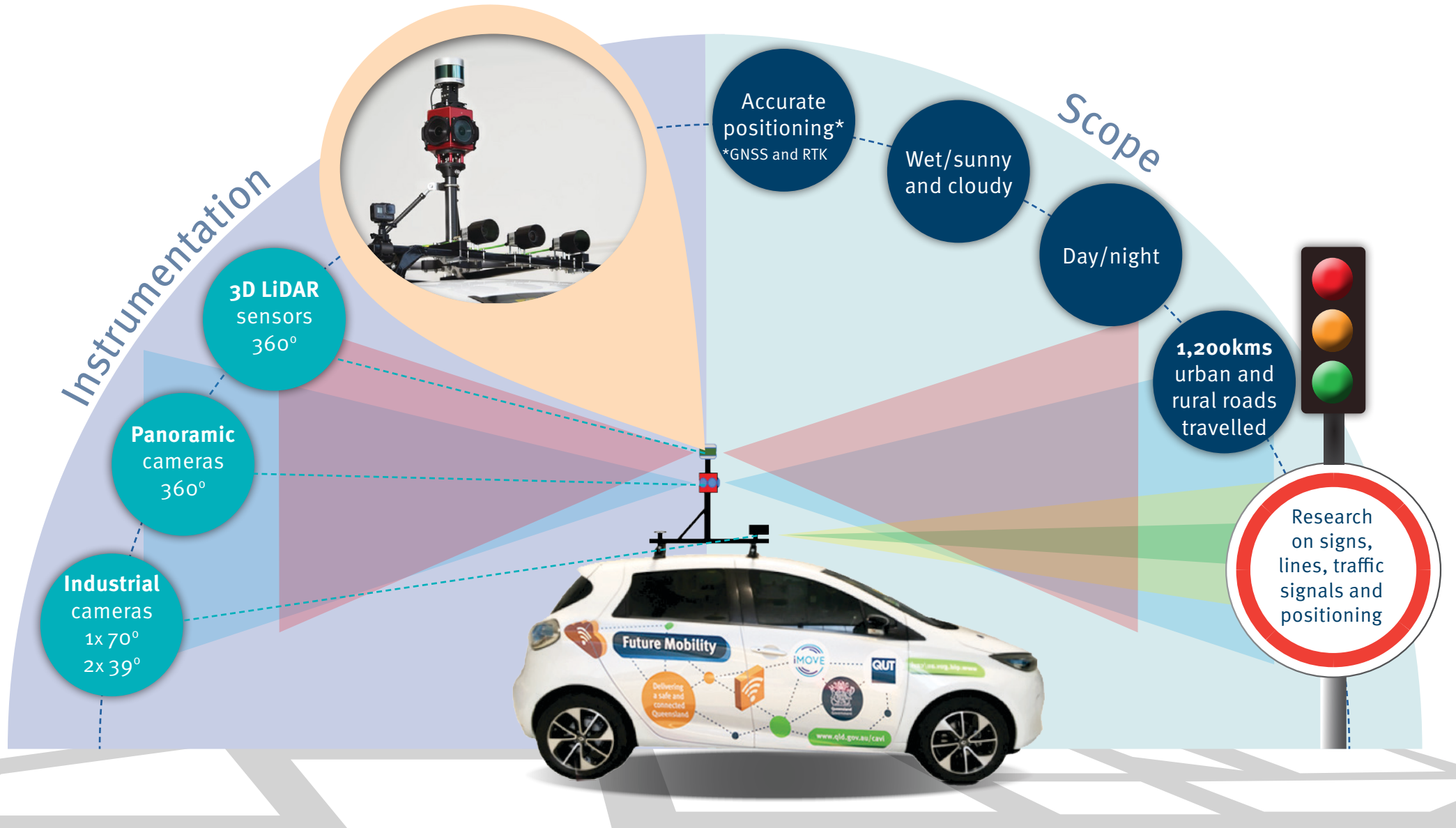


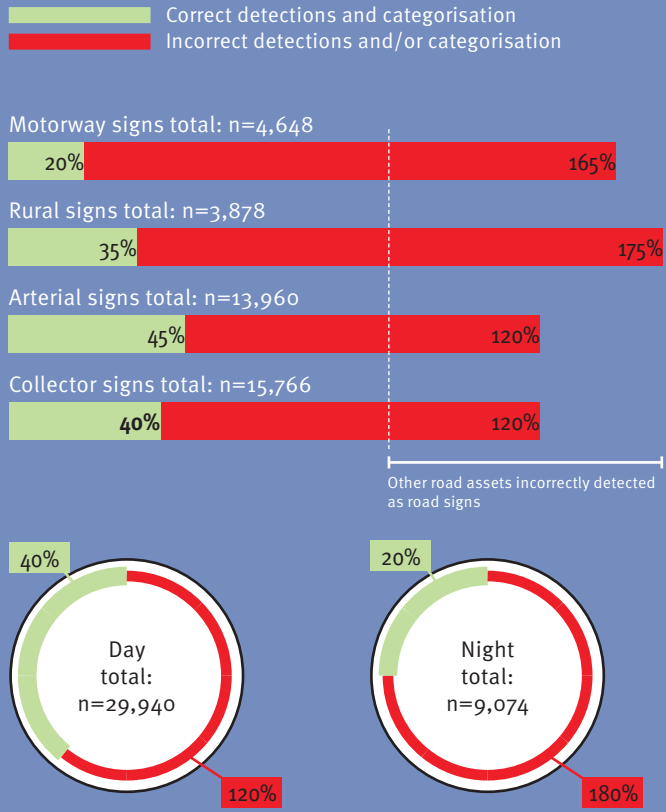
# Road Infrastructure Readiness Study

Featuring - ZOE1



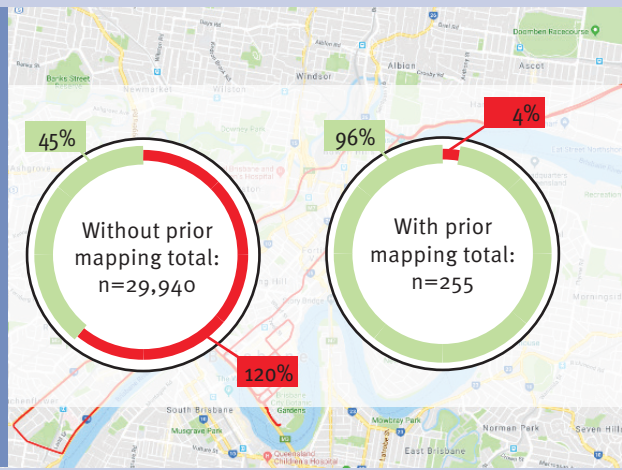
All data was analysed using trained/modified open source algorithms.

## Sign detection (using cameras only)

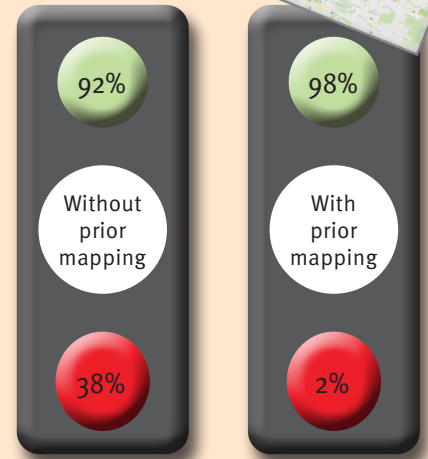


Signs assessed

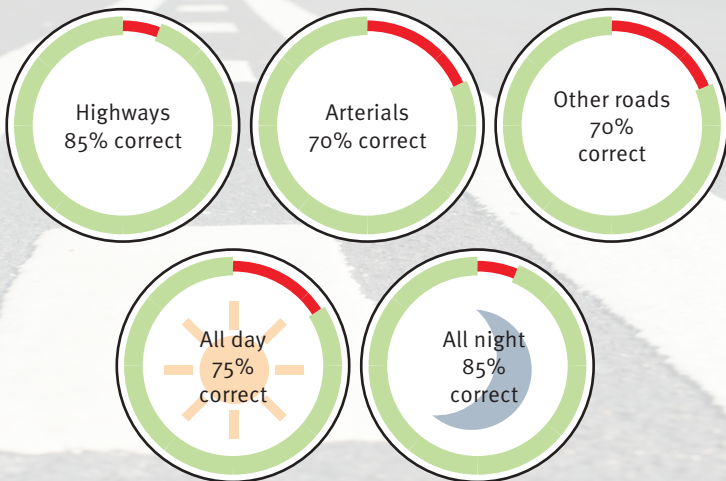
## Sign detection (prior mapping)



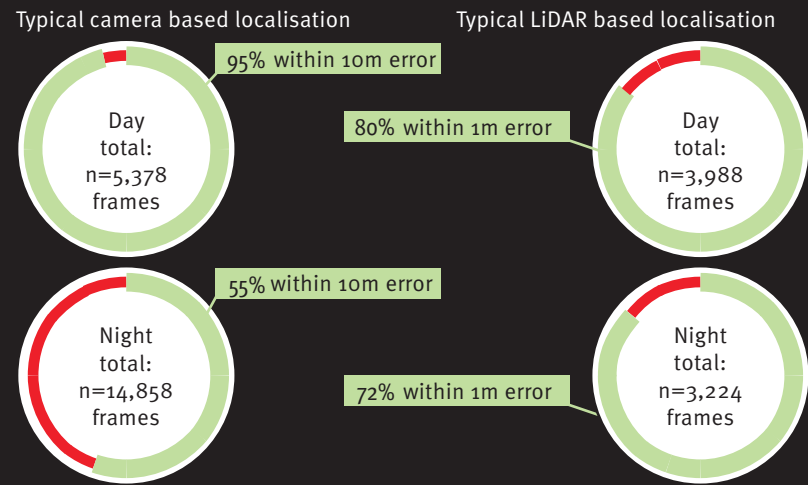
## Traffic light detection



## Lines - 30° or less (straight sections)



## Positioning



## Conclusion

Use of previously mapped information (prior mapping) to compare and verify detection improves performance significantly in all assessed competency.

# ZOE1 summary of findings

## Signs

- Camera vision with trained/modified open source algorithms resulted in poor sign detection.
- Around 40% of speed, give-way, no right turn, pedestrian crossing, and speed hump signs were accurately detected, however 120% (more than the total number of signs) were falsely detected or categorised on arterial and collector roads. Accurate detections halved at night.
- Use of a prior map - a map that is annotated with sign information in addition to camera detection on a sample of the data resulted in a significant improvement (around 95% accuracy).
- Only a fraction of detection would be improved using Light Detection and Ranging (LiDAR), and it is expected that camera vision will likely improve to support night driving.

## Longitudinal lines

- Camera vision was used to detect lines. The scope was limited to 30° turn angles or less (95% of 1,200kms). Trained/modified open source algorithms were reasonable – able to fill in short missing sections or poorly defined lane marking, but struggled to travel through intersections. The cameras worked well at night – better than in daytime conditions.
- Common line issues included, intersections, adjacent roadway lines (stop-bars, pedestrian crossings), poor pavement lines such as ghost lines or stick and stomp, cracked pavements, and water on the road.

## Traffic lights

- Camera vision was used to detect traffic lights but not to recognise its state (red, yellow or green).
- Around 68% were accurately detected and 85% falsely detected on arterial roads. Performance during the day was better than at night.
- Some of the detection errors were produced by falsely detecting adjacent railway signals, light displays at service stations and wet camera lens.
- Using prior map resulted in a significant improvement (around 98% accuracy).

## Vehicle positioning

### Camera based

- A deep learning algorithm was used to match a given image produced by the vehicle's camera against a library of pre-recorded images.

- Performance was found to be generally high, except at night and rural environments where unique visual landmarks are less frequent.
- Some of the challenges identified are; repetitive nature of the environment, non-uniform lighting variations and images with motion blur.

### LiDAR based

- The algorithm used to assess this competency uses a similar approach to the camera based algorithm, however to reduce intensive compute time LiDAR outputs were assessed every second - which would be longer than a production vehicle's needs.
- This method showed impressive results, with a vehicle positioning accuracy of within one metre. As expected the performance was not affected by day or night conditions.
- Some of the challenges include: transient objects such as other vehicles, and changes in the environment such as the removal of near static objects, for example scaffolding.

### Camera and LiDAR data fusion

- It is likely that with the availability of prior maps of the environment, a fused camera and LiDAR based positioning system will be able to provide adequate information under most conditions for accurate vehicle positioning.

## Industry approach

- Internationally, primarily there are two automated vehicle methods under development:
  - › with LiDAR and some form of High Definition (HD) map - almost all major automated vehicle manufacturers are using this method.
  - › without LiDAR or HD maps - only one manufacturer internationally.
- The study suggests without LiDAR or HD maps it is unlikely to provide satisfactory localisation performance for autonomous driving - the accuracy of signs and lines detection and categorisation is significantly improved with HD maps.

## Recommendations

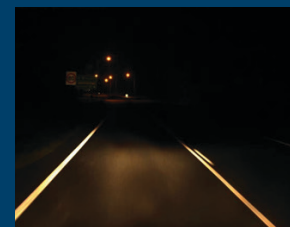
- With LiDAR/HD map, an infrastructure manager may only require minimal changes to the physical infrastructure and will likely have a role in providing supporting information for HD maps such as an intersection layout. An infrastructure manager should also be aware of the negative impact of repetition in infrastructure design, and the removal of key infrastructure which may be used by vehicles for accurate positioning.
- Without LiDAR/HD map, an infrastructure manager will likely need to harmonise signs, remove sign obscuration and improve illumination, add line markings within intersections, and add clearer line markings within roadworks.

Number of issues uncovered - some examples

Wet camera



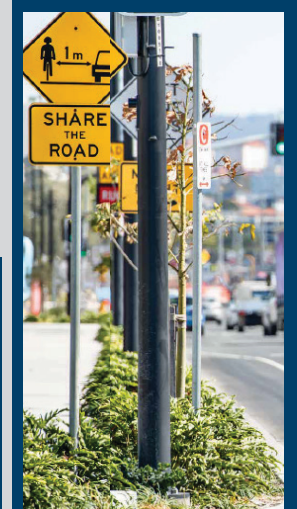
Lighting



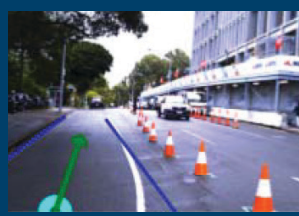
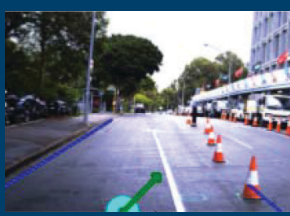
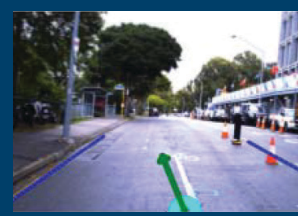
Out of context signs



Occlusion



Orientation



Challenges

# Other studies

There have been a number of other Australian studies exploring the interaction of automated vehicles with infrastructure, specifically lines and speed signs, on motorways and highways.

## Transurban: Queensland connected and automated vehicle trials: Stage one - partially automated vehicles (April 2019)

### Approach

The study used qualitative observations on 5,500km of South-east Queensland motorways using seven commercial (low to high cost) vehicles with lane keep assist (which use cameras and car-following algorithms), adaptive cruise control (which use cameras and radar) and speed sign recognition (use of cameras and/or a prior digital map which can include roadworks signs). The vehicles commonly use Mobileye products for sign and line detection.

### Motorway lines

Emergency bays, dashed lines, roadworks stick and stomp, and other pavement abnormalities force the disengagement of lane keep assist.

### Motorway speed signs

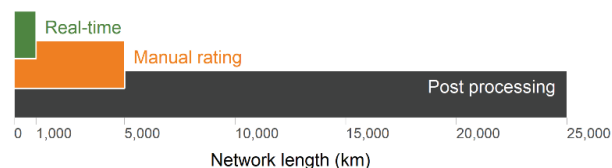
Prior digital maps were sometimes incorrect. Electronic speed signs were incorrect or not able to be read 65% of the time on open roads and 95% of the time in tunnel.

## Austrroads AP-R606-19: Infrastructure changes to support automated vehicles (October 2019)

*This project advances understanding and knowledge but does not fully answer the question of infrastructure readiness. The complementary Austrroads projects on traffic sign recognition (Austrroads 2018b) and pavement marking for machine vision (Project CAV6119) provide some further answers, although significant uncertainty remains.*

### Approach

The study used video driving data provided by state governments, including 4,854km of rural and urban highways and motorways in Queensland. RetinaVision post processed this data, to assess the detection of speed signs and lines. The team also used Mobileye products to collect real-time data and perform a manual rating on a sample of roads.



### Motorway/highway lines

Increasing use of edge line is beneficial to automated vehicles; a very large proportion of lines have an unacceptable width, but width is likely to be less important than contrast. Ghost lines, cracked pavements, variable lighting conditions, water on the road, and shadows from roadside furniture and trees impact the performance of line detection.

The line marking results identified a high percentage (86%) of low contrast longitudinal lines in Queensland, (although the manual analysis of images identified a greater proportion of lines as medium contrast).

### Motorway/highway speed signs

In comparing speed signs on the same roads, the post-processing method identified only 49%. While the Mobileye product, used on a smaller sample of roads, identified 99% of the speed signs detected by manual surveyors.

The report found that there are no significant differences between the states and territories of Australia and New Zealand, however it did note that speed signs on Queensland motorways were of a lower quality than those in other regions.

While sign condition was noted to be “typically high”, Queensland has a high proportion (6%) of low condition signs. Most other jurisdictions have less than 1% of low condition signs. Queensland also has a high proportion of obscured speed signs (7%) and the low readability result (3%) when compared with other jurisdictions. Electronic signs have a very low detection rate - low refresh rates were a problem.



Please note: these studies were limited to speed signs and lines on highways and motorways only.