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CASR221

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Report documentation

REPORT NO.	DATE	PAGES	ISBN	ISSN
CASR221	February 2024	31	978-1-925971-54-5	1449-2237

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Funding

This project was made possible with assistance from the ACT Government under the ACT Road Safety Fund Community Grant Program.

Available From

Centre for Automotive Safety Research; http://casr.adelaide.edu.au/publications/list

Abstract

To explore the compatibility of the ACT road network with modern vehicle ADAS, an instrumented vehicle was driven throughout the Territory to collect data over a period of five days. Feedback from the consultation of ACT road infrastructure stakeholders was used to assist in the selection of roads for data collection, which included all main highways as well as significant proportions of the urban and rural arterial network. The instrumented vehicle was fitted with a Mobileye dev-kit and Video Vbox HD2 system which provided the capability to collect details about what a commercial-grade ADAS is able to “see” while travelling through the road network. There were 759,772 points of data collected over 1,349 km of roadway during the study along with the detection of 1,963 speed limit signs. This dataset was then analysed to investigate what details regarding line markings and speed limit signs the Mobileye was able to detect. These analyses were also augmented with additional data obtained from the Open Street Map road network. Based on the analyses, high-resolution maps were generated that show ADAS is likely to have a good compatibility with the ACT road network in general. Geographic datasets were also generated as an output, providing an opportunity for further analyses.

Keywords

ADAS, line marking, speed sign

Summary

Advanced Driver Assistance Systems (ADAS) comprise various innovative vehicle technologies that have great potential to reduce fatalities and serious injuries on the road network. The effectiveness of some ADAS is reliant on features of the road network such as line markings and signage to enable proper functioning of technologies like lane departure warning or intelligent speed adaptation.

This project involved driving an instrumented vehicle along major roads within the ACT to assess and record the compatibility of the road infrastructure with ADAS. The data collection occurred over five days and the roads that were assessed were selected in consultation with several road infrastructure stakeholders from the ACT.

The collected data was processed and analysed to produce three types of output. The first type of output was summaries of the frequency of features that were detected along the assessed roadways such as line marking type, line marking quality, lane width, line marking width, and the number of signs showing different speed limits.

The second output was a set of high-resolution maps showing, in detail, the locations that various line marking features and speed limit signs were detected across the assessed road network. These maps provide insight into what areas of the ACT road network are compatible with ADAS and where they may be gaps that should be reviewed. Consultation of these maps provided confidence that ADAS is likely to operate effectively across the majority of the ACT.

The final output were geographic datasets containing all the details regarding line markings and speed limit signs that were recorded. These datasets will be useful for conducting further analyses and for review by third parties.

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1. Introduction

Advanced Driver Assistance Systems (ADAS) comprise a range of in-vehicle safety technologies that have be found to greatly reduce the occurrence of crashes. These include intelligent speed assistance (ISA) and lane support systems like lane departure warning (LDW) or lane keep assist (LKA).

ISA is a technology that compares the speed of a vehicle to the posted speed limit, based on GPS speed maps complemented by traffic sign recognition, and provides a warning to the driver when the vehicle is deemed to be exceeding the speed limit. An Australian based study (Doecke & Woolley, 2011) concluded ISA could result in reductions of serious injury and fatal crashes by 8.3% and 11.0% respectively.

Lane support systems are a family of technologies which aim to assist drivers in maintaining a suitable position within their current lane of travel. LDW utilises a front facing camera system to observe line markings on the road and alert the driver when their vehicle travels out of the current lane. LKA builds upon the capabilities of the LDW system by additionally being able to automatically manipulate the steering wheel to keep the vehicle in the centre of the current lane of travel. A study conducted in Sweden (Sternlund et al., 2017) found that vehicles equipped with LDW/LKA systems were 53% less likely to be involved in a lane departure casualty crash.

In 2014, a study on emerging vehicle safety technologies interviewed road safety experts from Australia (Searson et al., 2015). The experts acknowledged the immense potential benefits of ADAS, but expressed an opinion that Australian road infrastructure may not be optimal for effective use of some technologies. Indeed, to function properly, ISA systems must be able to detect the posted speed limit on the road being driven and LDW/LKA systems require line markings that are clear and well maintained.

ADAS manufacturers primarily develop their systems for the European and North American market. As such, their systems may not be designed to operate optimally in the unique Australian road environment. It is therefore important to establish whether our Australian road systems are compatible with Advanced Driver Assistance Systems that have the potential to reduce crashes and prevent road trauma. Furthermore, poor road infrastructure maintenance is also likely to reduce ADAS performance. Areas of a road network where line markings are faded or where signage is obscured may not be compatible with ADAS and should be identified so issues can be rectified.

This project seeks to explore the question of ADAS compatibility with the ACT road network and to identify areas where there may be gaps. In Section 2, the project methodology is presented which details the selection of roads to be assessed based on consultation with relevant stakeholder, the description of data collection from a commercial-grade ADAS, and the processing of the collected data. The results of the project are then shown in Section 3, followed by a discussion of the outcomes in Section 4.

2. Methodology

2.1. Ethics approval

Because the project involved a video camera that was recording the public roadway and road users, there was the possibility that personally identifying information, such as people's faces and vehicle registration plates, could be recorded. As such, an ethics approval for the activities being undertaken was required.

A previously submitted application to the Office of Research Ethics, Compliance and Integrity at the University of Adelaide was amended to cover the activities of this project and this application was approved with Ethics Approval No: H-2018-102.

2.2. Stakeholder engagement

It was not feasible to assess the entire ACT road network for ADAS suitability. As such, there was a need to identify and prioritise the roads which should be covered in the time available (five days). To achieve this, several road infrastructure stakeholders in the ACT were contacted to request feedback.

To assist with this process a brief presentation was prepared which described the project being undertaken, explained the ADAS technologies that were being evaluated, introduced the instrumentation that was being used to collect data, and provided a map showcasing the various types of roads within the ACT (see Appendix A). The presentation was designed to provide background and context to the stakeholders so they could give the most informed feedback and opinions.

Letters with a request for stakeholder feedback were sent via email to Transport Canberra (ACT government), City Services (ACT government), the National Roads and Motorist's Association (NRMA), the National Heavy Vehicle Regulator (NHVR), and Pedal Power ACT. Responses were received from the NRMA and Pedal Power ACT, along with a combined response from Transport Canberra and City Services.

Transport Canberra/City Services and the NRMA representatives relayed similar views in their feedback. They indicated that ACT roads were of a relatively high standard and that fatal crashes were randomly distributed and infrequent. As such, there were no roads or locations that they could suggest for specific targeting based on crashes. However, highways were nominated as the most important to assess, and there was a consensus that all the highways should be assessed in the five days of data collection. It was noted that rural arterial roads carry a lot of freight vehicles and subsequently there was strong interest in assessing these types of roads as well as urban arterial roads after data collection on highways was completed.

Pedal Power's feedback was to prioritise roads with cycling infrastructure and high cycling rates. Specific examples were provided, highlighting areas where there were higher speed limit roads with cycle lanes and merging ramps, where cycle lanes ended or were of poorer quality, as well as shared road areas and cycling infrastructure that was unique to the ACT.

As a result of the stakeholder consultation, a prioritised plan for data collection was developed. The first item in this plan was to cover all ACT highways in their entirety. Next was to cover a reasonable proportion of the urban and rural arterial road network, followed by a sample of urban and rural distributor roads. Finally, a small sample of local residential streets would be covered, as well as most of the specific roads nominated by Pedal Power.

2.3. Instrumented vehicle

An instrumented vehicle was utilised for data collection. The vehicle, a 2014 Subaru Outback, was fitted with a Mobileye dev-kit system as well as a RaceLogic Vbox Video HD2 system. These systems are described in greater detail below but, in tandem, they enable the collection of ADAS data regarding line markings and signage at a frequency of 10 times a second, along with synchronised GPS location and video of the forward driving scene. An example of this video scene, overlayed with various types of ADAS data, is shown in Figure 2.1 below.

Figure 2.1
An example of the video recorded by the instrumented vehicle, including a sub-set of data collected, a view of the forward driving scene, and the Mobileye display

Mobileye is a commercially available advanced driver assistance system (ADAS) that can be retrofitted into most standard vehicles. The performance of the system has been improved over time and in recent years been installed as original equipment in over 100 million vehicles worldwide by manufacturers such as Audi, BMW, FCA, Ford, General Motors, Honda, Hyundai, Kia, Nissan, Tesla, and Volkswagen. While many other versions of ADAS exist, the Mobileye system can be considered a suitable example of a modern, commercial-grade ADAS.

The Mobileye system views the driving scene via a single forward-facing camera and applies machine vision algorithms in real time to detect over 80 important road and traffic features such as line markings, the presence and location of other road users, and the details of roadside signs. The system is also connected to the vehicle’s controller area network (CAN) bus which provides information such as current vehicle travel speed, use of turn-signal indicators, and application of the brake pedal. Based on the video and CAN bus data, the Mobileye system is able to provide safety information to the driver, such as the current posted speed limit or headway to the vehicle in front, via a small in-cabin display unit (as shown in centre bottom of Figure 2.1). When a crucial safety event is detected, such as an unexpected lane departure (with no turn-signal indicator activated), significant exceeding of the speed limit, or an imminent collision with a vehicle in front, the system provides an audio alert to the driver. When the Mobileye system is installed as original equipment, the information provided by the Mobileye can be used to trigger autonomous emergency braking or provide a steering input via a lane keep assist (LKA) system.

It is worth noting that, while the Mobileye system is designed to detect many types of road signs, this sign-recognition capability is based on examples from Europe and North America. As such, the system has a limited capability to detect unique Australian signage and is only able to reliably recognise speed limit type signs on Australian roads.

The Mobileye “dev-kit” is a specialist version of the system that is usually provided to developers or manufacturers and provides access to all the features being detected by the Mobileye system in real-time. This access is gained via connection to a CAN output from the Mobileye system along with corresponding knowledge regarding how the CAN messages should be decoded.

The CAN data from the Mobileye was collected in two ways via connections to external systems as shown in Figure 2.2 below. The first connection was to a Vbox Video HD2 system. This system is able to capture, decode, and record the CAN messages along with GPS data and video from two cameras. The HD2 system records up to 80 CAN channels and GPS data synchronously at a frequency of 10 Hz. This recorded data is saved into a “.vbo” file which is formatted in a similar way to a .csv (comma-separated values) file. Additionally, the video from the two cameras is recorded in .mp4 video format with an overlay of other data (see Figure 2.1).

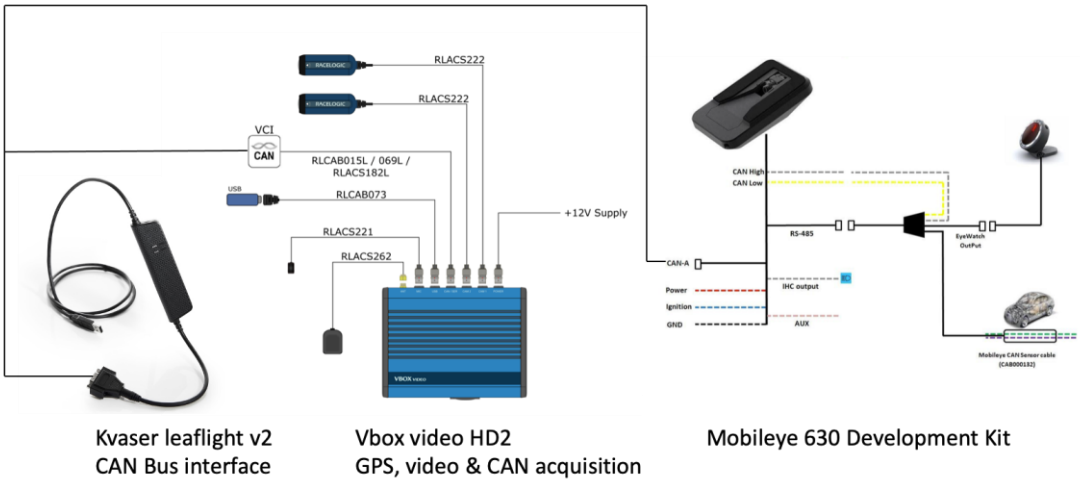

Figure 2.2
Data collection system layout

The HD2 system can be triggered to start and stop recording with a simple button press. Once a recording has been stopped, the system will save out a corresponding .vbo and .mp4 file onto an SD card that can be retrieved later.

The second connection to the Mobileye CAN data was to a Kavaser Leaflight v2 which was then connected to a laptop computer. This system allowed for the high-speed logging of all CAN data from the Mobileye, rather than only 80 channels at 10 Hz that was possible with the HD2 system. This system was used as a backup to ensure no data was lost, but was not utilised any further for this project.

2.4. Data collection

Researchers from the Centre for Automotive Safety Research travelled to the ACT and collected data (predominantly during daylight hours) with the instrumented vehicle for a total of five days between Thursday June 2 and Tuesday June 7 (excluding Sunday June 5). Data collection was focussed on prioritising those road types recommended by the consulted stakeholders, as described above. In total, approximately 1,200 km of road within the ACT was covered. For roads with more than one lane, attempts were made to drive along each lane in multiple passes as well as in each direction of travel. During this process, an effort was made to record data from each lane of each road once only, but a few lanes of some roads were inadvertently recorded multiple times.

Each day of data collection was planned the night before to optimise the driving route along the roads of interest and to maximise the amount of data that was recorded. During data collection, one researcher navigated and operated the data collection equipment, while the other researcher was solely responsible for driving. Individual data recordings were made for each distinct drive through a roadway of interest. At the conclusion of each day all recorded data was backed up via upload to a secure cloud storage system.

Weather conditions were dry for the first three days of the data collection period, but there were periods of rain in the final two days. Data collection was still conducted during these last two days, but halted when rainfall intensity was deemed sufficient to hinder the performance of the Mobileye system. Temperature and rainfall history recorded by the Bureau of Meteorology during the data collection period is shown in Figure 2.3.

Daily maximum temperatures for June 2022

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Canberra Airport	8.3	11.0	10.4	10.3	12.0	9.6	9.8	10.2	11.4	12.6	10.1	11.8	10.0	6.8	12.6	13.5	13.9	14.4	14.8	13.7	11.4	13.8	13.1	14.8	14.4	14.7	11.2	12.5	12.2	13.5
Mount Ginini AWS	-3.0	0.3	0.7	0.5	0.7	-2.1	-2.4	-2.4	-0.8	-0.4	-1.3	-0.4	2.0	4.3	1.7	2.3	5.3	4.0	4.9	3.2	2.2	1.6	2.3	2.4	1.9	3.3	2.9	6.0	3.1	4.0
Tuggeranong (Isabella Plains) AWS	8.4	11.3	10.0	10.4	12.3	8.8	8.2	10.3	11.4	13.2	10.7	12.8	9.7	7.0	13.2	13.0	13.5	13.9	15.0	13.6	10.9	14.2	13.5	13.5	14.7	14.7	11.0	12.6	12.2	13.4

*Values are the maximum temperature, usually in the 24 hours **from** 9 am on the day indicated, and typically occurred in the afternoon of that day.*

Temperatures coloured according to their difference from the long-term average for the period	-10.0	-9.0	-8.0	-7.0	-6.0	-5.0	-4.0	-3.0	-2.0	-1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	°C	*Grey outline marks highest and lowest for the period*

Daily minimum temperatures for June 2022

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Canberra Airport	1.4	-4.0	-2.8	2.5	7.0	2.8	4.1	1.5	2.9	4.8	1.8	5.2	-2.4	-3.1	-4.5	4.3	1.8	-2.4	-4.0	1.8	0.5	-2.7	-0.9	6.7	4.2	-1.8	-0.6	-6.0	-5.0	0.1
Mount Ginini AWS	-6.1	-5.6	-3.7	-2.6	-1.7	-4.0	-3.6	-4.5	-4.2	-2.8	-4.0	-3.2	-4.3	-2.1	-4.5	-2.2	-0.2	-1.4	-0.3	0.0	1.3	-2.7	-1.5	0.7	-0.8	-1.0	-3.1	-4.6	-1.3	-1.4
Tuggeranong (Isabella Plains) AWS	2.0	-4.2	0.2	0.6	6.9	3.0	4.4	0.8	-0.4	-0.8	-3.1	3.4	-2.3	1.2	-5.0	2.4	1.8	-2.7	-3.5	1.4	1.0	-2.7	-1.3	3.1	3.7	-3.0	0.9	-3.7	-5.2	-0.5

*Values are the minimum temperature, usually in the 24 hours **to** 9 am on the day indicated, and typically occurred that morning.*

Temperatures coloured according to their difference from the long-term average for the period	-10.0	-9.0	-8.0	-7.0	-6.0	-5.0	-4.0	-3.0	-2.0	-1.0	0.0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	°C	*Grey outline marks highest and lowest for the period*

Daily rainfall for June 2022

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Aranda (Bindaga St)	4.4	-	-	-	2.8	18.4	4.4	3.0	-	-	-	-	-	-	-	-	-	-	-	-	0.2	3.2	-	-	-	-	-	-	-	-
Bruce (Australian Institute of Sport)	4.4	-	-	→	→	15.6	3.4	3.0																						
Canberra (Australian National Botanic Ga	4.1	-	-	-	2.2	14.2	2.8	2.8	-	-	-	-	-	-	-	-	-	-												
Canberra Airport	8.6	-	-	-	0.6	7.2	1.0	2.8	-	-	-	-	-	-	-	0.2	-	-	0.2	-	-	2.4	-	-	-	-	-	-	-	-
Ginninderra (Charnwood (ACT))	3.6	-	-	-	3.2	14.8	3.6	2.4	-	-	-	-	-	-	0.2	-	0.2	-	0.2	-	-	2.8	-	-	-	0.2	-	-	-	0.2
Mount Ginini AWS	6.0	2.4	2.4	0.2	13.6	11.6	13.0	18.0	3.2	2.4	0.2	0.2	-	-	-	2.6	1.0	-	-	-	0.2	5.8	-	-	-	0.2	-	-	-	-
Nicholls (Gungahlin Lakes)	-	-	-	-	12.0	11.0	3.6	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	-	-	-	-	-	-	-	-
Torrens (Darke St)	12.2	-	-	-	-	12.4	→	6.6	-	-	-	-	-	-	-	-	0.4	-	0.2	-	-	2.6	-	-	-	-	-	-	-	0.2
Tuggeranong (Isabella Plains) AWS	7.6	-	-	-	0.6	19.0	2.0	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	2.8	-	0.2	-	-	-	-	-	-

*Most values are the precipitation in the 24 hours **to** 9 am on the day indicated. Days marked with → are part of a longer accumulation, which is shown on the final day. Values over 100 mm have been rounded to the nearest whole millimetre. Days marked with - have a rainfall report of zero; days left blank have no rainfall report (which often indicates no rain fell).*

Rainfalls coloured according to the amount	0	1.0	5.0	10.0	15.0	25.0	50.0	100	150	200	300	400	600	millimetres

Figure 2.3
Temperature and rainfall history during data collection period

2.5. Data analysis

After the data collection was completed, a brief period of data exploration and review was conducted. This process was used to ensure that there was no missing data and to gain an understanding of what techniques would need to be used to analyse the data effectively.

There were 64 separate data files recorded over the five days of data collection. Analysis of these files was conducted in three phases. The first phase consisted of pre-processing the data for the analysis in the later phases. The second phase was focussed on line marking detection, while the third was focussed on speed sign detection. These final two analysis phases were exploratory in nature, with the objective of investigating the compatibility of ADAS with the ACT road network.

The video files that correspond to each of the data files were used to visually check any unexpected results.

2.5.1. Pre-processing

Filtering

Each of the recorded data files were initially processed individually to check that they contained information relevant to the study. The average speed of the instrumented vehicle (while moving) was calculated for each file. If this average speed was found to be less than 50 km/h, it was assumed that the file was recorded in a low-speed environment and was removed from further analysis. In these situations, the recorded GPS heading data can sometimes be inaccurate, the Mobileye ADAS functionality may not be operating properly, and the instrumented vehicle may have been manoeuvring within a carpark or other zone that was not the focus of the study. For similar reasons, any data points recorded when the vehicle was travelling less than 20 km/h in the remaining 52 data files were also ignored during the analyses.

Clipping

Next the data was clipped to ignore any points that were collected outside of the ACT. The geographic boundary of the ACT was obtained from the ACT open data hub and any recorded data points that were not within this boundary were removed from the analysis.

Road network matching

The value of the recorded data can be enhanced significantly by matching (or snapping) to road network data which contains details about features such as speed limit, number of lanes, and road name.

While the Vbox Video HD2 system is able to capture fairly accurate GPS data, it suffers from the same limitations that effect all GPS receivers. Cloud cover, reflections from buildings or bridges, and other transient environmental conditions will reduce the accuracy of the GPS signal and result in small errors between the true vehicle location and what is recorded. Because of these errors, the road closest to the GPS location of each recorded data point is not necessarily the road that was being driven.

A process was undertaken to match the recorded data points to the Open Steet Map (OSM) road network, which is similar to Google Maps but crowd sourced and publicly available. This matching process was complex and technical so a fully detailed description is beyond the scope of this report. However, the general process involved the following steps:

- Extracting the GPS (latitude/longitude) points from a recorded data file
- Obtaining all OSM network data that exists within 30m of any of the GPS points
- Splitting the set of GPS points into several path segments based on where there are changes in travel direction
- Searching for candidate nodes within the obtained OSM network that may be a match for the start point and end point in each GPS path segment
- Rating the route through the OSM network between each start and end candidate node pair, based on how well they match the GPS points in the corresponding path segment
- Selecting the best overall route through the OSM network represented by the best rated series of routes for each path segment
- Matching the GPS points to the closest OSM road along the selected route

2.5.2. Line markings

After the pre-processing steps were completed, all variables in the remaining data files that were relevant to line markings were collated into a single output file. Table 2.1 shows the variables that are associated with each recorded data point in this output file. The output file was saved in GeoJSON format so it can be made available for use by third parties.

Analyses of the various line marking features were then conducted. Because the lane width and line width variables were continuous, they were explored by generating histograms. For this process, the left and right line width data was aggregated as it was not anticipated that there would be much difference in their respective characteristics.

The line quality and line type variables were categorical, and so were explored by generating tables that displayed the number and percentage of kilometres that were detected in each category. During this process the left and right line markings were processed separately to explore whether there may be any differences.

High-resolution digital maps were then generated for several of the variables. The collected data points were converted to lines (by linking one point to the next) and colour coded to generate maps showing lane width, line marking quality, line marking type, and line marking width across the ACT road network. The entire ACT road network was also displayed to provide location context.

A final map was then generated by using the data points that were snapped to the Open Street Map (OSM) network. The quality of any left and right line markings from data points associated with each road segment in the OSM network were aggregated to calculate an overall segment quality score. This quality score provides an estimate of the likelihood that ADAS will understand the line markings over that segment of roadway. The quality score aggregates the data collected from all lanes of travel (where data was collected) over each road segment, but different directions of travel were considered separately.

Table 2.1
Details of data contained within the line makings output file

Variable	Units / Format	Description
filename	text	Name of data files containing the data point (i.e. .mp4 video file and .vbo file)
datetime	yyyy-mm-dd hh:mm:ss	Date and time the data point was recorded in UTC
lat	degrees	Latitude of the recorded data point
lon	degrees	Longitude of the recorded data point
velocity	km/h	Speed of the vehicle
heading	degrees	Heading angle of the vehicle relative to True North (positive clockwise)
line_type_L	categorical	Type of line marking detected at the left of the vehicle's travel lane
line_type_R	categorical	Type of line marking detected at the right of the vehicle's travel lane
line_quality_L	categorical	Quality of the line marking detected at the left of the vehicle's travel lane
line_quality_R	categorical	Quality of the line marking detected at the right of the vehicle's travel lane
line_dist_L	metres	Lateral distance to the line marking at the left of the vehicle's travel lane, relative to vehicle centreline (left direction negative, right direction positive)
line_dist_R	metres	Lateral distance to the line marking at the right of the vehicle's travel lane, relative to vehicle centreline (left direction negative, right direction positive)
line_width_L	metres	Width of the line marking detected at the left of the vehicle's travel lane
line_width_R	metres	Width of the line marking detected at the right of the vehicle's travel lane
lane_width	metres	Width of vehicle's travel lane (calculated from line_dist_R - line_dist_L)

2.5.3. Speed signs

Speed limit signs appear at distinct points on the road network, rather than continuously like line markings. As such, the speed sign data was restricted to where an individual detection was made. Because some roadways were traversed multiple times during data collection, a single speed limit sign may have been detected multiple times. To filter out such instances, any speed signs that were detected within 10m of a previously detected sign were ignored.

All relevant speed sign data was collated into a single output file. Table 2.2 shows the variables that are associated with each detected speed sign in the output file. The output file was saved in GeoJSON format for review by third parties.

Table 2.2
Details of data contained within the speed signs output file

Variable	Units / Format	Description
filename	text	Name of data files containing the detected sign (i.e. .mp4 video file and .vbo file)
datetime	yyyy-mm-dd hh:mm:ss	Date and time the sign was detected in UTC
lat	degrees	Latitude of the recorded data point when the sign was detected
lon	degrees	Longitude of the recorded data point when the sign was detected
velocity	km/h	Speed of the vehicle
heading	degrees	Heading angle of the vehicle relative to True North (positive clockwise)
sign_limit	km/h	Speed limit indicated by the detected sign
sign_height	metres	Height of the detected sign
sign_lateral_offset	metres	Lateral offset of the detected sign, relative to vehicle centreline (left direction negative, right direction positive)
sign_lat	degrees	Latitude of the detected sign (based on lat/lon and sign_lateral_offset)
sign_lon	degrees	Longitude of the detected sign (based on lat/lon and sign_lateral_offset)
osm_speed	km/h	Speed limit of the Open Street Map associated roadway

A comparison between the detected speed limit signs and the reported speed limit of the associated Open Street Map (OSM) roadway was then performed. Tables were generated that explore the frequency and percentage of correlation or mismatch between the detected sign speed limits and the OSM reported speed limits.

Finally, a high-resolution digital map was generated that displayed the location and speed limit of all the detected signs across the ACT road network. Again, the entire ACT road network was also displayed to provide location context.

3. Results

After pre-processing the collected data, there were 759,772 data points across 1,349 km of roadway remaining for analysis. This analysis was split into exploring how the Mobileye ADAS was able to interpret line markings and speed limit signs.

3.1. Line markings

All the data relevant to line markings was collated and saved into a 353 Mb GeoJSON file. Along with the collected line marking information, each data point was also associated with a filename and datetime, which can be used to look up the video captured with that data point where necessary.

The results from the analyses regarding the line marking quality, line marking type, lane width, and line marking width are shown in Table 3.1, Table 3.2, Figure 3.1, and Figure 3.2 respectively.

The majority of line markings were found to have been rated as “good” quality by the Mobileye system with a smaller percentage rated as “satisfactory”. These two ratings indicate where the system rated the line marking quality as sufficient to enable ADAS features such as lane departure warning. Only a small proportion of line markings were rated as “poor”. Around 10 per cent of the line markings were rated as “undetectable”, but this is likely to include locations were there were no line marking present.

Table 3.1
Line marking quality across the assessed network

Quality	Left line marking (km)	Left line marking (%)	Right line marking (km)	Right line marking (%)
Undetectable	128	9%	135	10%
Poor	14	1%	15	1%
Satisfactory	223	17%	278	21%
Good	984	73%	921	68%
Total	**1,349**	**100%**	**1,349**	**100%**

Indeed, the Mobileye system found that line markings were not present in 12 per cent of the data sample. In locations where line markings were detected, the majority were found to be either dashed or solid lines. Solid lines were more common for the left line marking, while right line markings were more likely to be dashed lines. While less common, a small proportion of double line markings were also identified, usually on the right line marking. A few kilometres of roadway were found to have line markings designated by Bott’s Dots (where cat’s eyes are used rather than painted lines).

The width of lanes that were detected across the assessed road network varied but were generally between 2.8 to 3.8 metres, with the majority between 3.2 and 3.5 metres. The width of most detected line markings was found to be between 9 and 17 cm. There was a small proportion that were detected to be wider (20+ cm), including a curious set that were found to be 50 cm wide.

Table 3.2
Line marking type across the assessed network

Type	Left line marking (km)	Left line marking (%)	Right line marking (km)	Right line marking (%)
Dashed	531	39%	652	48%
Solid	645	48%	354	26%
None	157	12%	168	12%
Road Edge	0	-	0	-
Double Line	11	1%	171	13%
Bott's Dots	5	0%	4	0%
Total	**1,349**	**100%**	**1,349**	**100%**

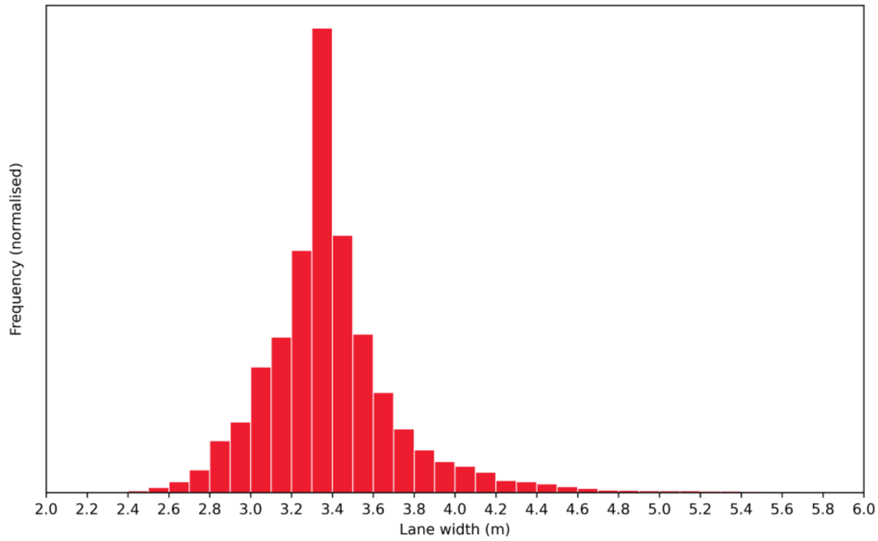

Figure 3.1
Frequency of lane widths identified along the roads where data collection occurred

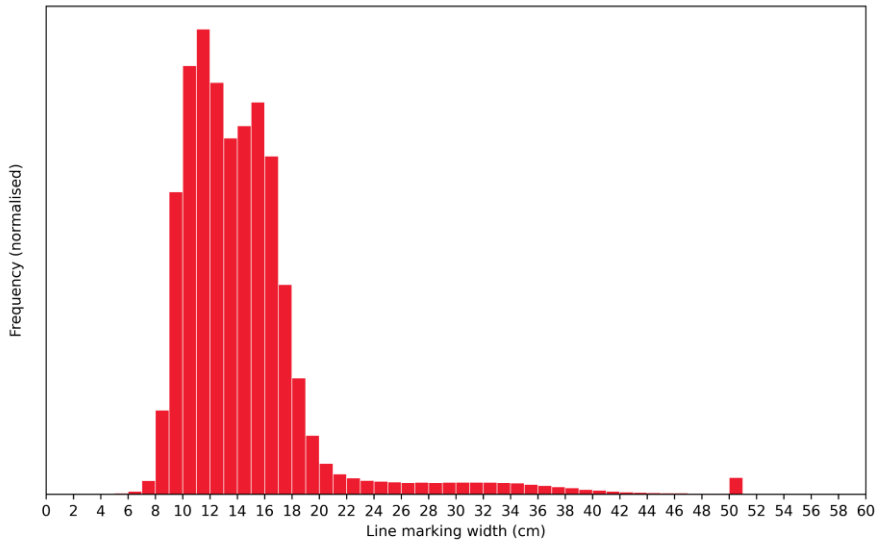

Figure 3.2
Frequency of line marking widths along the roads where data collection occurred

The generation of high-resolution digital maps resulted in images that were approximately 30,900 pixels wide and 50,500 pixels in height, with files sizes between 50 and 90 Mb. These images were too large to include in their entirety within this report, but samples of the detail and resolution found within each of the generated images are shown in Figures 3.3 to 3.7 below[1]. The full images include detailed legends, but general descriptions are provided below in the figure captions.

The high-resolution digital maps that are depicted by Figures 3.3 to 3.6 show the line marking features detected by the Mobileye system mapped to the GPS location recorded at the time. It can be seen that there are many instances where the GPS location data drifted off the roadway or where there are gaps in the data. These gaps may be due to filtering that occurred during the data pre-processing phase or situations where the Mobileye system was not able to detect a line marking. Additionally, data collection that occurred multiple times in the same lane, in adjacent lanes, or in opposing travel directions of a roadway often result in overlapping lines in the images.

Because of the GPS drift, the gaps in data, and the overlapping data it is difficult to conclude a generalised interpretation of the data within the high-resolution maps. Rather, it is hoped that they present a useful tool for the review of specific roads or areas of interest. For example, if a specific roadway was found to be experiencing a significant number of loss-of-control crashes, the maps could be consulted to investigate whether there may be an issue that is preventing ADAS from operating effectively.

The high-resolution digital map depicted by Figure 3.7 shows the advantage of being able to snap the collected data to the Open Street Map (OSM) road network. By aggregating all the line marking quality scores for each road segment, the outcome is a crisp image that contains few gaps and no overlapping details.

The interpretation of this map is also best conducted with knowledge about specific road sections of interest, but generally it appears that line markings are well recognised by the Mobileye system. It can be seen that there are clear limitations in the ability of the system to recognise line markings at roundabouts and through intersections. However, it is likely that this is because there are no line markings present in these locations.

Despite the generally good recognition of line markings, there are still many instances of mid-block road segments where line marking recognition was found to be poor. These locations have the potential to be incompatible with ADAS and thus present potential safety gaps in the road network.

[1] These figures are best viewed on a digital version of the report. Depending on the print settings applied, the details may not be clear when printed.

Figure 3.3
Sample of high-resolution map detail showing lane width across the roads where data collection occurred (lighter shades indicate narrower widths progressing to darker shades which indicate wider widths)

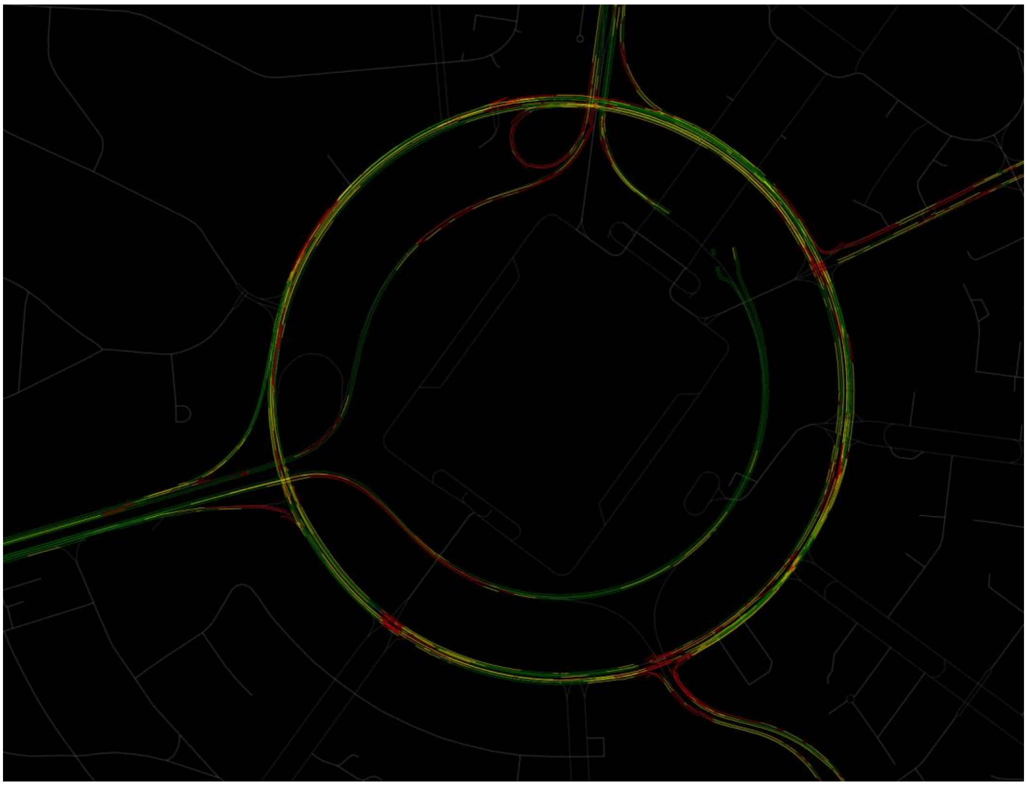

Figure 3.4
Sample of high-resolution map detail showing line marking quality across the roads where data collection occurred (Red: undetectable, Orange: poor, Yellow: satisfactory, Green: good)

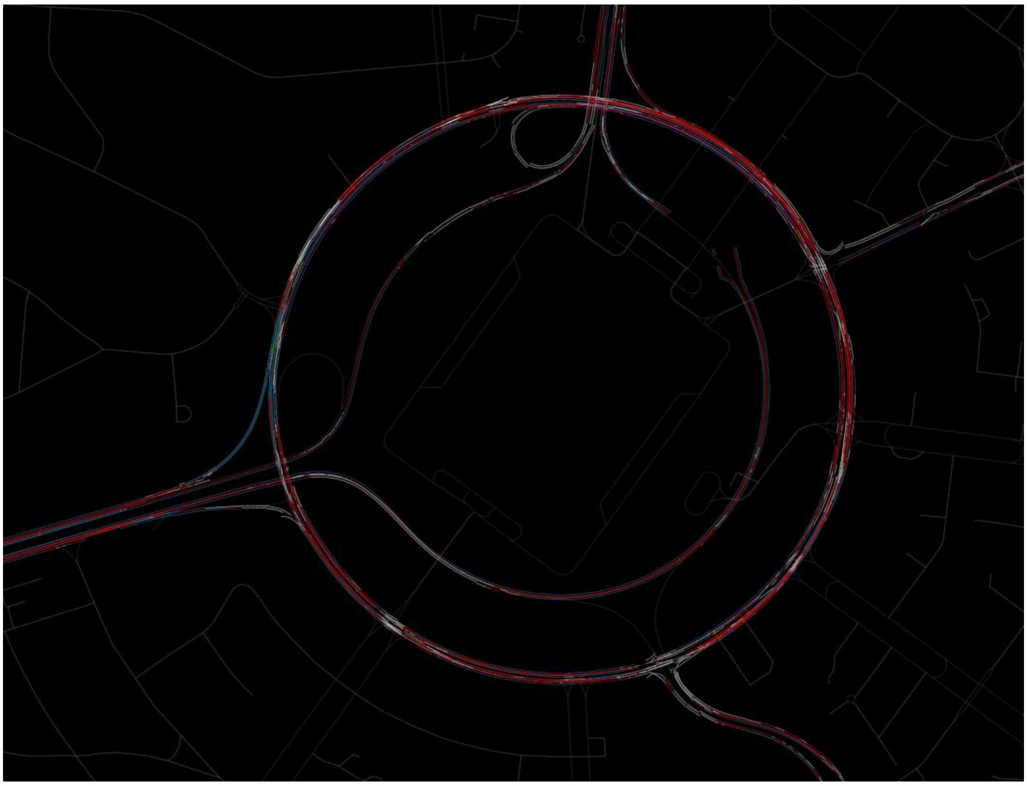

Figure 3.5
Sample of high-resolution map detail showing line marking type across the roads where data collection occurred
(Red: dashed, Blue: solid, White: none, Green: double line)

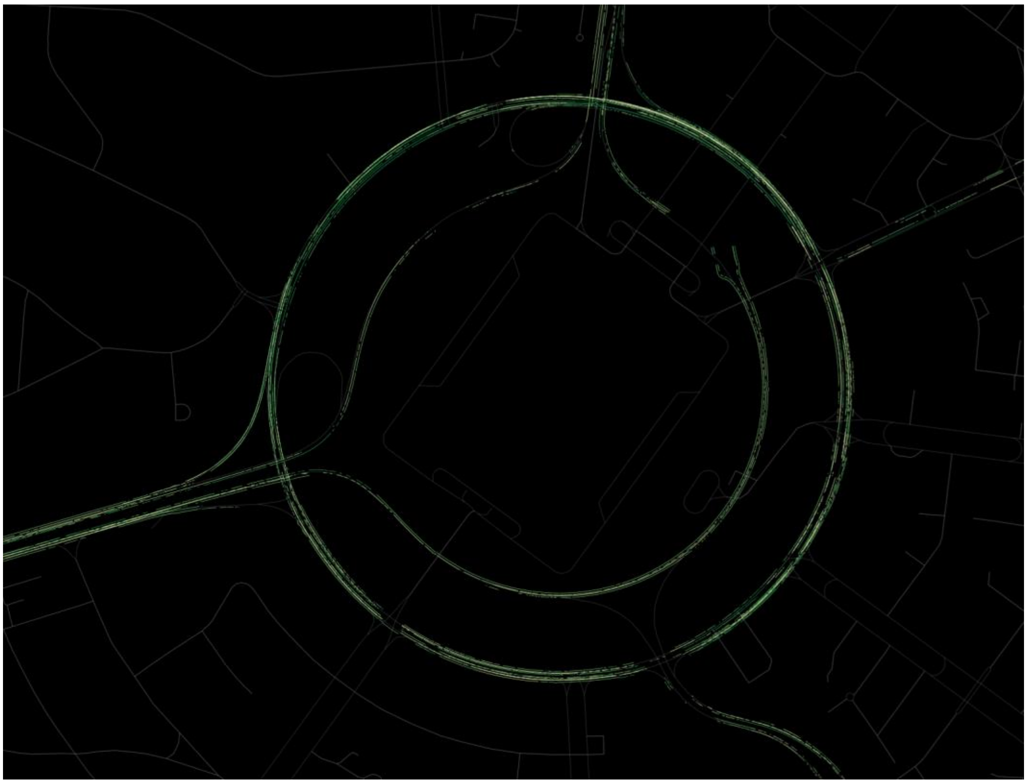

Figure 3.6
Sample of high-resolution map detail showing line marking width across the roads where data collection occurred
(lighter shades indicate narrower widths progressing to darker shades which indicate wider widths)

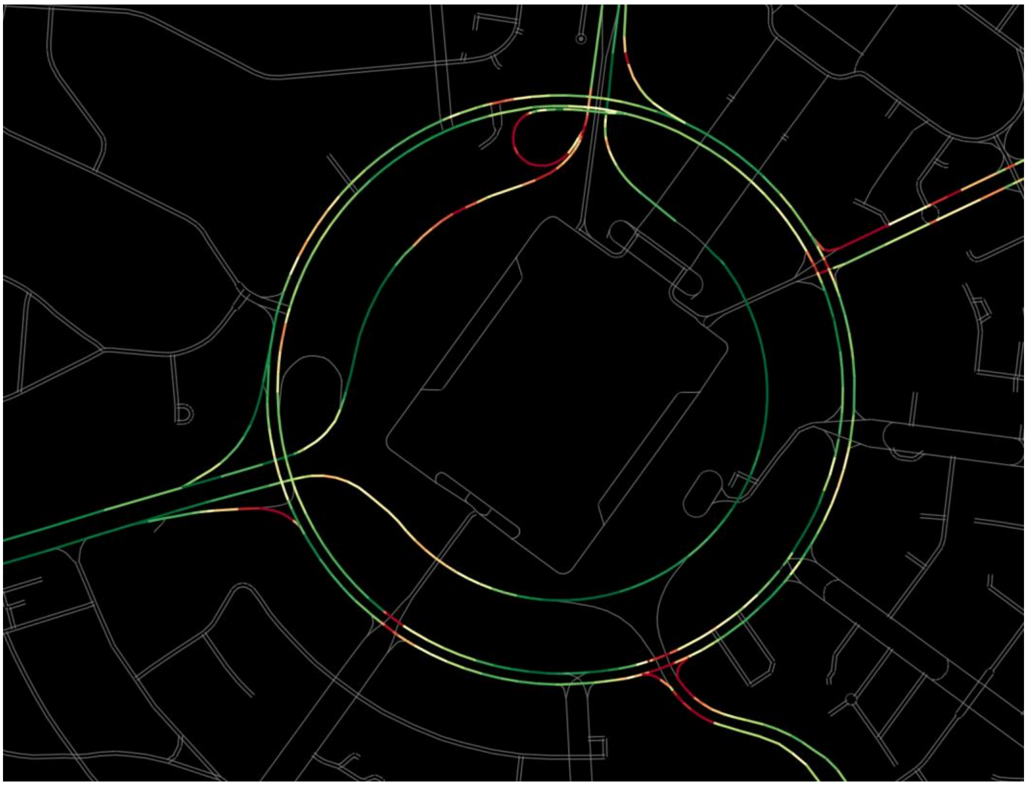

Figure 3.7
Sample of high-resolution map detail showing line quality across the OSM road segments where data collection occurred (Red: undetectable, Orange: poor, Yellow: satisfactory, Green: good)

3.2. Speed signs

There were 1,963 speed limit signs detected in the recorded data. While efforts were made to filter the data, it should be noted that the detected set of signs may include some instances of multiple detections of the same sign. The filtering may also have resulted in some detections of individual signs being removed.

The detected sign data was collated and saved into a 1 Mb GeoJSON file. Much like the line marking data set, each detected sign is associated with a filename and datetime, which can be used to look up the video captured at the time of the detection.

The results of the comparison between the detected sign speed limits and the reported speed limit from the associated Open Street Map (OSM) roadway are shown in Table 3.3 (by frequency) and Table 3.4 (by percentage) below.

For the signs detected as showing a speed limit of 70, 80, 90 or 100 km/h there was a fairly good correlation (70% - 90%) with the associated OSM road segment speed limit. The remaining uncorrelated speed limit signs were generally distributed fairly evenly between other OSM speed limits.

There was little correlation between signs detected with a speed limit of 40 km/h or 50 km/h and the associated OSM road segment speed limit. The majority of these signs were detected on roads that were tagged with a speed limit of 80 km/h or 60 km/h in the OSM road network. Only three signs were detected as displaying a speed limit of 110 km/h and these were all found to be on road segments tagged with an OSM speed limit of 100 km/h.

Table 3.3
Frequency of correlation between detected sign speed limit and
the OSM speed limit for the matched roadway section

Detected sign speed limit	Open Street Map road segment speed limit								
	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	N/A	**Total**
40 km/h	23	-	28	4	34	-	-	1	**90**
50 km/h	-	2	4	4	17	4	5	2	**38**
60 km/h	7	3	295	14	112	-	5	25	**461**
70 km/h	-	-	16	123	23	3	-	10	**175**
80 km/h	-	-	17	15	893	13	32	23	**993**
90 km/h	-	-	2	-	12	67	4	2	**87**
100 km/h	-	-	1	-	12	3	87	13	**116**
110 km/h	-	-	-	-	-	-	3	-	**3**
Total	**30**	**5**	**363**	**160**	**1,103**	**90**	**136**	**76**	**1,963**

Table 3.4
Percentage of correlation between detected sign speed limit and
the OSM speed limit for the matched roadway section

Detected sign speed limit	Open Street Map road segment speed limit								
	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	N/A	**Total**
40 km/h	25.6%	-	31.1%	4.4%	37.8%	-	-	1.1%	**100.0%**
50 km/h	-	5.3%	10.5%	10.5%	44.7%	10.5%	13.2%	5.3%	**100.0%**
60 km/h	1.5%	0.7%	64.0%	3.0%	24.3%	-	1.1%	5.4%	**100.0%**
70 km/h	-	-	9.1%	70.3%	13.1%	1.7%	-	5.7%	**100.0%**
80 km/h	-	-	1.7%	1.5%	89.9%	1.3%	3.2%	2.3%	**100.0%**
90 km/h	-	-	2.3%	-	13.8%	77.0%	4.6%	2.3%	**100.0%**
100 km/h	-	-	0.9%	-	10.3%	2.6%	75.0%	11.2%	**100.0%**
110 km/h	-	-	-	-	-	-	100.0%	-	**100.0%**

There are many possible reasons for a mismatch between the detected sign speed limit and the speed limit of the associated OSM roadway, including:

- Presence of a temporary speed limit sign (e.g. road works)
- Detection of a non-speed limit sign
- Detection of a speed limit sign on a side road
- An incorrect match between the collected data and the OSM network roadway
- An error in the OSM network data
- An error in sign recognition by the Mobileye

It was not practical to perform an exhaustive investigation into every instance of a mismatch between the detected sign speed limit and the OSM road segment speed limit. However, an ad-hoc check of some of the most common instances of a mismatch was conducted by viewing the videos that were recorded at the time the speed limit signs were detected. The outcomes of these visual checks are shown in Appendix B with images of the detected signs and summarised in Table 3.5.

There were three instances where a temporary speed limit sign was detected within, or on the approach to, a road works site. There were four instances where the detected sign was an official speed limit sign, indicating that the mismatch was due to an error in the OSM data. The final mismatch that was checked visually revealed that the Mobileye system had detected a “50 UNLESS OTHERWISE SIGNPOSTED” sign. In this sign the number “50” is displayed within a black annulus which mimics the layout of an official speed limit sign, and this is suspected to be the reason it was detected.

It was notable that no errors were identified in the Mobileye system’s ability to correctly identify the numerical value of any speed limit signs. This suggests that where there was a mismatch, it would be prudent to put more trust in the speed limit detected by the Mobileye system (rather than the OSM suggested speed limit) or assume that a temporary speed limit was in place.

Table 3.5
Summary of the outcomes of an ad-hoc visual check of common miss-matches between detected sign speed limit and OSM road segment speed limit

Detected sign speed limit	OSM roadway speed limit	Visual check outcome
40 km/h	60 km/h	Temporary 40 km/h sign at road works site
40 km/h	80 km/h	Temporary 40 km/h sign at road works site
50 km/h	80 km/h	Non speed limit sign (50 UNLESS OTHERWISE SIGNPOSTED)
50 km/h	100 km/h	50 km/h speed limit sign (error in OSM data)
60 km/h	80 km/h	Temporary 60 km/h sign at road works site
70 km/h	80 km/h	70 km/h speed limit sign (error in OSM data)
90 km/h	80 km/h	90 km/h speed limit sign (error in OSM data)
110 km/h	100 km/h	110 km/h speed limit sign (error in OSM data)

The generation of a high-resolution digital map resulted in an image that was 30,946 pixels wide and 50,450 pixels in height, with a file size of 88 Mb. This image was too large to include within this report, but a sample of the detail and resolution found within the full generated image is shown in Figure 3.8 below.

Different speed limits are shown with different coloured icons that are rotated to indicate the direction of travel for which they are relevant. As there is no official database of sign locations across the ACT, it is not possible to determine whether any signs have been missed. However, there appears to be generally good coverage across the roads that were assessed.

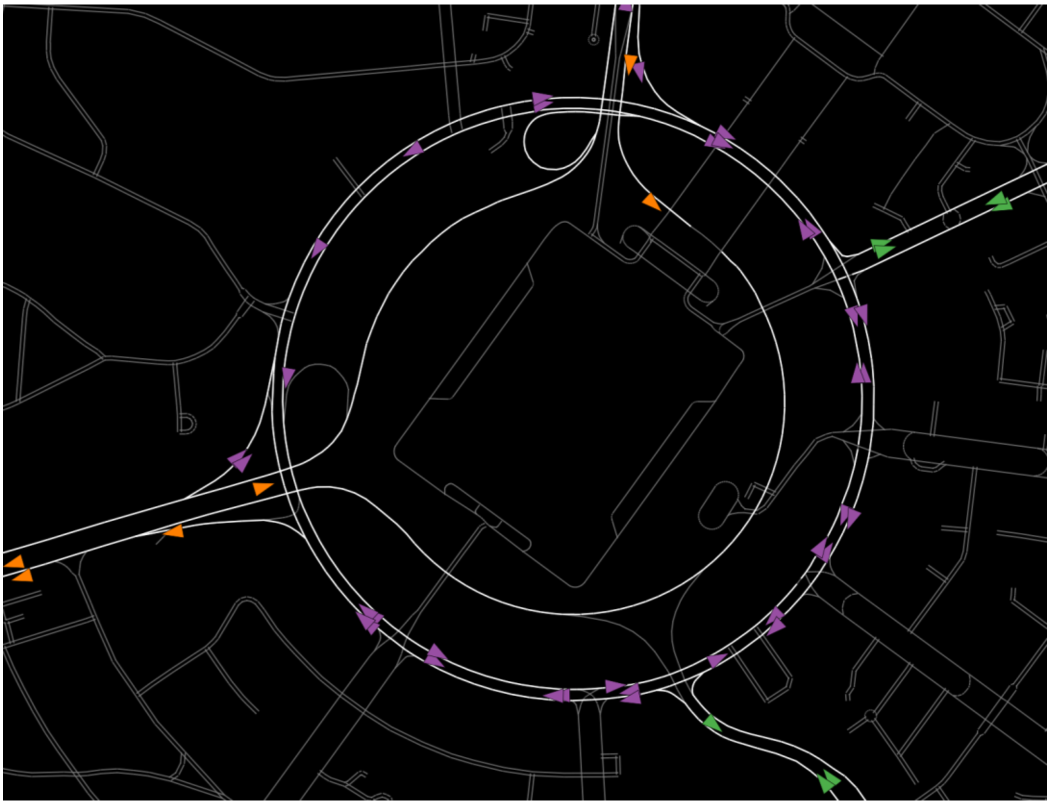

Figure 3.8
Sample of high-resolution map detail showing detected speed limit signs across the roads where data collection occurred
(Green: 60 km/h, Purple: 70 km/h, Orange: 80 km/h)

4. Discussion

To explore the compatibility of the ACT road network with modern vehicle ADAS, an instrumented vehicle was driven throughout the Territory to collect data over a period of five days. Feedback from the consultation of ACT road infrastructure stakeholders was used to assist in the selection of roads for data collection, which included all main highways as well as significant proportions of the urban and rural arterial network. The instrumented vehicle was fitted with a Mobileye dev-kit and Video Vbox HD2 system which provided the capability to collect details about what a commercial-grade ADAS is able to "see" while travelling through the road network.

There were 759,772 points of data collected over 1,349 km of roadway during the study along with the detection of 1,963 speed limit signs. This dataset was then analysed to investigate what details regarding line markings and speed limit signs the Mobileye was able to detect. These analyses were also augmented with additional data obtained from the Open Street Map road network.

Results were presented that showed summaries of the detected line marking quality, line marking type, lane width, and line marking width across the assessed road network. A review of the correlation between the detected sign speed limits and the corresponded Open Street Map reported speed limits was also conducted.

One of the main outputs from the project was a set of high-resolution digital maps, that provide the details of what the Mobileye system was able to detect as it was driven along the roads being assessed. These maps provide insight into what areas of the ACT road network are compatible with ADAS and where they may be gaps that should be reviewed.

Across most of the network the line markings were detectable by ADAS and thus would be compatible with safety systems such as Lane Keep Assist (LKA) and Lane Departure Warning (LDW). Line marking detection was limited at roundabouts and intersections, which is likely due to the absence of lines in these areas.

The Mobileye system was also able to accurately detect a significant number of speed limit signs across the assessed roads, indicating that systems such as Intelligent Speed Adaptation (ISA) should operate effectively.

One limitation of the project is that there is no existing dataset which catalogues the location and details of all the current line markings and signs across the ACT. As such, it was not possible to conduct a comprehensive review of the Mobileye system's ability to capture all line and sign details accurately. Even so, the amount of detail that was captured across the whole length of the roads that were assessed provides a reason to have confidence that ADAS will generally operate effectively in the ACT. In locations of specific interest, it would be prudent to conduct a visual assessment of the roadway and compare the existing infrastructure to the details that were recorded by the Mobileye system.

The analyses presented in this report were fairly rudimentary as they were exploratory in nature. Further geographic processing of the data is likely to provide greater insights. Geographic datasets with all the recorded details regarding line markings and speed limit signs were generated as an output for this purpose and for review by interested third parties.

Acknowledgements

This project was made possible with assistance from the ACT Government under the ACT Road Safety Fund Community Grant Program.

The authors would like to acknowledge the assistance of the Project Manager Juliet Gray and thank the organisations which responded to the stakeholder engagement process; Transport Canberra, City Services, the NRMA, and Pedal Power ACT.

The views expressed in this report are those of the authors and do not necessarily represent those of the University of Adelaide or the funding organisations.

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Appendix A – ACT road hierarchy map

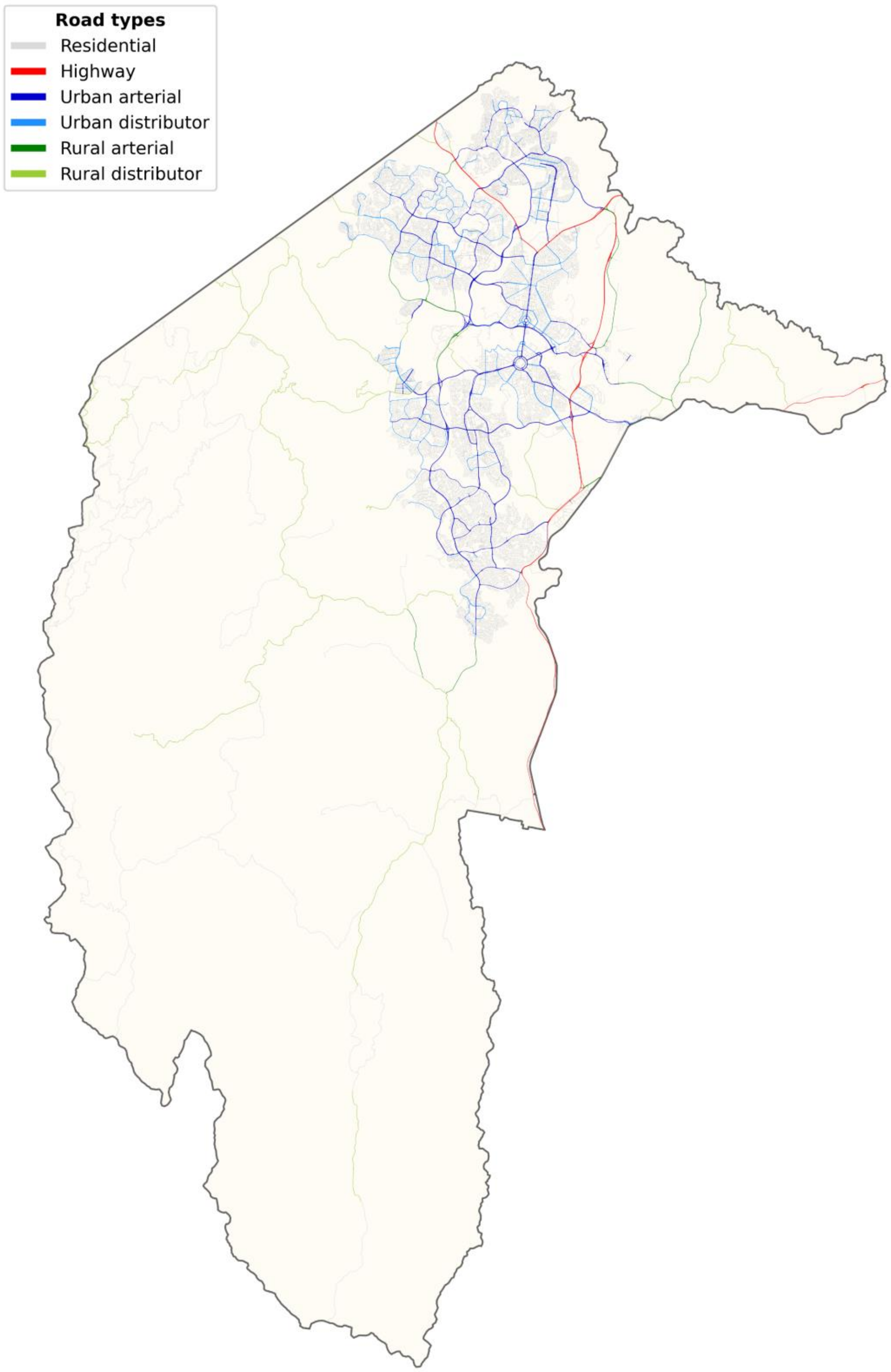

Figure A.1
ACT road hierarchy map that was provided to ACT road infrastructure stakeholders

Appendix B – Speed limit sign visual audit

The images below show the result of an ad-hoc audit of instances where the speed limit of a Mobileye detected sign did not match with the listed speed limit of the corresponding road in Open Street Map.

The images show a point in time where the detected speed limit sign can be seen best, as indicated by a red circle. Note that the Mobileye system does not update the display (shown bottom centre in each image) until the vehicle has passed the sign. As such, the speed limit shown on the display may not align with the sign shown in the images.

Figure B.1
Detected sign with a 40 km/h speed limit with a road segment tagged with a 60 km/h speed limit in the Open Street Map road network

Figure B.2
Detected sign with a 40 km/h speed limit with a road segment tagged with an 80 km/h speed limit in the Open Street Map road network

Figure B.3
Detected sign with a 50 km/h speed limit with a road segment tagged with an 80 km/h speed limit in the Open Street Map road network

Figure B.4
Detected sign with a 50 km/h speed limit with a road segment tagged with a 100 km/h speed limit in the Open Street Map road network

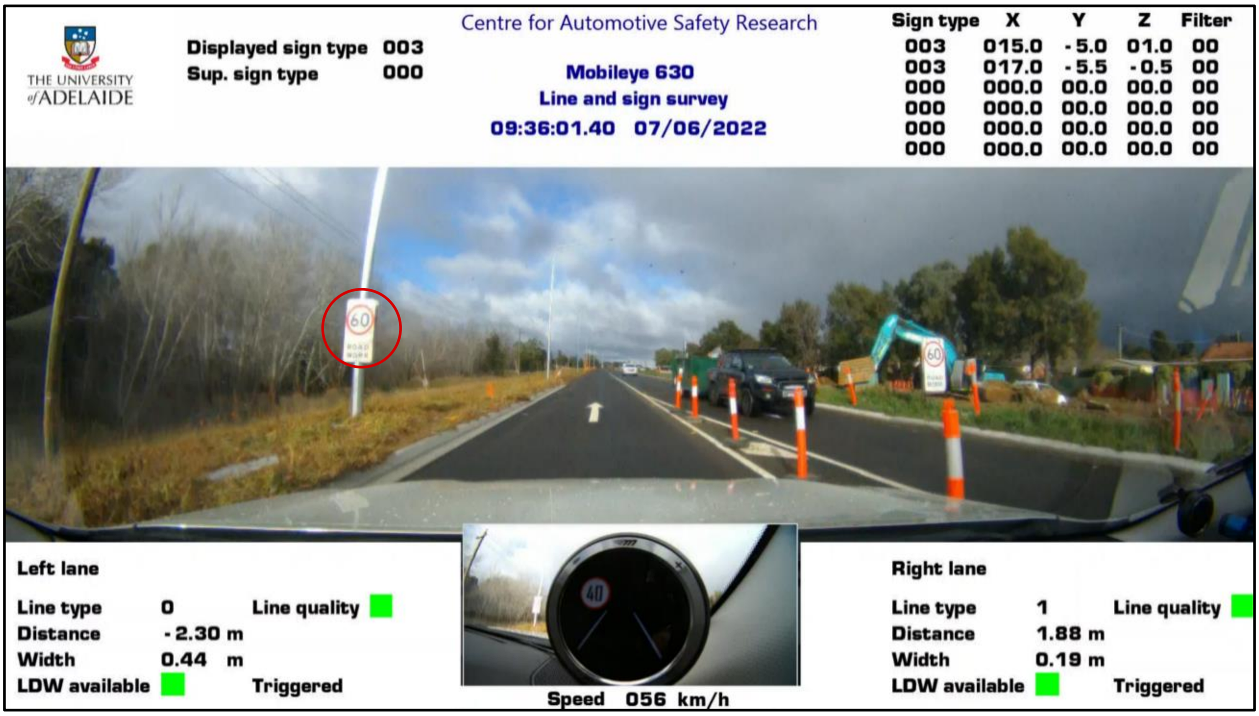

Figure B.5
Detected sign with a 60 km/h speed limit with a road segment tagged with an 80 km/h speed limit in the Open Street Map road network

Figure B.6
Detected sign with a 70 km/h speed limit with a road segment tagged with an 80 km/h speed limit in the Open Street Map road network

Figure B.7
Detected sign with a 90 km/h speed limit with a road segment tagged with an 80 km/h speed limit in the Open Street Map road network

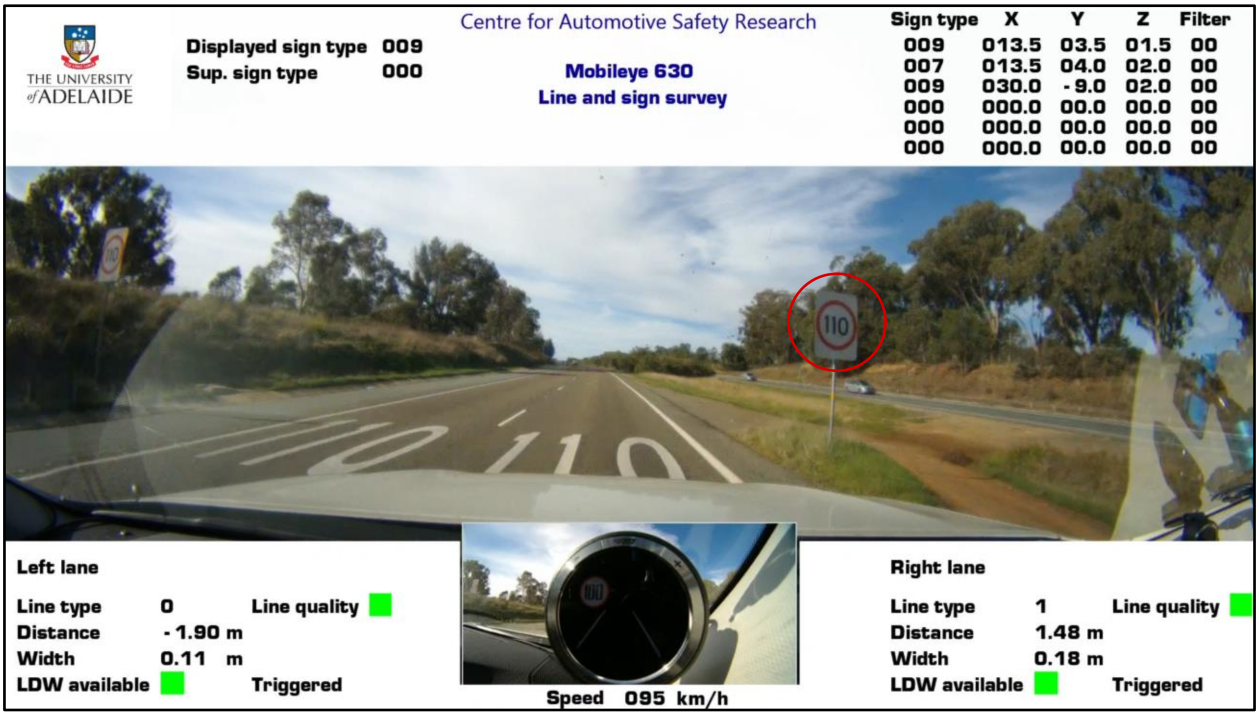

Figure B.8
Detected sign with a 110 km/h speed limit with a road segment tagged with a 100 km/h speed limit in the Open Street Map road network