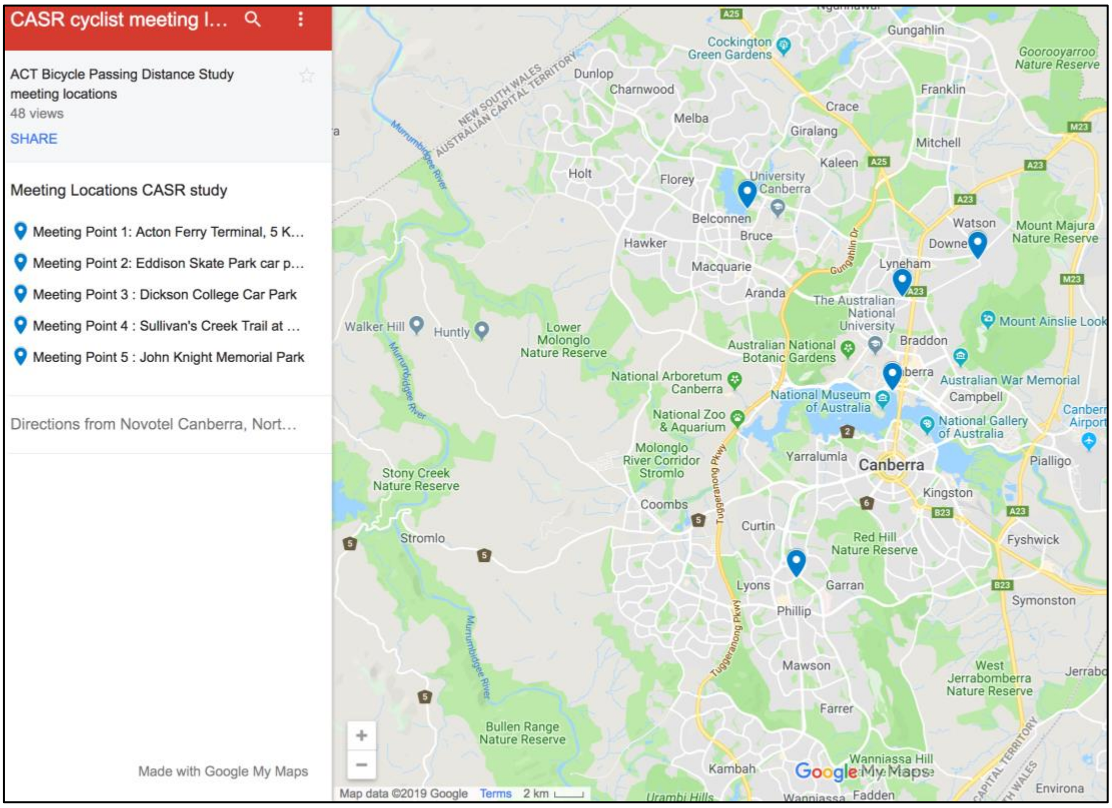
Yes No

8. Are you comfortable using technology?

Yes No

9. Are you available to have a device fitted at any of the times and locations below? (Please select suitable time/locations)

Click here for a map of the locations



☐ 8:30am to 10:00am Saturday 18th August 2018 at Acton Ferry Terminal, 5 Kuttabul Place, Acton

☐ 10:30am to 11:30am Saturday 18th August 2018 at John Knight Park, car park, Townsend Place Belconnen

☐ 1:00pm to 2:00pm Saturday 18th August 2018 at Acton Ferry Terminal, 5 Kuttabul Place, Acton

☐ 2:30pm to 3:30pm Saturday 18th August 2018 at Eddison Park Skateboard car park, off Launceston Street, opposite Canberra College, Woden

☐ 4:00pm to 5:00pm Saturday 18th August 2018 at Sullivans Creek bike barometer, MacArthur Avenue, O'Connor

☐ 8:30am to 10:00am Sunday 19th August 2018 at Acton Ferry Terminal, 5 Kuttabul Place, Acton

☐ 10:30am to 11:30 am Sunday 19th August 2018 at Sullivans Creek bike barometer, MacArthur Avenue, O'Connor

☐ 2:00pm to 3:00pm Sunday 19th August 2018 at John Knight Park, car park, Townsend Place Belconnen

☐ I can't make any of the above dates, times or locations but I am interested in participating in the study

10. If you would like to participate, please provide your name, email address, postcode and mobile phone number so the researchers can contact you with details about the project.

Name: ____________________

E-mail address: ____________________

Postcode: ____________________

Mobile Phone Number: ____________________

Thank you very much for taking the time to complete this survey. We will be in contact with you by email to let you know whether you are eligible to participate in the trial of a device that measures bicycle passing distances.

Appendix B – Post-study survey

Participant ID: __________

1. How confident are you when riding on roads with traffic?

Not at all --- Not very --- Reasonably --- Very --- Completely

2. What clothing do you normally wear when you cycle?

Work clothes --- Cycling clothes (i.e. lycra) --- Casual clothes --- Sports clothes --- Other: ______

3. Do you wear high-visibility clothing (i.e. fluorescent -green or orange colours)?

Yes No

4. Do you have lights on your bicycle?

Yes No

5. Do you have your lights running whenever you ride (i.e. day and night)?

Yes, day and night --- No, night only --- No, I never use lights --- No, I don't have lights on my bike

6. How safe do you feel when you ride your bike?

Unsafe at All times					Undecided					Safe at all times
□	□	□	□	□	□	□	□	□	□	□

7. In what situations do you feel unsafe?

Please specify. ____

8. The distance at which motorists pass me when cycling concerns me…

Never --- Rarely --- Sometimes --- Often --- Always

9. How often do you perceive that vehicles pass too close to cyclists?

Never --- Rarely --- Sometimes --- Often --- Always

10. Are there any types of vehicles that regularly pass too close (e.g. buses, trucks, cars, taxis)? Please specify:

____

11. How much distance do you provide when passing cyclists while driving your car? Please specify:

____

It is a requirement by law in many states in Australia that drivers provide a gap of at least one metre when passing cyclists (for road speed limits posted 60 km/h and less) and a minimum of 1.5 m (for road speed limits posted above 60 km/h). ***With this information in mind, how much do you agree with the following statements?***

12. I like the idea of bicycle passing laws.

Strongly disagree --- Disagree --- Agree --- Strongly agree

13. Bicycle passing laws would not address the issue; other or further measures are needed.

Strongly disagree --- Disagree --- Agree --- Strongly agree

14. A one-metre passing distance is still too close.

Strongly disagree --- Disagree --- Agree --- Strongly agree

15. Bicycle passing laws would make riding safer for bicyclists.

Strongly disagree --- Disagree --- Agree --- Strongly agree

16. I would personally feel safer because of bicycle passing laws.

Strongly disagree --- Disagree --- Agree --- Strongly agree

17. I think it would be difficult to enforce bicycle passing laws.

Strongly disagree --- Disagree --- Agree --- Strongly agree

18. If you agreed or strongly agreed that it would be difficult to enforce bicycle passing laws, please explain why.

____

19. During the period of time when you were participating in the bicycle passing distance study, did you ride your bike about the same amount as you normally would?

☐ Yes

☐ No, I rode more than normal

☐ No, I rode less than normal

20. Did you generally ride the same routes as you normally do?

☐ Yes

☐ No

(if No, why not?) ______________________

21. Did your participation in this study change your riding behaviour in any way? If Yes, what changed?

____

22. Did the passing distance measurement device itself, or knowing data was being collected by the device, influence the way you rode? If Yes for how long and what influence did it have?

____

23. How many times do you think you had a close pass, during the study?

____

How much do you agree with the following statements?

24. It was easy to take part in the trial.

Strongly disagree --- Disagree --- Agree --- Strongly agree

25. I found the device to be annoying.

Strongly disagree --- Disagree --- Agree --- Strongly agree

26. The device distracted me while I was riding.

Strongly disagree --- Disagree --- Agree --- Strongly agree

27. The device interfered with the normal practice of riding my bike.

Strongly disagree --- Disagree --- Agree --- Strongly agree

28. The device was user friendly.

Strongly disagree --- Disagree --- Agree --- Strongly agree

29. Was there anything about the bicycle passing distance device that you found troublesome or annoying? Please specify.

____

30. What improvements would you make to the device? Please specify.

____

31. Do you have any other comments you would like to make, regarding the trial or the device?

Please specify.

____