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# FINAL REPORT

## R54 – Automated Collection of AusRAP Road Attributes using DVR and Pattern Recognition Techniques – Y3 (2019/20)

ARRB Project No.: 014962

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# SUMMARY



This report presents the research methodology, experiments, results, analysis, and future research directions for the automated collection of AusRAP road attributes using Digital Video Recorded (DVR) and pattern recognition techniques. The deep learning based 2-D segmentation and classification methods using DVR data for identifying AusRAP attributes are presented. The methods were used to develop new models and functions to detect AusRAP attributes. The models were evaluated on test data and incorporated into the development of software for automatically identifying AuSRAP attributes. The results and instructions on how to use the developed software are presented in this report.

In all, 61 models (one for each attribute) and 9 functions have been developed to detect AusRAP attributes from video files and associated metadata.

The individual models have been evaluated using training, testing, and misclassification errors. Some models provided very high accuracy (above 90%); however, some of the models provided low accuracy and many misclassifications. Based on the case study, the attributes that can be detected with high accuracy at the 10 m level include:

- delineation
- road signs
- chevron alignment markers
- poles/posts
- linemarkings
- traffic signals at intersections
- metal safety barriers.

The misclassifications and the failure of the model to identify some attribute categories have impacted greatly on the accuracy of detection at the 100 m section level required by AusRAP. Only delineation and speed limit satisfy the AusRAP quality assurance process.

Further research is needed to improve the accuracy for some difficult-to-detect attributes and to reduce the level of misclassifications. The level of misclassification can be reduced with the addition of more trained objects.



# ACKNOWLEDGEMENTS

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# 1 Introduction

## 1.1 Background

For improved road safety, Queensland Department of Transport and Main Roads (TMR) routinely undertakes proactive risk assessment of the road network for the identification and treatment of high-risk sections, thereby eliminating the crash risk on the network. The risk assessment models used include Australian Road Assessment Program (AusRAP) and Australian National Risk Assessment Model (ANRAM). These models require the collection of more than 50 road attributes and roadside features at 100 m intervals, which is a very expensive exercise.

In Australia and around the world, the current systems for collecting road condition data for the above purposes are labour intensive (manual), expensive and prone to many errors. Furthermore, much of the available data is inaccurate due to changing conditions, requiring regular updates.

Automating the data collection process is essential for improving road infrastructure and reducing fatalities on the roads, by providing up-to-date and reliable datasets needed for the timely assessment of the road network.

Research has shown that 'image pattern recognition' can be adapted to develop automated systems for the collection and analysis of road safety and road condition data, providing quality road attribute data consistently and inexpensively from video data. These attributes include for road condition (e.g. deflection, cracking, rutting), road safety (e.g. AusRAP and ANRAM attributes), environmental (e.g. fire risk and vegetation encroachment), improved obstacle clearance estimates (e.g. overhead wires, roadside hazards), etc.

TMR collects vehicle mounted video data (DVR) annually over every state-controlled road, and Mobile Laser Scanning (MLS) data is available periodically. Using expertise within the Australian Road Research Board (ARRB) and Central Queensland University (CQU), supported by TMR, the purpose of this collaborative project was to develop and evaluate deep learning neural network–based methods for automating the extraction of road attributes, especially those required by AusRAP road safety risk assessment models.

## 1.2 Aims and Objectives

The main aim of the project was to develop a process for automating the extraction of road attributes from DVR video using advanced image analysis. The automatic collection of road attributes from video data using machine learning techniques and cross-validation with other data sources has the potential to provide a range of value-added products for road condition, road safety, environmental and improved obstacle clearance estimates consistently and inexpensively.

Specific objectives of the project included the following:

- Review video (DVR) and MLS data sources to determine their usefulness and applicability.
- Develop deep learning techniques for automatically identifying road infrastructure features and roadside hazards for AusRAP and ANRAM models.
- Incorporate the techniques into an automatic system (software program) for the assessment of road safety and road rating.
- Undertake a case study to demonstrate the application of the program to collect road attributes from selected state-controlled roads.

# 2 Review of Data Sources

## 2.1 AusRAP Attributes Investigated

At the start of the project, the AusRAP attributes were reviewed. Table 2.1 lists the complete list of road attributes investigated over the course of the project. The first 26 attributes listed in Table 2.1 were identified as suitable to be extracted from video data. In addition, road name, road curvature, grade, GPS location coordinates and distance can be extracted automatically from the DVR metadata. These additional attributes, combined with the first 26 attributes, were determined to be the critical ones required for assessing vehicle occupant risk in AusRAP.

As the project progressed, the initial list of AusRAP attributes/categories was extended, and new attributes/categories were added.

Table 2.1: List of AusRAP attributes identified at the beginning of the project

| No | Attribute | No | Attribute |
|---|---|---|---|
| 1 | Area type | 22 | Sidewalk – passenger-side |
| 2 | Centreline rumble strip | 23 | Speed limit |
| 3 | Delineation | 24 | Speed management/traffic calming – speed humps |
| 4 | Facilities for bicycles – pick if we can see | 25 | Street lighting |
| 5 | Intersection type | 26 | Vehicle parking |
| 6 | Lane width | 27 | Bicycle flow |
| 7 | Median type | 28 | Motorcycle flow |
| 8 | Number of lanes | 29 | Pedestrian flow |
| 9 | Paved shoulder – driver-side | 30 | Carriageway code |
| 10 | Paved shoulder – passenger-side | 31 | Intersection legs |
| 11 | Pedestrian crossing – inspected road | 32 | Intersection quality |
| 12 | Pedestrian fencing | 33 | Right turn lane |
| 13 | Quality of curve | 34 | Left slip lane |
| 14 | Road condition | 35 | Left turn lane |
| 15 | Roadside severity – driver-side distance | 36 | Sidewalk – driver-side |
| 16 | Roadside severity – driver-side object | 37 | Sidewalk – passenger-side |
| 17 | Roadside severity – passenger-side distance | 38 | Pedestrian crossing sign |
| 18 | Roadside severity – passenger-side object | 39 | Curvature |
| 19 | Roadworks sign | 40 | Pedestrian fencing |
| 20 | School zone warning | 41 | Service road |
| 21 | Shoulder rumble strips | | |

## 2.2 Data Sources

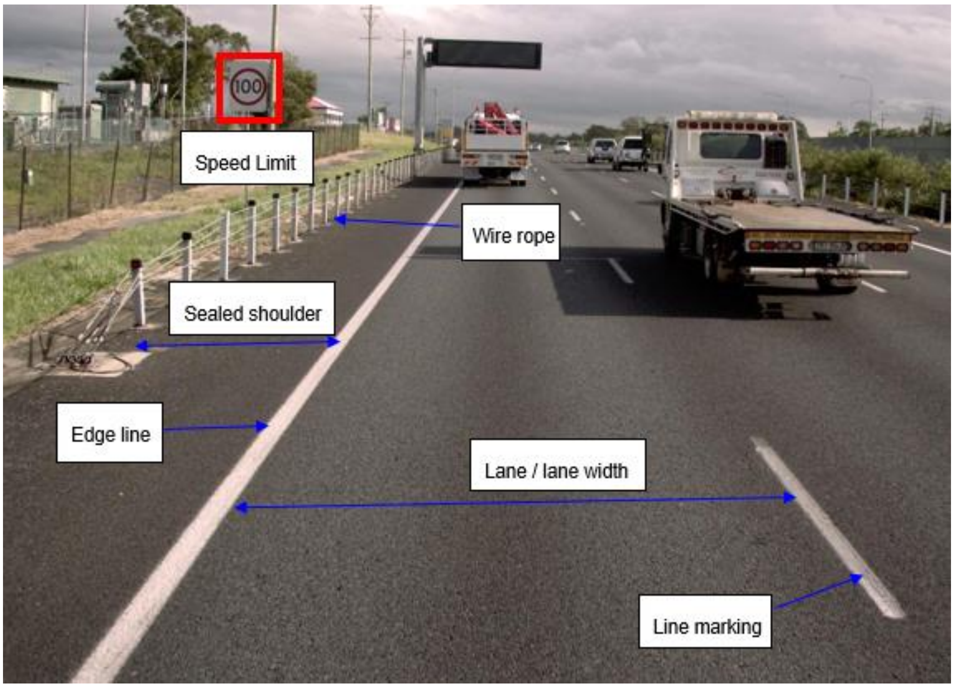
The following 2 data sources were investigated to assess their usefulness and practicality for the automatic collection of AusRAP attributes:

- Digital Video Recorded (DVR) data – preferred source, DVR for state roads readily available
- MLS (Mobile Laser Scanning) data

### 2.2.1 Road Survey Video Data (DVR)

In order to automatically detect the AusRAP attributes, video data from TMR Digital Video Recorded (DVR) was used. The video data was collected using a special survey vehicle, equipped with 4 cameras (forward camera, right camera, left camera and rear camera). After analysing the videos, the video data from the front camera was found to be appropriate to extract the AusRAP variables. Suitable frames were extracted and used in the development of models to detect the attributes listed in Table 2.1. A typical example of a suitable frame is shown in Figure 2.1, showing some attributes.

Figure 2.1: Examples of attrbutes detected




To train and evaluate the accuracy levels of the deep learning models, a large number of frames from different roads were annotated. A unique RGB colour code was assigned to each attribute's category, and using the Photoshop software, the annotation of each frame having the attributes was created. Some sample annotations are shown in Figure 2.2.

Figure 2.2: Sample image frames and their annotations

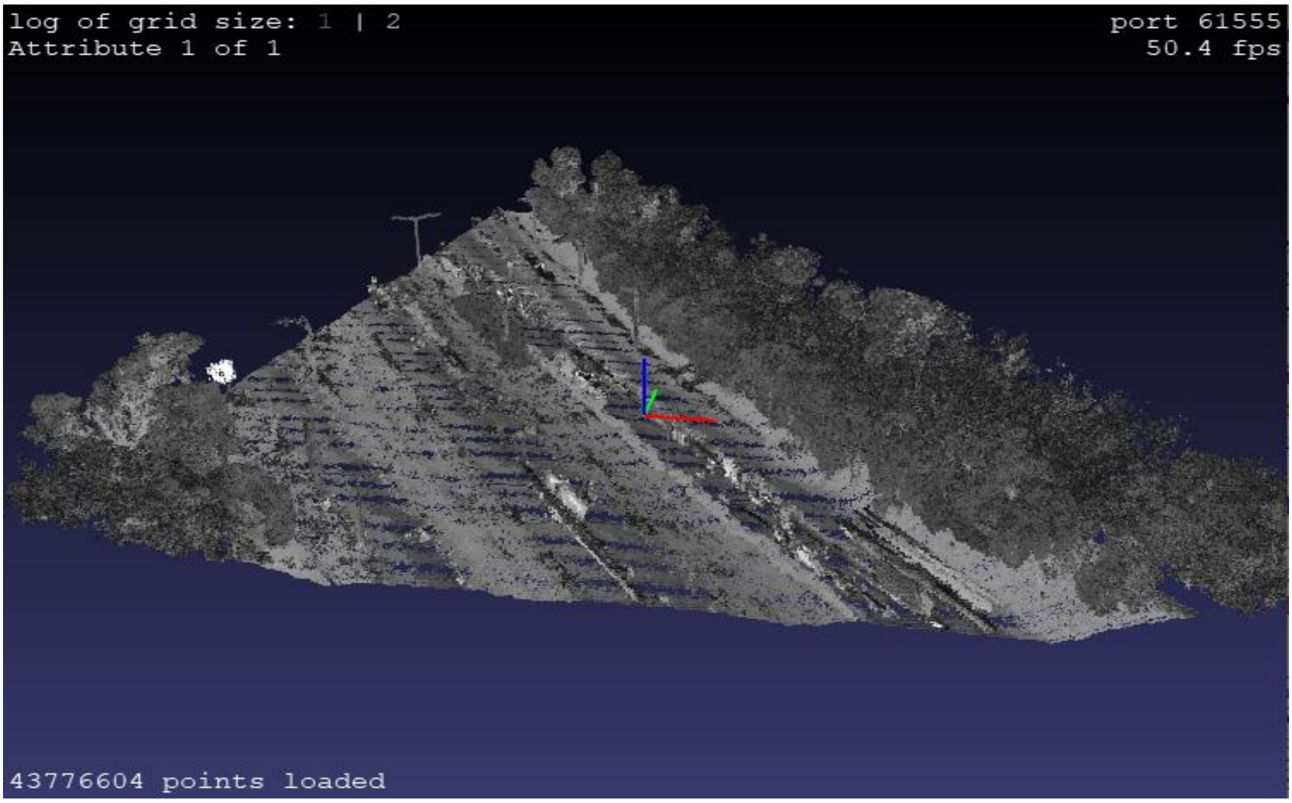

### 2.2.2 Using LIDAR Data (Mobile Laser Scanning (MLS) Data)

When collected road attribute data for AusRAP assessment a possible alternative to video footage is LIDAR (Light Detection and Ranging) data. This method creates a 3D model of the environment, compared to the 2D photographic images produced by a video camera.

As part of the initial investigation into the possibilities of using LIDAR data for this study, several specific objects were extracted and analysed. The main source of information that can be used for object recognition is 'intensity'. Intensity is a measure of the return strength of the LIDAR laser pulses. In short, it measures the reflectivity of the object struck by the laser pulse, though it is affected by other factors, such as the angle of reflection. Unfortunately, intensity measurements are relative, not absolute; different laser pulses will return different intensity values for the same object, depending on other factors such as the angle of reflection and the distance to the object. This makes it difficult to map intensity values to object classification.

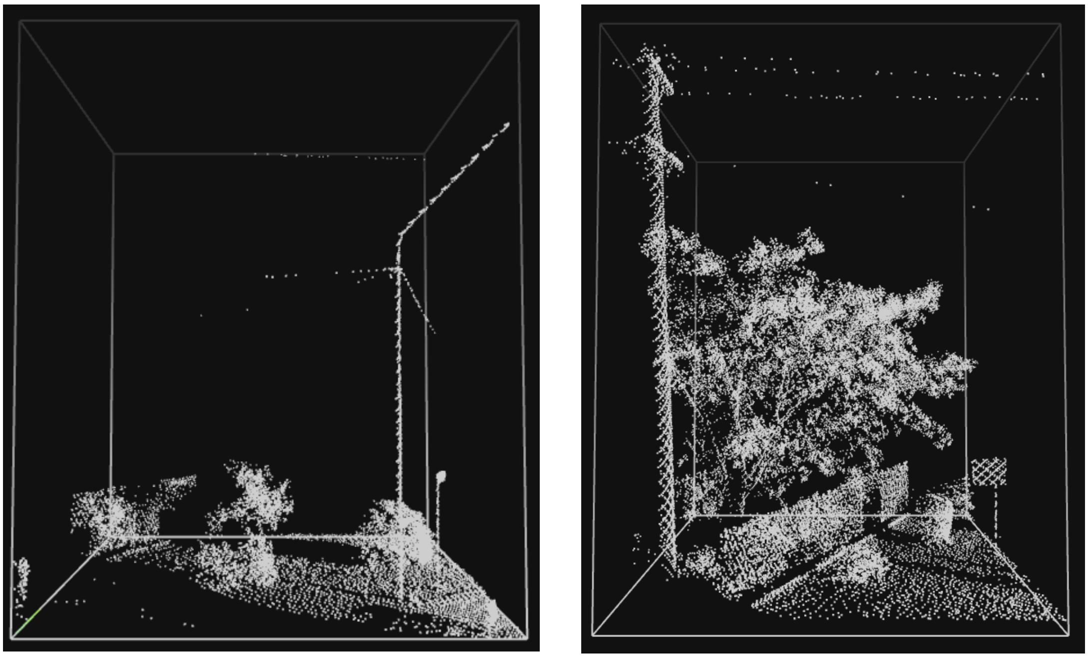
In order to investigate the detection of AusRAP attributes using MLS data, point cloud data provided by TMR from a recent survey for 4 roads, including 10L, 10A, 14A and 210A, was used. The data, provided in the form of large LAS files, was reviewed and analysed. The visualisations of samples from road 210A are shown in Figure 2.3, and Figure 2.4 visualises a part of an LAS file of 210A containing approximately 43,776,604 points.

Figure 2.3: Sample MLS data




*Source: Department of Transport and Main Roads*

Figure 2.4: Details of sample MLS data and some attributes (pole, tree, road sign and ground)

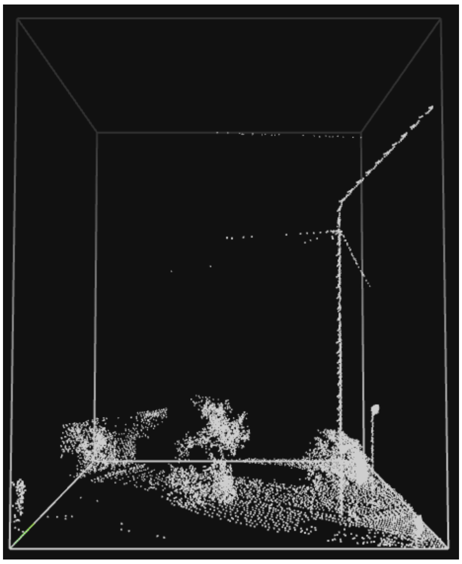


*Source: Department of Transport and Main Roads*

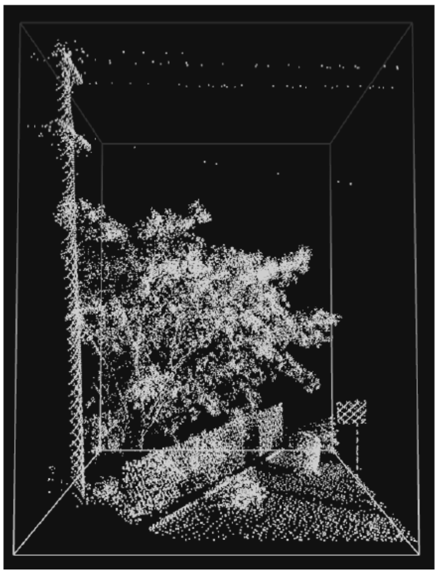
The 3-D model for the MLS data has been trained to identify 5 different attributes in roadside point cloud data. The assessment frameworks involved the creation of datasets for training and testing. Approximately 150 grids that were extracted from LAS files in different locations with different appearances were manually annotated/labelled, and then the annotated grids of point cloud data were divided into 2 groups for training and testing. Some examples of the annotation for preparing the training dataset are shown in Figure 2.5. Sample results from implementation of the framework is shown in Figure 2.6.

The detailed process and results are provided in the Year 2 summary report (Verma & Affum 2019).

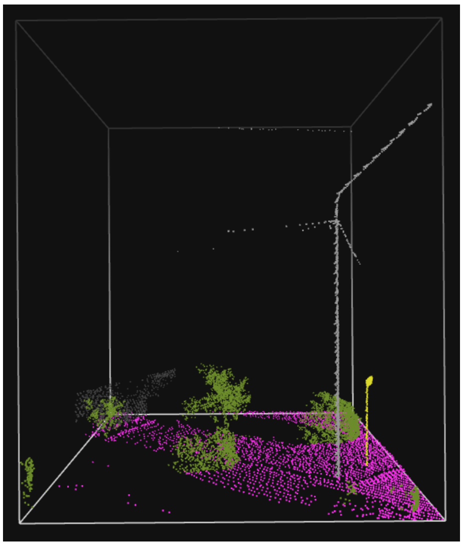
Figure 2.5: Annotation for preparing the training dataset



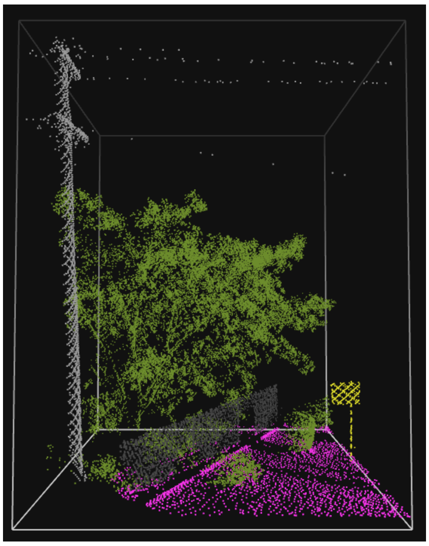
(a) Original point cloud of sample grid 1



(b) Original point cloud of sample grid 2

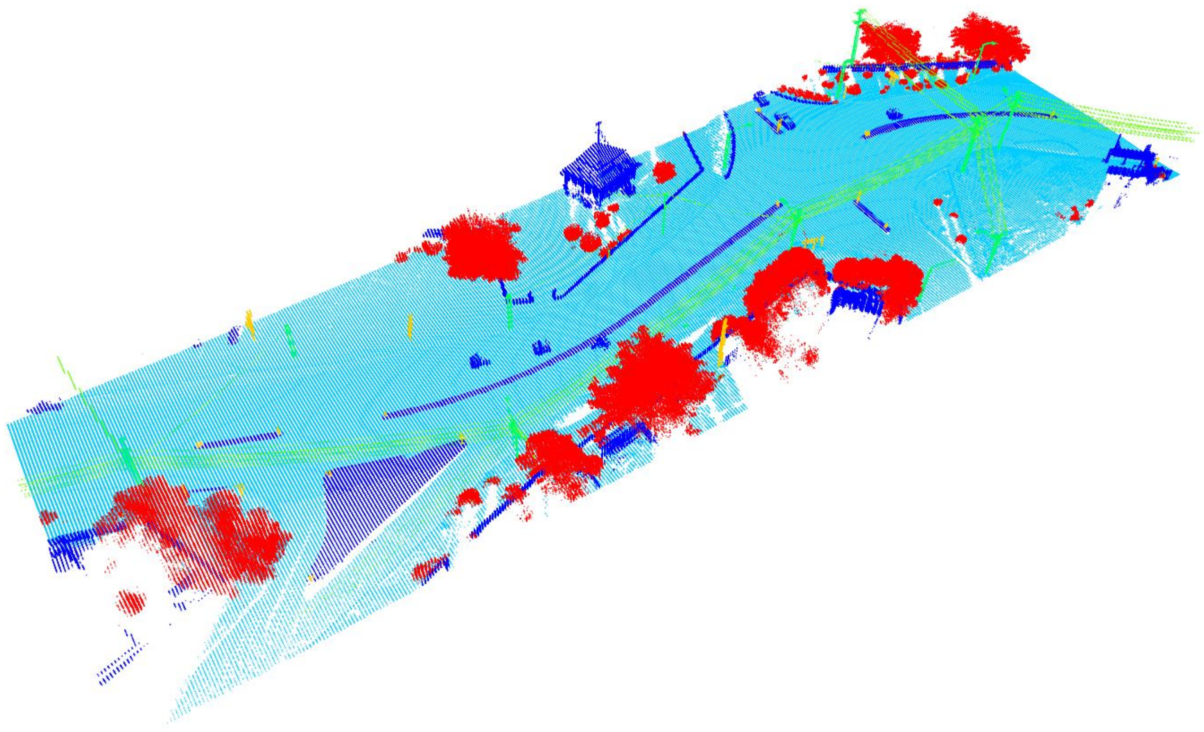


(a) Ground Truth of sample grid 1

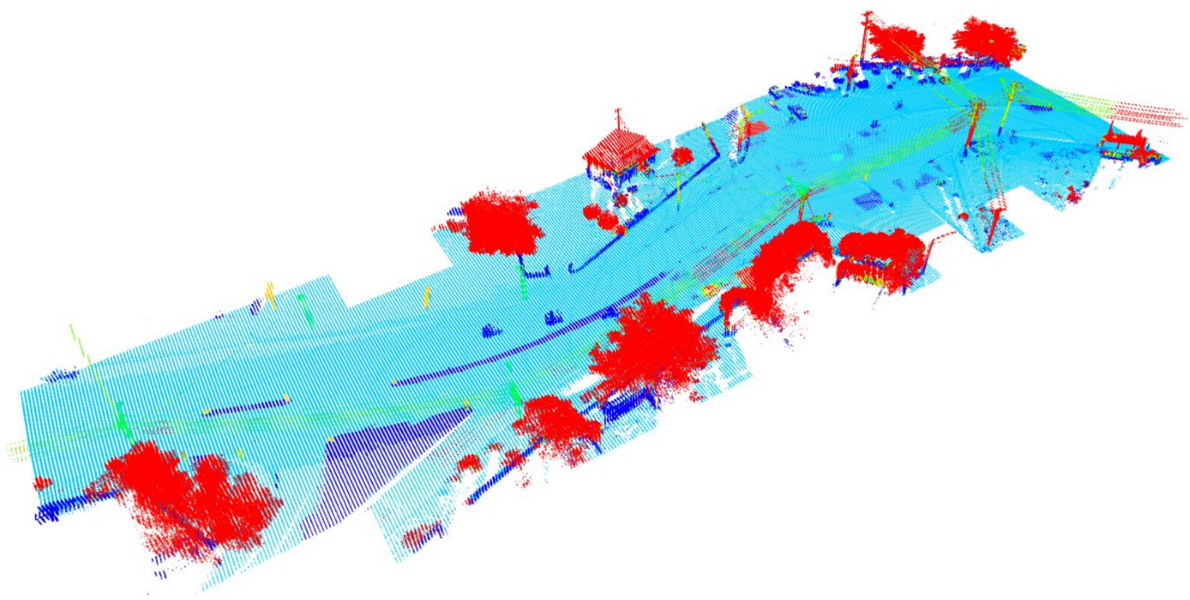


(b) Ground Truth of sample grid 2

Figure 2.6: Test results of an example road section – MLS data



(a) Ground Truth of a sample road section



(b) Recognition results of a sample road section

## 2.3 Outcome of Review of Data Sources

A system based on a 2-D segmentation and classification method using video data and on a 3-D segmentation and classification method using MLS data were developed for identifying AusRAP attributes using DVR. In addition, techniques for calculating distance were developed for both the DVR and MLS data sources. In general, both systems for MLS and DVR achieved reasonable performance for identifying AusRAP attributes. The accuracy of identifying an object is expected to improve with the increase in the number of training samples.

Although the distance calculation is more accurate based on MLS data than DVR data, there are many issues with MLS data. Some major issues include the following:

- Annotation is very difficult and time-consuming. Annotation on point cloud data requires assigning a class label to every point in the cloud point data. To develop a reasonable training data, millions of points would need to be annotated.
- A limited number of attributes can be recognized. As the current MLS data only contains the geographical coordinates and intensity of each point, some attributes cannot be identified. For example, the characters on the signs are not visible using MLS/LiDAR data only with intensity.
- MLS data is available for a limited number of roads, whilst DVR data is collected every year for all state-controlled roads.
- Visualisation of an LAS file is also very time-consuming. For example, visualising an LAS file with around 1GB requires 15 to 30 minutes on normal desktops.

The above issues limit the use of MLS data as a viable data source for automating AusRAP data for this project. Hence, the subsequent development of the software was based solely on the use of DVR data.

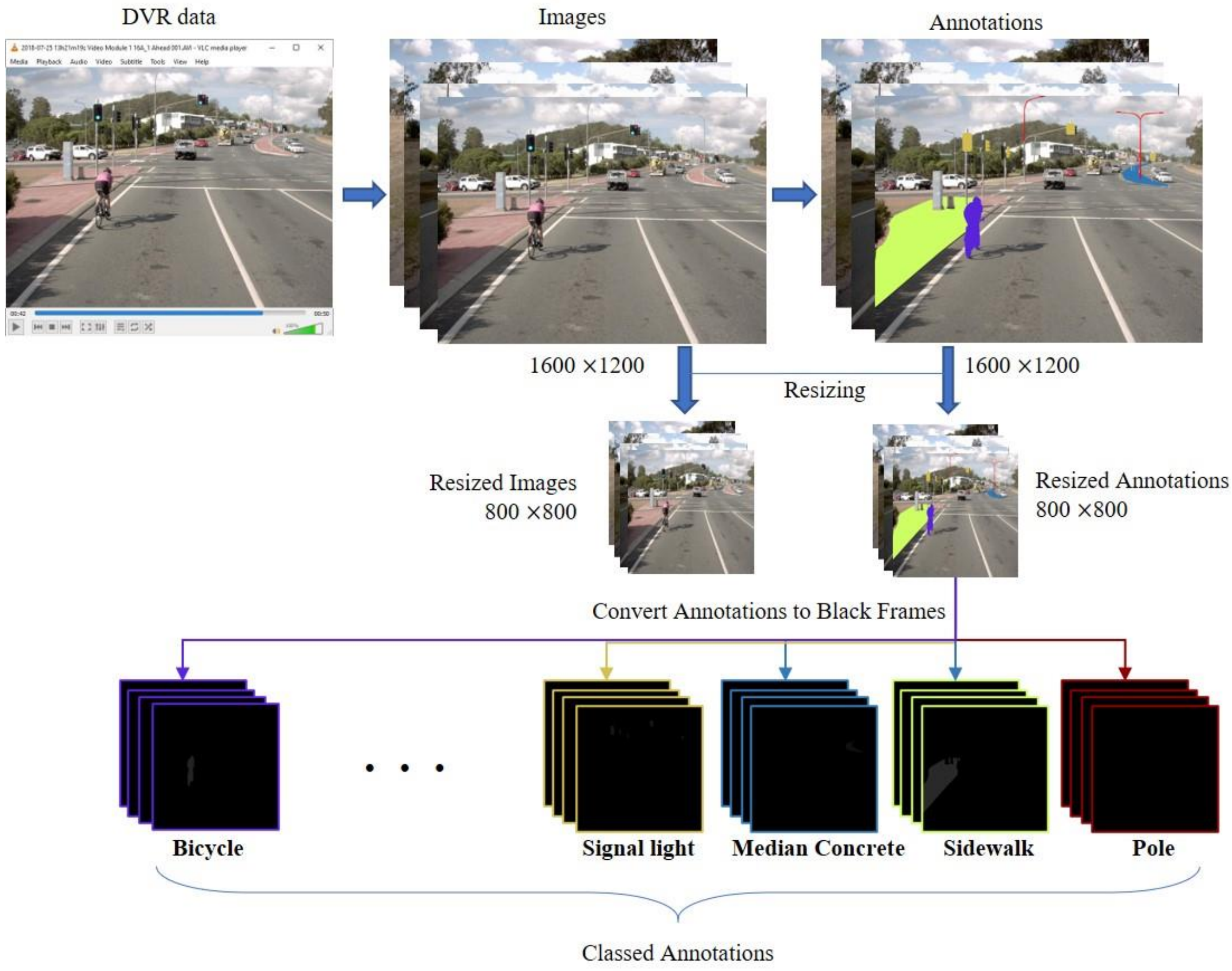
# 3 Research Framework

The research methodology for identifying road attributes based on DVR data was divided into 3 main parts: data preparation, model creation and evaluation. The details of each part are presented in the following sections.

## 3.1 Data Preparation

The training dataset was prepared for each model separately. This dataset included 2 folders: 'Images' and 'Annotations'. The main part of data preparation involved the annotation of frames, which were converted into binary frames, also called 'Class Images'. Pixels of the class images were assigned to 1 for each corresponding attribute pixel or 0 for every other pixel. All images were resized to make training more efficient. The whole process for data preparation is shown in Figure 3.1.

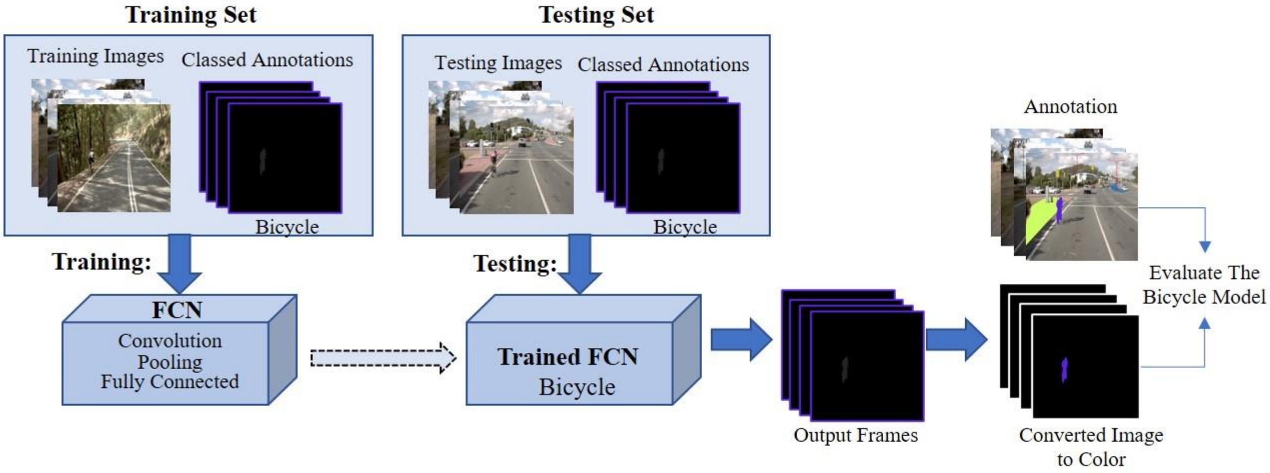
Figure 3.1: Creating the dataset from DVR data including 2 sets of images and their annotations




## 3.2 Model Creation and Training

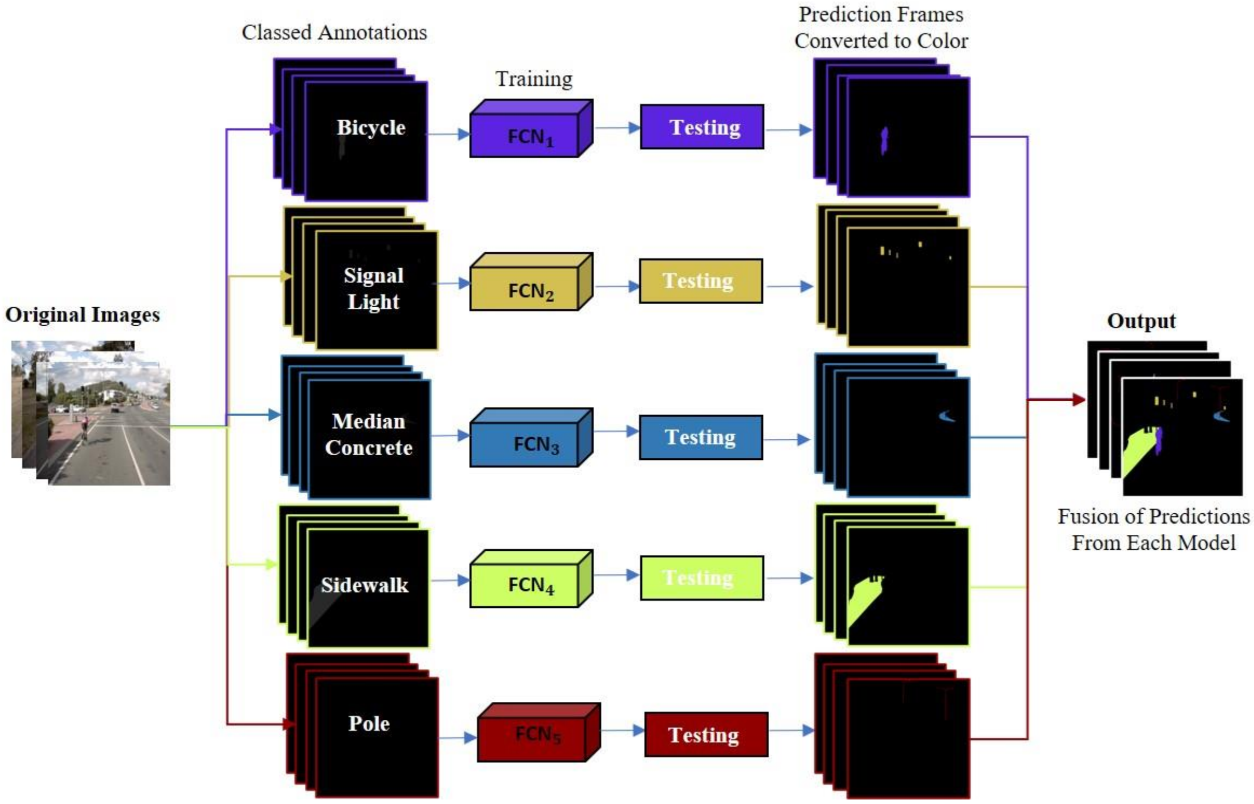
The models were created for each attribute/category. The models were trained separately using the created training and testing datasets and Fully Convolutional Network (FCN) architecture. An overview of the training and testing process (Bicycle model example) is shown in Figure 3.2. The models were trained iteratively by changing multiple parameters and iterations. The prediction frames were created and compared in order to find the best model for each attribute.

Figure 3.2: Training and testing process for bicycle flow model




The overall methodology for combining all models is illustrated in Figure 3.3. All the attributes were trained based on the process illustrated in Figure 3.2. During the testing, the prediction frames from each model were fused together to create the final predictions, where the value of each pixel was between 1 and 61 presenting the corresponding attribute (e.g. 1 means attribute 1/model 1). In the post-processing step, a decision-making approach was applied to the pixels with more than 1 class prediction. These pixels were assigned to a class with higher attribute probability. Finally, frames were converted into coloured frames to evaluate the final visualised prediction by comparing it with the annotation.

Figure 3.3: 2-D segmentation and classification using FCN




Overall, 65 models, as described below, were developed and trained:

1. **Road:** One model has been trained for Road attribute.
2. **Line:** One model has been trained for Line attribute.
3. **Pole:** One model has been trained for Pole attribute.

4. **Speed sign model**: 11 separate speed sign models have been trained including: Sign 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110.
5. **Median type:** 10 different models have been trained including: Metal barrier, Concrete barrier, Median concrete, Median grass, Flexi-post, Central hatching, Line, Motorcycle-friendly barrier, One-way and Wire rope barrier.
6. **Rumble strip:** One model has been trained and a function has been written to differentiate between shoulder and centreline rumble strips.
7. **Roadside severity:** 12 models have been trained for the various roadside object categories, 4 of them are the same models as median types (Metal barrier, Concrete barrier, Motorcycle-friendly barrier, Wire rope barrier). Functions have been written to differentiate these roadside severity types from median types. Roadside severity models are available for Metal barrier, Concrete barrier, Motorcycle-friendly barrier, Wire rope barrier, Aggressive vertical face, Upward slope, Deep drainage ditch, Tree, Pole/post, Rigid structure, Unprotected barrier end, and Large boulders.
8. **Intersection type:** 5 different models have been trained including Merge Lane, Roundabout, Signal light, Railway sign, Railway Crossing sign.
9. **Intersection Legs:** 2 models have been trained including Intersection 3-leg and Intersection 4-leg.
10. **Left Turn Lane:** One model has been trained for Left turn lane.
11. **Right Turn Lane:** One model has been trained for Right turn lane.
12. **Left Slip Lane:** One model has been trained for Left slip lane.
13. **Quality of curve:** 2 models have been trained including chevron alignment markers (CAMs) and Curvature sign.
14. **Road surface condition:** One model has been trained called Defect.
15. **Delineation:** 2 models have been trained including: Guidepost and Line.
16. **Street lighting:** One model has been trained and a function has been written to differentiate the street lighting from other types of poles.
17. **Pedestrian crossing facilities**: 4 models have been trained including Pedestrian crossing, Pedestrian sign, Signal light (the same as Intersection type), Refuge.
18. **Pedestrian fencing:** One model has been trained for Pedestrian fencing attribute.
19. **Sidewalk:** One model has been trained for Sidewalk formal attribute.
20. **Vehicle parking:** One model called Parking slot has been trained for vehicle parking.
21. **Bicycle facilities:** 3 models have been trained including Segregated bicycle path with barrier, Dedicated bicycle lane on roadway, Signed shared roadway.
22. **Roadworks:** 2 models have been trained including roadwork warning signs and other roadwork signs.
23. **School zone warning:** One model for school zone static sign has been trained.
24. **Motorcycle observed flow:** One model has been trained for Motorcycle attribute.
25. **Bicycle observed flow:** One model has been trained for Bicycle attribute.
26. **Pedestrian observed flow**: One model has been trained for Pedestrian attribute.

In addition to the above models, functions have been written determine the locations, extract information, measure various distances, etc. for various AusRAP attributes. Specifically, functions have been written to:

1. retrieve information from the metadata such as Road name, Chainage, Latitude and Longitude and Carriageway
2. find the distance between the road/edge line and the objects
3. find if the objects are located passenger side/driver side/median/across the road
4. find safety barriers such as Metal, Concrete, Metal MC friendly, Wire rope, etc. for median and roadside severity
5. decide if Rumble strips are located in centre or shoulder

6. find the Street lights from the detected poles
7. differentiate the Paved shoulder from the road
8. differentiate the Service Road from the main road
9. find flow of pedestrians, motorcycles, and bicycles.

## 3.3 Evaluation

To evaluate the model, the prediction results were compared with the original annotations, which were manually created. Three evaluation measures were used as follows:

- Training accuracy – the accuracy of the model was calculated during the training process on training data. The training process was evaluated using this accuracy calculation.
- Testing accuracy – the trained models were evaluated on testing data. The testing data, which included 281 frames, were selected from different roads having all the attributes. This testing data set was totally new from the trained models and had not been used during the training process, and therefore, they provided an accurate validation of the model.
- Misclassification – the number of frames with misclassified attributes among the 281 frames were counted.

# 4 Implementation and Results

## 4.1 Training and Testing Datasets

A large dataset containing images of the attributes investigated was created for training and testing purposes. Approximately 2,273 images from different locations with different appearances were chosen and manually annotated/labelled, and then the images and annotations were divided into training and testing sets. The training dataset comprises between 40 and 50 frames for each attribute. The testing dataset was totally separate from the training dataset. There were 440 images and their corresponding annotations in the testing dataset, including 5 to 10 frames from each attribute. Some examples of the training and testing datasets are shown in Figure 4.1.

Figure 4.1: Creation of training and testing datasets


The training time of a deep learning model depends on 3 main factors: the depth of the network, the number of iterations and the size of the dataset. To find the best combination of these parameters, the models were tuned by changing one parameter at a time. To optimise the training time, a customised training dataset was created for each model by using all (approximately 50) training frames and selecting only 5 frames of other attributes. Using this technique, a smaller dataset of almost 350 frames including all attributes was created. The validation results proved that this technique is appropriate for optimising the size of the training dataset, which significantly reduces the training time.

To provide a meaningful evaluation, all trained models were tested on the same testing dataset. The testing dataset contained 281 images created by selecting 5 frames from each attribute. The real number of frames per attribute was higher, though, since most of the time there was more than 1 attribute in each frame.

## 4.2 Results

The testing results at the 10 m frame level based on 281 images and annotated frames that were not used during the training process (i.e., a different set of images separate from the training dataset) are listed in Table 4.1.

Table 4.1: Results of all trained models

| No | Model | Accuracy on test data [%][(1)] | Misclassifications [%](Num)[(2)] | No | Model | Accuracy on test data [%][(1)] | Misclassifications [%](Num)[(2)] |
|---|---|---|---|---|---|---|---|
| 1 | Aggressive vertical face | 40 | 2.4 (7) | **32** | Railway sign | 100 | 0 (0) |
| 2 | Bicycle | 100 | 7.4 (21) | **33** | Refuge | 83 | 5.6 (16) |
| 3 | CAM | 100 | 1.0 (3) | **34** | Right turn lane | 87 | 3.5 (10) |
| 4 | Central hatching | 87 | 1.4 (4) | **35** | Rigid structure | 60 | 2.1 (6) |
| 5 | Concrete barrier | 100 | 10.3 (29) | **36** | Road | 80 | 0 (0) |
| 6 | Continue central turning lane | 100 | 2.1 (6) | **37** | Roadwork warning sign | 100 | 0 (0) |
| 7 | Curvature sign | 100 | 0.3 (1) | **38** | Roadwork sign | 100 | 0.3 (1) |
| 8 | Bicycle lane | 94 | 0.7 (2) | **39** | Roundabout | 100 | 1.7 (5) |
| 9 | Deep drainage ditch | 93 | 2.4 (7) | **40** | Rumble strip | 79 | 2.1 (6) |
| 10 | Defect | 71 | 7.8 (22) | **41** | School zone sign | 100 | 2.1 (6) |
| 11 | Flexipost | 60 | 0 (0) | **42** | Segregated bicycle path | 88 | 2.1 (6) |
| 12 | Guidepost | 77 | 0.7 (2) | **43** | Sidewalk formal | 60 | 4.6 (13) |
| 13 | Intersection leg 3 | 60 | 2.1 (6) | **44** | Signal light | 93 | 0 (0) |
| 14 | Intersection leg 4 | 40 | 0.3 (1) | **45** | Signed shared roadway | 75 | 2.1 (6) |
| 15 | Large boulders | 64 | 4.6 (13) | **46** | Slip lane | 80 | 0 (0) |
| 16 | Left turn lane | 100 | 2.1 (6) | **47** | Sign 10 | 100 | 0 (0) |
| 17 | Line | 92 | 0 (0) | **48** | Sign 20 | 33 | 2.8 (8) |
| 18 | MC friendly barrier | 100 | 4.6 (11) | **49** | Sign 30 | 100 | 6.7 (19) |
| 19 | Median concrete | 71 | 4.6 (11) | **50** | Sign 40 | 100 | 0.7 (2) |
| 20 | Median grass | 92 | 6.4 (18) | **51** | Sign 50 | 100 | 2.1 (6) |
| 21 | Merge lane | 100 | 0 (0) | **52** | Sign 60 | 100 | 1.0 (3) |
| 22 | Metal barrier | 71 | 7.4 (21) | **53** | Sign 70 | 82 | 2.1 (6) |
| 23 | Motorcycle | 100 | 1.0 (3) | **54** | Sign 80 | 100 | 2.1 (6) |
| 24 | One way | 100 | 3.1 (9) | **55** | Sign 90 | 100 | 1.7 (5) |
| 25 | Parking slot | 83 | 43.4 (123) | **56** | Sign 100 | 88 | 2.1 (6) |
| 26 | Pedestrian | 100 | 6.4 (18) | **57** | Sign 110 | 100 | 0.7 (2) |
| 27 | Pedestrian crossing | 44 | 6.0 (17) | **58** | Tree | 100 | 3.5 (10) |
| 28 | Pedestrian fencing | 100 | 5.6 (16) | **59** | Unprotected barrier end | 83 | 2.1 (6) |
| 29 | Pedestrian crossing sign | 100 | 0 (0) | **60** | Upward slope | 100 | 18.3 (52) |
| 30 | Pole | 83 | 2.8 (8) | **61** | Wire rope barrier | 88 | 0 (0) |
| 31 | Railway crossing sign | 100 | 0.7 (2) | | | | |

1. *Accuracy [%] = (detected attributes in test frames/total number of attributes in test frames) * 100.*
2. *Number within brackets represents misclassifications (e.g. (6) means that 6 frames out of 281 detected by attribute model did not contain that attribute).*

The status of the models/functions for all the attributes/categories of road features investigated is provided in Table 4.2.

Table 4.2: Status of all attributes investigated.

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| **1.** Road | Road | Completed | Function |
| **2.** Road name | Road name | Completed | Function |
| **3.** Chainage | Chainage | Completed | Function |
| **4.** Frame number | Frame number | Completed | Function |
| **5.** Latitude | Latitude | Completed | Function |
| **6.** Longitude | Longitude | Completed | Function |
| **7.** Carriageway | A-divided forward direction | Completed | Function |
| | B-divided reverse direction | Completed | Function |
| | U-undivided | Completed | Function |
| **8.** Speed limit | Speed (value) | Completed | Model |
| | 10 | Completed | Model |
| | 20 | Completed | Model |
| | 30 | Completed | Model |
| | 40 | Completed | Model |
| | 50 | Completed | Model |
| | 60 | Completed | Model |
| | 70 | Completed | Model |
| | 80 | Completed | Model |
| | 90 | Completed | Model |
| | 100 | Completed | Model |
| | 110 | Completed | Model |
| | Passenger side | Completed | Function |
| | Median | Completed | Function |
| | Drivers side | Completed | Function |
| **9.** Median type | Safety barrier – metal | Completed | Model/function |
| | Safety barrier – concrete | Completed | Model/function |
| | Physical median width (distance) | Completed | Model |
| | Median concrete | Completed | Model |
| | Median grass | Completed | Model |
| | Continuous central turning lane | Completed | Model |
| | Flexipost | Completed | Model |
| | Central hatching (width) | Completed | Model |
| | Centreline | Completed | Model |
| | Motorcyclist friendly barrier | Completed | Model/function |
| | One way | Completed | Model |
| | Wide centreline (width) | Completed | Model |
| | Safety barrier – wire rope | Completed | Model/function |
| **10.** Centreline rumble strip | Not present | Completed | Model |
| | Present | Completed | Model |
| **11.** Severity – RHS | Distance | Completed | Function |
| **12.** Severity – RHS | Safety barrier – metal | Completed | Model |

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| | Safety barrier – concrete | Completed | Model |
| | Safety barrier – metal mc friendly | Completed | Model |
| | Safety barrier – wire rope | Completed | Model |
| | Aggressive vertical face | Completed | Model |
| | Upwards slope – (rollover gradient) | Completed | Model |
| | Upwards steep slope (> 75°) | Difficult to measure angle/slope in images. No clear samples for training | |
| | Deep drainage ditch | Completed | |
| | Downwards slope | Difficult to measure angle/slope in images. No clear samples for training | No model |
| | Cliff or the like | Difficult to define cliff samples from 2D image to train the model. | No model |
| | Tree > 10 cm | Completed | Model |
| | Non-frangible sign/post/pole >= 10 cm | Completed | Model |
| | Frangible sign/post/pole < 10 cm | Completed | Model |
| | Rigid structure/bridge or building | Completed | Model |
| | Semi-rigid structure or building | This attribute contains many objects. They will misclassify other attributes. | No model |
| | Unprotected barrier end | Completed | Model |
| | Large boulders >= 20 cm high | Completed | Model |
| | None (> 20 m) | Difficult to see/detect in videos > 20 m | No model |
| **13.** Severity – LHS | Distance | Completed | Model |
| **14.** Severity – LHS | Safety barrier – metal | Completed | Function |
| | Safety barrier – concrete | Completed | Model |
| | Safety barrier – metal MC friendly | Completed | Model |
| | Safety barrier – wire rope | Completed | Model |
| | Aggressive vertical face | Completed | Model |
| | Upwards slope – (rollover gradient) | Difficult to measure angle/slope in images. No clear samples for training | Model |
| | Upwards steep slope (> 75°) | Completed | |
| | Deep drainage ditch | Difficult to measure angle/slope in images. No clear samples for training | |
| | Downwards slope | Difficult to define cliff samples from 2D image to train. | No model |
| | Cliff or the like | Difficult to define cliff samples from 2D image to train the model. | No model |
| | Tree > 10 cm | Completed | Model |
| | Non-frangible sign/post/pole >= 10 cm | Completed | Model |
| | Sign/post/pole < 10 cm | Completed | Model |
| | Rigid structure/bridge or building | This attribute contains many objects. They will misclassify other attributes. | Model |
| | Semi-rigid structure or building | Completed | Model |
| | Unprotected barrier end | Completed | Model |
| | Large boulders >= 20 cm high | Difficult to see/detect in videos > 20 m | No model |
| | None (> 20 m) | Completed | Model |

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| **15.** Shoulder rumble strip | Not present | Completed | Model |
| | Present | Completed | Model |
| **16.** Paved shoulder – RHS | Width (Measure) | Completed | Model |
| **17.** Paved shoulder – LHS | Width (Measure) | Completed | Model |
| **18.** Intersection type | Merge lane | Completed | Model |
| | Roundabout | Completed | Model |
| | Signalised | Completed | Model |
| | Unsignalised | | Model |
| | Railway Crossing – passive (signs only) | Completed | Model |
| | Railway Crossing – active (flashing lights/boom gates) | Completed | Model |
| | Mini roundabout | Will misclassify other attributes | Model |
| | Median crossing point – informal | Will misclassify other attributes | Model |
| | Median crossing point – formal | Will misclassify other attributes | Model |
| | None | | No model |
| **19.** Intersection legs | 2 | Legs are misclassifying with each other | Model |
| | 3 | Completed but it was not easy | Model |
| | 4 | Completed but it was not easy | Model |
| | 5 | Difficult to detect | No model |
| | 6 | Difficult to detect | No model |
| | 6+ | Difficult to detect | No model |
| **20.** Right turn lane | No right turn lanes on through road | Not in AusRAP attributes | No model |
| | Right turn lane in direction of travel | Completed | Model |
| | Right turn lane in opposite direction of travel | Not always visible | No model |
| | Right turn lane in both directions of travel | Not always visible | No model |
| **21.** Left turn lane | No left turn lanes on through road | Not in AusRAP attributes | No model |
| | Left turn lane in direction of travel | Completed | Model |
| | Left turn lane in opposite direction of travel | Not in AusRAP attributes | No model |
| | Left turn lane in both directions of travel | Not in AusRAP attributes | No model |
| **22.** Left slip lane | No left slip lane on through road | Not always visible | No model |
| | Left slip lane in direction of travel | Completed | Model |
| | Left slip lane in opposite direction of travel | Not always visible | No model |
| | Left slip lane in both directions of travel | Not always visible | No model |

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| **23.** Intersection quality | Advanced intersection sign present | Identified based on sign. We will try to detect based on road in future research. | Model |
| **24.** Property access points | Count | Not always visible. We will try to develop better road model in future research. | No model |
| **25.** Number of lanes | Count in gazettal | Completed | Model |
| **26.** | Count in anti-gazettal | Road is not always visible, even when visible, lanes are not clear. We may use right video. | Model |
| **27.** Lane width | Width (distance) | Completed | Model |
| **28.** Curvature | Inside curve radius angle | Difficult to measure angle. Will try again. | No model |
| **29.** Quality of curve | CAMs present | Completed | Model |
| | Advisory curve sign present | Completed | |
| | Advisory curve and speed sign present | Completed | Model |
| **30.** Grade | Grade records the gradient of the road along its length | There is nothing in images which tells gradient. We may try in future research. | No model |
| **31.** Road condition | Road surface condition<br>Good | Completed | Model |
| | Medium | Only good/poor | No model |
| | Poor | Completed | Model |
| **32.** Skid resistance | Sealed – adequate | Other data sources to be used | No model |
| | Sealed – medium | Other data sources to be used | No model |
| | Sealed – poor | Other data sources to be used | No model |
| | Unsealed – adequate | Other data sources to be used | No model |
| | Unsealed – poor | Other data sources to be used | No model |
| **33.** Delineation | Centreline | Completed | Model |
| | Edge line | Completed | Model |
| | Guideposts | Completed | Model |
| | None | Completed | Model |
| **34.** Street lighting | Not present | Completed only based on poles | Model |
| | Present | Completed only based on poles | Model |
| **35.** Pedestrian crossing | Inspected road<br>Grade separated facility – no ped fencing | No specific object/sign to detect | No model |
| | Signalised with refuge | Completed | Model |
| | Signalised without refuge | Completed | Model |
| | Unsignalised marked crossing with refuge | Completed | Model |
| | Unsignalised marked crossing without refuge | Completed | Model |
| | Refuge only | Completed | Model |
| | No facility | Completed | Model |
| | Grade separated facility – ped fencing present | Completed | Model |
| | Unsignalised raised marked crossing with refuge | Raised or Non-Raised – recognised as 1 type. Will misclassify other attributes | Model |
| | Unsignalised raised marked crossing without refuge | Raised or Non-Raised – recognised as 1 type | Model |

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| | Raised unmarked crossing with refuge | Raised or Non-Raised – recognised as 1 type | Model |
| | Raised unmarked crossing without refuge | Raised or Non-Raised – recognised as 1 type | Model |
| **36.** Pedestrian crossing | Quality<br>Pedestrian signage | Completed | Model |
| **37.** Pedestrian crossing – intersecting road | Intersecting road<br>Grade separated facility – no ped fencing | No specific object/sign | No model |
| | Signalised with refuge | Completed (only if visible) | Model |
| | Signalised without refuge | Completed | Model |
| | Unsignalised marked crossing with refuge | Completed (only if visible) | Model |
| | Unsignalised marked crossing without refuge | Completed | Model |
| | Refuge only | Completed (only if visible) | Model |
| | No facility | Completed (only if visible) | Model |
| | Grade separated facility – ped fencing present | Completed (only if visible) | Model |
| | Unsignalised raised marked crossing with refuge | Raised or Non-Raised – recognised as 1 type. Will misclassify other attributes | Model |
| | Unsignalised raised marked crossing without refuge | Raised or Non-Raised – recognised as 1 type | Model |
| | Raised unmarked crossing with refuge | Raised or Non-Raised – recognised as 1 type | Model |
| | Raised unmarked crossing without refuge | Raised or Non-Raised – recognised as 1 type | Model |
| **38.** Pedestrian fencing | Not present | Completed | Model |
| | Present | Completed | Model |
| **39.** Speed management | Not present | No sign is available. Taking surface part will misclassify other attributes | Model |
| | Present | Same as above | Model |
| **40.** Vehicle parking | None | Completed | Model |
| | Passenger side | Completed | Model |
| **41.** Parking (activities within 2 m) | Activities within 2 m of the outside edge Median | Completed | Model |
| | Drivers side | Completed | Model |
| **42.** Sidewalk – RHS | Non-physical separation distance to facility or barrier | Completed | Model |
| | Physical barrier (concrete, metal, ped fencing, hedge and so on) | Completed | Model |
| | Formal path provided (sealed) | Completed | Model |
| | Informal path provided (unsealed) | Will misclassify other attributes. | Model |
| | Width of path | Completed | Model |
| **43.** Sidewalk- LHS | Non-physical separation distance to facility or barrier | Completed | Model |

| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| | Physical barrier (concrete, metal, ped fencing, hedge and so on) | Completed | Model |
| | Formal path provided (sealed) | Completed | Model |
| | Informal path provided (unsealed) | Will misclassify other attributes. | Model |
| | Width of path | Completed | Model |
| **44.** Service road | Not present | Completed | Model |
| | Present | Completed | Model |
| **45.** Bicycle facilities | Segregated bicycle path with barrier | Completed | Model |
| | Segregated bicycle path | Completed | Model |
| | Dedicated bicycle lane on roadway | Completed | Model |
| | None | Completed | Model |
| | Extra wide outside (≥ 4.2 m) | Completed | Model |
| | Signed shared roadway | Completed | Model |
| | Shared use path | Completed | Model |
| **46.** Roadworks | No roadworks | We are only detecting roadworks, or no roadworks based on signs | No model |
| | Minor roadworks in progress | Completed | Model |
| | Major roadworks in progress | Completed | Model |
| **47.** Sight distance | Measure visibility furthest visible pavement | Difficult to measure as it is not clearly visible in images | Model |
| **48.** School zone | School zone flashing beacons | Same as static sign data | Model |
| | School zone static signs or road markings | Completed | Model |
| | No school zone warning | No specific object/sign | No model |
| | Not applicable (no school at the location) | No specific object/sign | No model |
| **49.** Crossing supervisor | Crossing supervisor not present | Difficult to detect. Will misclassify with other attributes | No model |
| | Crossing supervisor present during school time | Difficult to detect. Will misclassify with other attributes | No model |
| | Not applicable (no school at the location) | No specific object/sign | No model |
| **50.** Motorcycle flow | Count of motorcycles in opposite direction of travel | Completed | Model/function |
| **51.** Bicycle flow | Count of bicycles in both directions of travel (or opposite if did not work) | Completed | Model/function |
| **52.** Pedestrian | Count pedestrians across road | Completed | Model/function |
| **53.** Pedestrian | Count pedestrians RHS | Completed | Model/function |
| | Count pedestrians LHS | Completed | Model/function |
| **54.** Land use – RHS | Access count | Access points are not specific and not always visible in 2D images. | No model |
| | Does the building have a name | No specific object/sign/place to train the model | No model |
| | Large building count (larger than a house) | Building object – large/small – difficult to train the model | No model |
| | Number of post boxes. | No specific object/sign/place to train the model | No model |

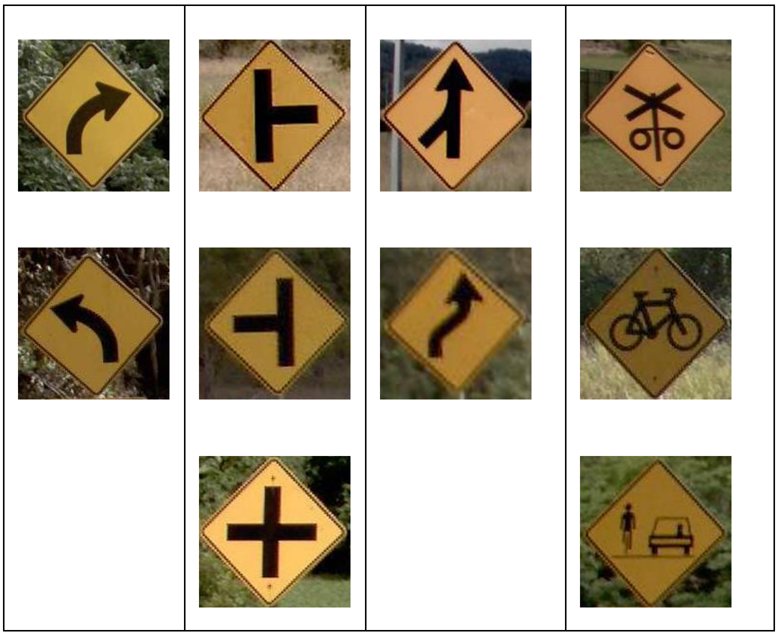
| No/Attributes | Categories | Status/Comments | Program type |
|---|---|---|---|
| | Small building count (house size or smaller) | No specific object/sign/place to train the model | No model |
| | Building location (longitudinal distance) | | No model |
| | Building location (lateral distance) | | No model |
| **55.** Land use – LHS | Access count | Access points are not specific and not always visible in 2D images | No model |
| | Does the building have a name | No specific object/sign/place to train the model | No model |
| | Large building count (larger than a house) | Building object – large/small – difficult to train the model | No model |
| | Number of post boxes. | No specific object/sign/place to train the model | No model |
| | Small building Count (house size or smaller) | No specific object/sign/place to train the model | No model |
| | Building location (longitudinal distance) | | No model |
| | Building location (lateral distance) | | No model |
| **56.** Intersecting road volume | Count of intersecting lanes (both approach and departure). | Intersection is recognised based on sign | No model |
| **57.** Area type | Rural | There are no signs to distinguish rural and urban | No model |
| | Urban (Development of congregation of houses over 200 m) otherwise rural | No single object to train. We may try again. | No model |

## 4.3 Problems and Issues

The evaluation indicated high accuracies obtained for many AusRAP attributes; however, there were issues with some attributes including failure to detect (i.e., unable to identify the attribute) or were able to detect but with large number of misclassifications or calculated incorrect values (e.g., pedestrian flow, number of lanes, etc.). The results were analysed and some detailed analyses and reasons for low accuracy are given below:

1. **Parameter tuning:** The parameters of the deep learning technique had to be tuned individually for each attribute (model). For example, the number of iterations, the number of samples, layers, filters, etc for the training process varied for each model. It was very time consuming to tune the parameters for each attribute as models had to be retrained many times taking many days of training. Sometimes after even long and different parameter tuning processes, it was not possible to get high accuracy and low misclassifications for some attributes. More research will be conducted to overcome this problem.
2. **Similar attributes**: Some attributes are very similar in shape, size and colour, so it was difficult to differentiate them. For example, Figure 4.2 shows (a) attributes with diamond frame and yellow background, (b) speed sign with similar numbers and (c) parking slots with similar colour as lines.

Figure 4.2: Example of attributes with similar shapes and colours



(a) Road signs


(b) 30 and 80 km/h signs (c) Parking slot and lines

3. **Attribute inconsistency**: Same attributes contain different distances, shapes and colours making them difficult to identify. For example, there are many types of centrelines with different gaps/shapes as shown in Figure 4.3, many types of dedicated bicycle paths (green and white colours) as shown in Figure 4.4, and 5 different types of speed signs as shown in Figure 4.5.

Figure 4.3: Three different types of centrelines

Two broken centrelines with a large gap | Two continuous centrelines with a small gap | Two continuous centrelines with a large gap

Figure 4.4: Three different types of on-road bicycle paths

| White lane with bicycle sign | Green lane with bicycle sign | Green lane without bicycle sign |
|---|---|---|

Figure 4.5: Five different types of speed signs


4. **Median vs RHS:** In some frames, it was difficult to differentiate between the location of the attributes as median or right side of the road as shown in Figure 4.6. It was difficult to say/detect that metal barrier in left frame is a median.

Figure 4.6: Location of attributes as median or right-hand side (RHS)

Speed sign 90 and Metal barrier as Median

Speed sign 90 and Metal barrier at RHS

5. **Functions do not work due to misclassifications:** Sometimes the functions do not work correctly when there are misclassifications due to similarity between attributes or the attributes are not detected, or the attributes are misclassified. Figure 4.7 shows examples of misclassification between speed signs and Figure 4.8 shows that an attribute is missing (not detected) and Figure 4.9 shows that upwards slope is misclassified as building.

Figure 4.7: Misclassification between 90 sign and 70 km/h (top frame) & between 90 sign and 100 km/h (bottom frame)

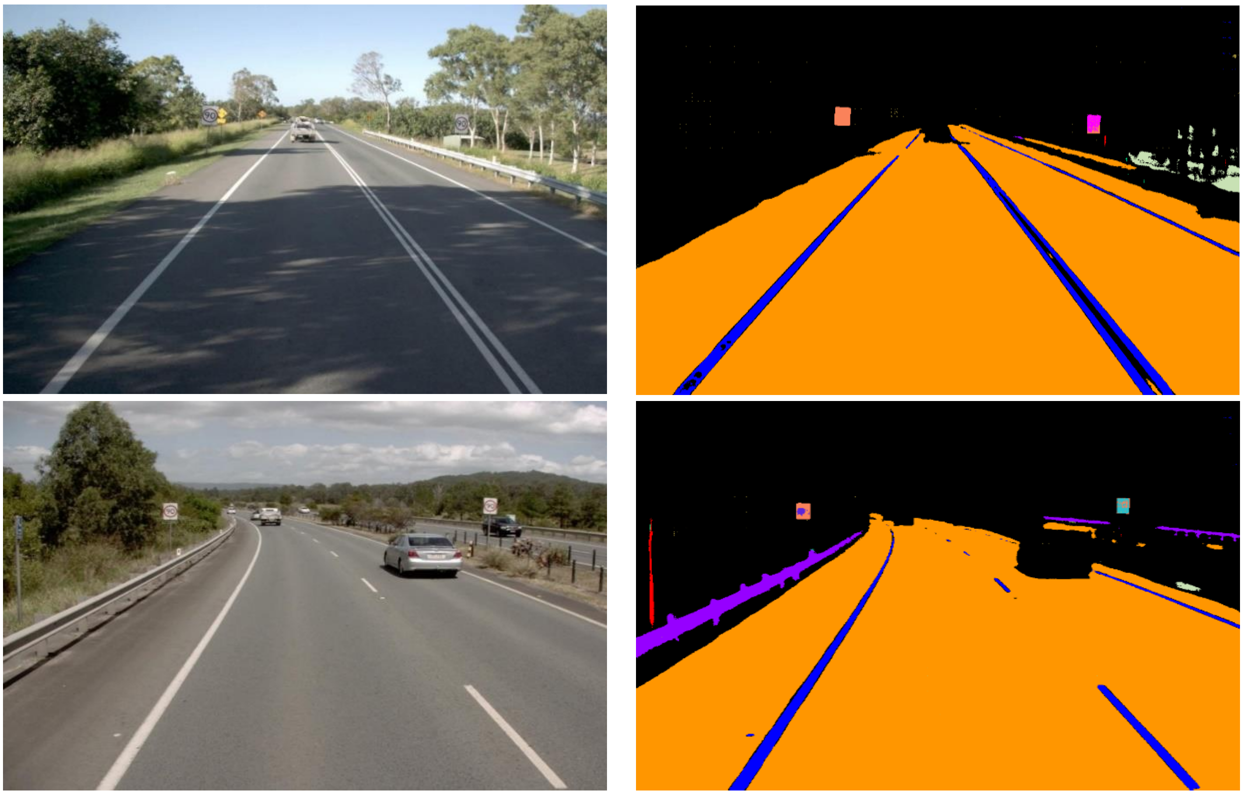


Figure 4.8: Road attribute missing in reverse direction (difficult to determine if grass is median or not)

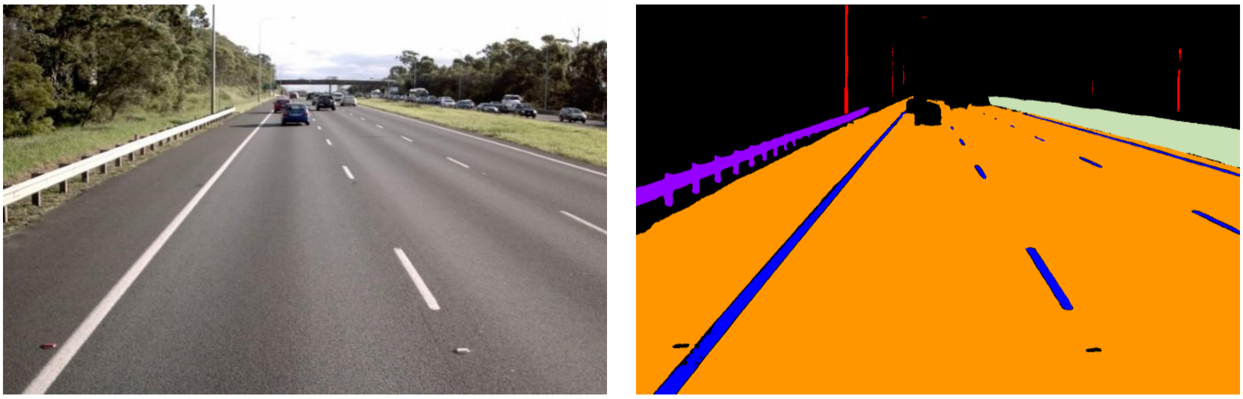
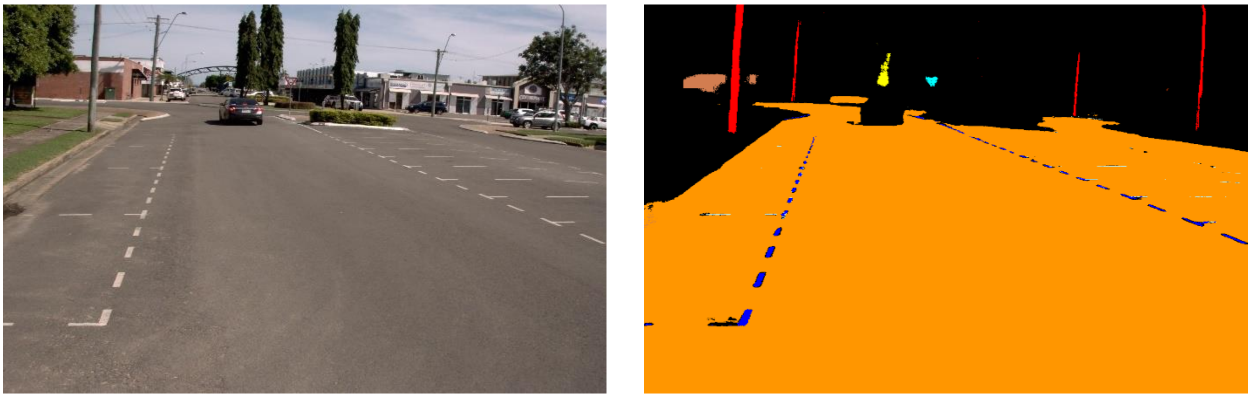


Figure 4.9: Misclassification of upward slope with part of building wall



## 4.4 The Automated Program

For ease of usage a computer program has been developed to automate the process of collecting AusRAP attributes from video data. The components and requirements are provided below.

### 4.4.1 Components

The program comprised the following components:

- ausrapProgram – The main program provided as compiled Exe file.
- vid2frame – Utility program to convert video files (*.avi files) into individual frames required by the program.
- Instruction sheet – How to use the program. Details are provided in Appendix A.

### 4.4.2 Requirements

Data required by the program was as follows:

- Video files or images (frames), usually at 10 m intervals in .jpg format >= 800x800 size
- Metadata file (e.g., 10C_23A.nvg) for the images or video file.

### 4.4.3 Output Data

The output from the program is provided in 2 files in Excel format as follows:

- Video_filename_output – The raw results provided at 10 m section level (frame) – re 1 means object detected, 0 means not detected.
- Video_filename_output100metre – Processed results provided at 100 m section level in AusRAP format by aggregated the results at the 100 m level in line with AusRAP methodology.

## 4.5 Case Study Results

The automated 'ausrapProgram' was applied to collect AusRAP attributes from selected state-controlled roads. The output for road 10A (gazetted direction) was reviewed and compared with manual assessment results. Sample outputs are shown in Appendix B.

### 4.5.1 Frame (10 m Section) Output

At the frame level (10 m) the following features were identified to a high degree of accuracy (noting that an object may be detected in several frames):

- road signs
- linemarkings
- speed limit signs (some objects were identified as a speed limit sign; this misclassification impacted the results at the AusRAP required 100 m section level)
- poles/posts
- metal safety barriers (some metal barrier sections were not identified; the impact of the missing gaps resulted in a reduced accuracy level for recording metal barriers at the AusRAP required 100 m section level).

Features that recorded low identification levels included the following:

- trees
- wire rope safety barrier
- guidepost (most of the delineators on the w-beam safety barriers were not identified). Note normal guideposts were generally detected.

### 4.5.2 100 m Section Output

At the 100 m level, the attributes (considering all categories for the attribute) that pass the AusRAP quality assurance process are:

- delineation
- speed limit (if misclassifications of other objects as speed limits are reduced).

In addition to wrong aggregation and missing gaps for safety barriers (metal, concrete and wire rope) misclassification of objects at the 10 m frame level impacted negatively on the accuracy at the 100 m level. For example, all speed limit signs on 10A were identified, but due to misclassification of some objects as 60 km/h (Figure 4.10) and 70 km/h (Figure 4.11) signs, the accuracy of reported 110 km/h section was only 67%. The problem with the misclassified objects was ratified by including these signs in the training data in the updated program. This improved the accuracy for reporting 110 km/h at 100 m level to 94% (Appendix B).

Figure 4.10: Misclassification of no U-turn sign as 60 km/h sign

Figure 4.11: Misclassification of no right-turn sign as 70 km/h sign

# 5 Conclusion

As part of a worldwide movement, the use of risk assessment models AusRAP/iRAP is dedicated to saving lives through advocating for safer road infrastructure. AusRAP considers physical road attributes to quantify the safety risk for different road user groups such as vehicle occupants, motorcyclists, cyclists and pedestrians. The objective is to reduce the death and injuries on Australia's roads using the risk assessment strategy to prevent road crashes from occurring and to reduce the severity of those crashes which do occur.

In this project, software for identifying many AusRAP attributes has been developed and tested based on machine language. Tasks completed included a review of AusRAP attributes from DVR and MLS data, designed research methodology, the creation of a large dataset of 2,273 images from different roads using DVR data and the evaluation of the proposed methodology. Image frames for AusRAP attributes were annotated by assigning a unique colour code to each attribute. The colour codes assisted in distinguishing the attributes in training and evaluation of deep learning techniques. The original dataset was divided into 2 separate sets of training data (1,837 images) and testing data (436 images).

The project outcomes include the following:

- 61 trained separate models (one for each attribute) developed to detect AusRAP attributes from video files
- 9 functions developed based on the trained models' output to measure distance, indicate location of attributes (driver side of the road, passenger side of the road or median) and extract relevant data from metadata associated with the video file
- compilation of the trained models and functions into an easy-to-use software program for detecting AusRAP attributes based on video data.

The individual models have been evaluated using training, testing and misclassification errors. The test accuracy and misclassifications demonstrate the accuracy of each model in detecting the attributes. Some models provided very high accuracy (above 90%); however, some of the models provided low accuracy and many misclassifications. The misclassification had a major impact on the accuracy of detection at the 100 m section level required by AusRAP. The level of misclassification can be reduced with the addition of more trained datasets.

The attributes that can be detected with high accuracy at the 10 m frame level include:

- delineation
- road signs
- chevron alignment markers
- poles/posts
- linemarkings
- traffic signals at intersections
- metal safety barriers.

The AusRAP attributes and its categories that pass the required quality assurance process are:

- delineation
- speed limit (if misclassifications of other objects as speed limits are reduced).

The results and analysis presented above show that proposed methodology is able to correctly identify a large number of AusRAP attributes. The research method and the software developed to automatically detect AusRAP attributes in this project is a great achievement. This was possible because of the huge amount of additional time put in by CQU researchers.

However, further research is needed to improve the accuracy for some difficult-to-detect attributes and to reduce the level of misclassifications. In addition, there will be further work required to improve software performance including its execution time.

# References

Verma, B & Affum, J 2019, *R54 – Automated collection of AusRAP road attributes using DVR and pattern recognition techniques – Y2 annual summary*, Unpublished NACOE report.

# Appendix A How to Run the Program

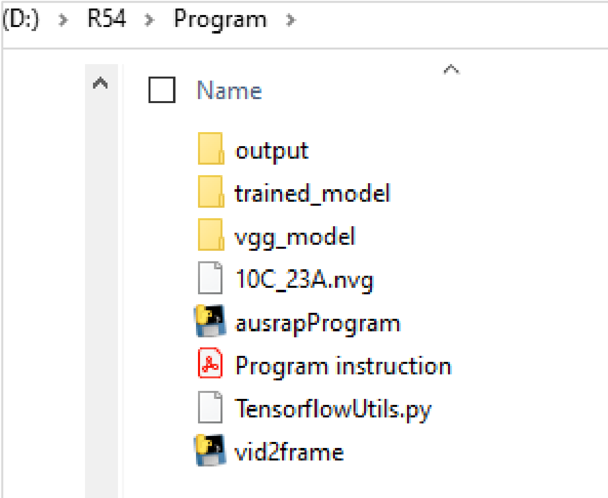
The steps required to run the program are presented below.

**Step 1:** Download **ausrapProgram.zip** file using the following link:

**https://drive.google.com/drive/folders/1F7vdKsoBrOVcJDR2K0pb_zInsRpSGxS0?usp=sharing**

**Step 2:** Unzip **ausrapProgram.zip** file and put **all files and directories** at one place. The extracted data contains the following folders and files (Figure A.1).

Figure A.1: Program folders and files




**Step 3:** Put all test images (.jpg format) with a size greater than 800x800 (RGB colour) in directory output/ori.

**Or** if you have video files instead of images then put the video files (e.g. 2019- 05-02 08h12m08s Video Module 1 10A_1 Ahead 001.avi) in the same directory where vid2frame.exe is and click on vid2frame.exe file or run it by typing vid2frame in the command prompt. This program will create and store images in the 'Frames' directory. Copy all created images in 'Frames' to output/ori directory.

**Step 4:** Put metadata file (e.g. 10A_1.nvgx, 10A_46R.nvgx) for the images of road videos you are testing in the same directory where **ausrapProgram.exe** is.

**Step 5:** Click on **ausrapProgram.exe** file or run it by typing **ausrapProgram** in the command prompt.

**Step 6:** The program will run and display various outputs on the screen, wait until it finishes. It takes a long time to finish, and time depends on number of images (length of road) inside output/ori directory.

**Step 7:** View the results in the Output directory provided in Excel format as follows:

- Video_filename_output: results provided at 10 m section level (frame) – re 1 means object detected, 0 means not detected.
- Video_filename_output100metre: results provided at 100 m section level in AusRAP format. Further processing is required to generate the required AusRAP codes for some attributes.
- You can also view the images as follows:
  - segmented images in output/fuse_vis directory
  - original resized images are in output/ori_resized directory.
  - original input files are in output/ori directory.

Important Note:

To run the program again, you must delete all directories and files from 'output' directory except 'ori' directory. Output/ori directory should have test images/frames which you want to test.

# Appendix B Sample Outputs – 10A Gazetted Direction

## B.1 Output File at the 10 m Frame Level

Table B.1: Sample output at 10 m frame level – 10A

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coder name | Coding date | Survey date | Road number | Frame | Chainage | Latitude | Longi-tude | Line | Road | Pole | Sign 10 | Sign 20 | Sign 30 | Sign 40 | Sign 50 | Sign 60 | Sign 70 | Sign 80 | Sign 90 | Sign 100 | Sign 110 |
| 2 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00001.jpg | 0 | -27.2914 | 153.0189 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00002.jpg | 0.01 | -27.2913 | 153.019 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00003.jpg | 0.02 | -27.2912 | 153.019 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00004.jpg | 0.03 | -27.2911 | 153.019 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00005.jpg | 0.04 | -27.291 | 153.0191 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00006.jpg | 0.05 | -27.2909 | 153.0191 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00007.jpg | 0.06 | -27.2908 | 153.0191 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00008.jpg | 0.07 | -27.2908 | 153.0191 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00009.jpg | 0.08 | -27.2907 | 153.0192 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00010.jpg | 0.09 | -27.2906 | 153.0192 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Program | 12-May-2021 | 02-May-2019 | 10A | Frame00011.jpg | 0.1 | -27.2905 | 153.0192 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | W | X | Y | Z | AA | AB | AC | AD | AE | AF | AG | AH | AI | AJ | AK | AL | AM | AN | AO | AP | AQ | AR | AS | AT | AU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Speed sign location | Tree | Signal sign | One way sign | Signed shared roadway | Concrete barrier | Metal barrier | MC friendly | Wire rope barrier | CAM | Curvature sign | Guide post | Flexi post | Merge lane | Defect | Warning sign | School zone warning sign | Road work sign | Railway sign | Railway crossing-gate | Median grass | Median concrete | Rumble strip | Ped. crossing sign | Ped. crossing |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| | AV | AW | AX | AY | AZ | BA | BB | BC | BD | BE | BF | BG | BH | BI | BJ | BK | BL | BM | BN | BO | BP | BQ | BR | BS | BT | BU | BV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ped. fencing | Pedes-trian | Motor-cycle | Bicycle | Bicycle path | Seg bike path with barrier | Parking slot | Sidewalk-formal | Aggress-ive vertical face | Central hatching | Left turn | Right turn | Cont. cent turning lane | Inter-section 3 | Inter-section 4 | Roundab out sign | Protec-ted barrier end | Deep drainage ditch | Boulder | Upwards slop | Slip lane | Rigid structure | Refuge | Delinea-tions found | Medians found | Median width | Severity:LHS object |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 0.847 | 1 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 0.596 | 1 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 0.658 | 12 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 1.9 | 12 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 0.782 | 1,12 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 1.04 | 12 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 0.724 | 12 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 1.92 | 12 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1 | 1.1 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (1,2) | 1,5 | 1.164,0.511 | 12 |

| | BW | BX | BY | BZ | CA | CB | CC | CD | CE | CF | CG | CH | CI | CJ | CK | CL | CM | CN | CO | CP | CQ | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Severity:LHS distance | Severity:RHS object | Severity:RHS distance | Number of lanes | Lane width | Left shoulder | Right shoulder | Service road | Left sidewalk | Right sidewalk | Rumble (Sh, Ct) | Bicycle flow | Motor-cycle flow | Pedes-trian flow | WCL width/ present | Street light | Carriage way | Pedestrian facility | Bicycle facility | Parking facility | LHS sidewalk distance | RHS sidewalk distance |
| 2 | 0 | 0 | 0 | 4 | 3.95 | 0.207 | 0.525 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 3 | 1 | 1 | 1 | 4 | 4.059 | 3.584 | 0.56 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 4 | 1 | 1 | 1 | 4 | 4.221 | 4.305 | 0.292 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 5 | 2 | 12 | 2 | 4 | 3.404 | 1.806 | 2.003 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 6 | 1 | 12 | 1 | 4 | 3.222 | 1.786 | 1.594 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 7 | 1,2 | 1,12 | 1,2 | 4 | 3.639 | 1.774 | 1.633 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 8 | 1 | 12 | 1 | 4 | 3.908 | 1.886 | 1.193 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 1 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 9 | 2 | 12 | 2 | 4 | 3.908 | 1.854 | 1.517 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 10 | 1 | 12 | 1 | 4 | 3.518 | 1.552 | 1.468 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |
| 11 | 0 | 0 | 0 | 4 | 3.798 | 1.679 | 1.295 | 0 | 0.123 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | Non-physical separation Dist | No RHS sidewalk detected |
| 12 | 2 | 12 | 2 | 4 | 3.72 | 1.789 | 1.478 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 1 | No facility | No facility | No facility | No LHS sidewalk detected | No RHS sidewalk detected |

## B.2 Evaluation of Coded Data at 100 m Level

Table B.2: Evaluation results at the 100 m level

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| Carriageway | 1 | A-Divided forward direction | 138.3 | 140.5 | 2% | Failed |
| | 2 | B-Divided reverse direction | NA | NA | NA | Undivided sections not coded correctly; some divided sections recorded as undivided |
| | 3 | U-Undivided | 6.7 | 4 | 67% | |
| Major upgrade cost impact | 1 | Low | NA | NA | | |
| | 2 | Medium | NA | NA | | |
| | 3 | High | NA | NA | | |
| Motorcycle observed flow | 1 | None | | | | Failed |
| | 2 | 2 – 1 motorcycle per 100 m | 0.2 | 0 | | Misclassifications |
| | 3 | 2 to 3 motorcycles per 100 m | | | | |
| | 4 | 4 to 5 motorcycles per 100 m | | | | |
| | 5 | 6 to 7 motorcycles per 100 m | | | | |
| | 6 | 8+ motorcycles per 100 m | | | | |
| Bicycle observed flow | 1 | 1 – None | | | | Failed |
| | 2 | 1 bicycle per 100 m | 1 | 0 | | Misclassifications |
| | 3 | 2 to 3 bicycles per 100 m | | | | |
| | 4 | 4 to 5 bicycles per 100 m | | | | |
| | 5 | 6 to 7 bicycles per 100 m | | | | |
| | 6 | 8+ bicycles per 100 m | | | | |
| Pedestrian observed flow across road | 1 | 1 – None | | | | Failed |
| | 2 | 1 pedestrian per 100 m | 2 | 0 | | Misclassifications |
| | 3 | 2 to 3 pedestrians per 100 m | | | | |
| | 4 | 4 to 5 pedestrians per 100 m | | | | |
| | 5 | 6 to 7 pedestrians per 100 m | | | | |
| | 6 | 8+ pedestrians per 100 m | | | | |
| Pedestrian observed flow along road driver side (RHS) | 1 | 1 – None | | | | |
| | 2 | 1 pedestrian per 100 m | | | | |
| | 3 | 2 to 3 pedestrians per 100 m | | | | |
| | 4 | 4 to 5 pedestrians per 100 m | | | | |
| | 5 | 6 to 7 pedestrians per 100 m | | | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| | 6 | 8+ pedestrians per 100 m | | | | |
| Pedestrian observed flow along road passenger side (LHS) | 1 | 1 – None | | | | Failed |
| | 2 | 1 pedestrian per 100 m | 4 | 1 | 300% | Misclassifications |
| | 3 | 2 to 3 pedestrians per 100 m | 2 | 2 | 0% | |
| | 4 | 4 to 5 pedestrians per 100 m | | | | |
| | 5 | 6 to 7 pedestrians per 100 m | | | | |
| | 6 | 8+ pedestrians per 100 m | | | | |
| Land use – right (driver side) | 1 | Undeveloped land | NA | NA | | No R54 model |
| | 2 | Farmland/Agriculture | NA | NA | | |
| | 3 | Residential | NA | NA | | |
| | 4 | Commercial/shops | NA | NA | | |
| | 5 | Not applicable/recorded | NA | NA | | |
| | 6 | Educational facilities | NA | NA | | |
| | 7 | Industrial & manufacturing | NA | NA | | |
| Land use – left (passenger side) | 1 | Undeveloped land | NA | NA | | No R54 model |
| | 2 | Farmland/Agriculture | NA | NA | | |
| | 3 | Residential | NA | NA | | |
| | 4 | Commercial/shops | NA | NA | | |
| | 5 | Not applicable/recorded | NA | NA | | |
| | 6 | Educational facilities | NA | NA | | |
| | 7 | Industrial & manufacturing | NA | NA | | |
| Area type | 1 | Rural | | | | No R54 model |
| | 2 | Urban | | | | |
| Speed limit | 1 | < 30 km/h | | | | Individual speed limit signs are identified at high accuracy level.<br><br>However, failed at 100 m level due to misclassifications |
| | 3 | 40 km/h | | | | |
| | 5 | 50 km/h | 1.2 | 0 | | |
| | 7 | 60 km/h | 5.7 | 2.8 | 104% | |
| | 9 | 70 km/h | 4.2 | 2.7 | 56% | |
| | 11 | 80 km/h | 15.6 | 13.3 | 17% | |
| | 13 | 90 km/h | | | | |
| | 15 | 100 km/h | 24.1 | 24.7 | 2% | |
| | 17 | 110 km/h | 94.2 | 100.4 | 6% | |
| | 19 | 120 km/h | | | | |
| | 21 | 130 km/h | | | | |
| | 23 | 140 km/h | | | | |
| | 25 | > 150 km/h | | | | |
| Differential speed limit | 1 | Not present | NA | NA | | |
| | 2 | Present | NA | NA | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| Median type | 1 | Safety barrier – metal | 43.1 | 43.3 | 0% | Failed |
| | 2 | Safety barrier – concrete | 35.2 | 30.1 | 17% | |
| | 3 | Physical median width > 20 m | 0 | 0.3 | 100% | |
| | 4 | Physical median width 10–20 m | 0 | 19.7 | 100% | |
| | 5 | Physical median width 5–10 m | 0 | 12 | 100% | |
| | 6 | Physical median width 1–5 m | 0 | 4.7 | 100% | |
| | 7 | Physical median width up to 1 m | 47.1 | 0 | | Misclassifications |
| | 8 | Continuous central turning lane | | | | |
| | 9 | Flexipost | 0.5 | 0 | | Misclassifications |
| | 10 | Central hatching (> 1 m) | 2.8 | 1.3 | 115% | |
| | 11 | Centreline | 0 | 2.2 | 100% | |
| | 12 | Motorcyclist friendly barrier | 0.7 | 0.5 | 40% | |
| | 13 | One way | | | | |
| | 14 | Wide centreline (0.3 m to 1 m) | 0 | 0.5 | 100% | |
| | 15 | Safety barrier – wire rope | 5.3 | 29.9 | 82% | |
| | 0 | No recorded | 10.2 | 0 | | |
| Centreline rumble strips | 1 | Not present | 144.5 | 144 | | Failed |
| | 2 | Present | 0 | 0.5 | 100% | |
| Roadside severity – driver-side distance | 1 | 0 to < 1 m | 103.6 | 38.6 | 168% | Failed |
| | 2 | 1 to < 5 m | 11.3 | 70.6 | 84% | |
| | 3 | 5 to < 10 m | 1.3 | 14.4 | 91% | |
| | 4 | >= 10 m | 0.2 | 20.9 | 99% | |
| | | 0 | 28.6 | 0 | Distance not recorded for a large part of the road | |
| Roadside severity – driver-side object | 1 | Safety barrier – metal | 24.3 | 44.1 | 45% | Failed |
| | 2 | Safety barrier – concrete | 9 | 38.9 | 77% | |
| | 3 | Safety barrier – metal MC friendly | 0.2 | 0.5 | 60% | |
| | 4 | Safety barrier – wire rope | 8.1 | 32.8 | 75% | |
| | 5 | Aggressive vertical face | 0.4 | 0 | | Misclassifications |
| | 6 | Upwards slope – (rollover gradient) | 1.1 | 0.2 | 450% | |
| | 7 | Upwards slope – (no rollover gradient) | 0 | 1.1 | 100% | |
| | 8 | Deep drainage ditch | 3.6 | 1.1 | 227% | |
| | 9 | Downward slope | | | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| | 10 | Cliff or the like | | | | |
| | 11 | Tree > 10 cm | 1.3 | 0.6 | 117% | |
| | 12 | Rigid sign, post or pole >= 10 cm | 63.4 | 2.5 | 2,436% | Manual coding will underestimate this, frangible poles not recorded. |
| | 13 | Rigid structure/bridge or building | 4.4 | 0.1 | 4,300% | |
| | 14 | Semi-rigid structure or building | | | | |
| | 15 | Unprotected barrier end | 0 | 3.9 | 100% | |
| | 16 | Large boulders >= 20 cm high | 0.6 | 0 | | Misclassifications |
| | 17 | None (> 20 m) | 28.6 | 18.7 | 53% | |
| Roadside severity – passenger-side distance | 1 | 0 to < 1 m | 93.2 | 3.6 | 2,489% | Failed |
| | 2 | 1 to < 5 m | 10.9 | 67.4 | 84% | |
| | 3 | 5 to < 10 m | 1.8 | 39.1 | 95% | |
| | 4 | >= 10 m | 0.5 | 34.4 | 99% | |
| | 0 | | 38.6 | | Distance not recorded for a large part of the road | |
| Roadside severity – passenger-side object | 1 | Safety barrier – metal | 17.2 | 28.2 | 39% | Failed |
| | 2 | Safety barrier – concrete | 6.2 | 17.6 | 65% | |
| | 3 | Safety barrier – metal MC friendly | 0.3 | 2.9 | 90% | |
| | 4 | Safety barrier – wire rope | 3.6 | 7 | 49% | |
| | 5 | Aggressive vertical face | 0.6 | 4 | 85% | |
| | 6 | Upwards slope – (rollover gradient) | 1.9 | 6.3 | 70% | |
| | 7 | Upwards slope – (no rollover gradient) | 0 | 18.4 | 100% | |
| | 8 | Deep drainage ditch | 0 | 2.9 | 100% | |
| | 9 | Downward slope | 0 | 0.3 | 100% | |
| | 10 | Cliff or the like | 0 | 0 | | |
| | 11 | Tree > 10 cm | 1.3 | 39.6 | 97% | |
| | 12 | Rigid sign, post or pole >= 10 cm | 70.3 | 6.2 | 1,034% | Manual coding will underestimate this, frangible poles not recorded. |
| | 13 | Rigid structure/bridge or building | 4.3 | 0.7 | 514% | |
| | 14 | Semi-rigid structure or building | 0 | 0.4 | 100% | |
| | 15 | Unprotected barrier end | 0.1 | 0.7 | 86% | |
| | 16 | Large boulders >= 20 cm high | 0.6 | 0 | | Misclassifications |
| | 17 | None (> 20 m) | 38.6 | 9.3 | 315% | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| Shoulder rumble strips | 1 | Not present | 145 | 73.4 | 98% | Failed |
| | 2 | Present | 0 | 71.1 | 100% | |
| Paved shoulder – driver-side | 1 | Paved >= 2.4 m | 0 | 23.4 | 100% | Failed<br><br>Measurement – calibrations wrong |
| | 2 | Paved 1 < Width < 2.4 m | 28.7 | 19.3 | 49% | |
| | 3 | Paved 0 < Width <= 1 m | 116.3 | 101.4 | 15% | |
| | 4 | None | 0 | 0.4 | 100% | |
| Paved shoulder – passenger-side | 1 | Paved >= 2.4 m | 9.4 | 51 | 82% | Failed<br><br>Measurement – calibrations wrong |
| | 2 | Paved 1< Width < 2.4 m | 77.7 | 84.1 | 8% | |
| | 3 | Paved 0< Width <= 1 m | 57.9 | 9.3 | 523% | |
| | 4 | None | 0 | 0.1 | 100% | |
| Intersection type | 1 | Merge lane | 24 | 28 | 14% | Failed |
| | 2 | Roundabout | | | | |
| | 3 | 3-leg (unsignalised) with protected turn lane | 0 | 12 | 100% | |
| | 4 | 3-leg (unsignalised) with no protected turn lane | 1 | 3 | 67% | |
| | 5 | 3-leg (signalised) with protected turn lane | | | | |
| | 6 | 3-leg (signalised) with no protected turn lane | | | | |
| | 7 | 4-leg (unsignalised) with protected turn lane | | | | |
| | 8 | 4-leg (unsignalised) with no protected turn lane | | | | |
| | 9 | 4-leg (signalised) with protected turn lane | 0 | 3 | 100% | |
| | 10 | 4-leg (signalised) with no protected turn lane | | | | |
| | 12 | None | | | | |
| | 13 | Railway crossing – passive (signs only) | 1 | 0 | | Misclassifications |
| | 14 | Railway crossing – active (flashing lights/ boom gates) | | | | |
| | 15 | Median crossing point – informal | | | | |
| | 16 | Median crossing point – formal | | 1 | 100% | |
| | 17 | Mini roundabout | | | | |
| Channelisation – splitter and median islands | 1 | Not present | 144.9 | 141.8 | | Failed |
| | 2 | Present | 0.1 | 2.7 | 96% | |
| Intersection quality | 1 | Adequate | | | | No R54 model |
| | 2 | Poor | | | | |
| | 3 | Not applicable | | | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| Property access points | 1 | Commercial Access 1+ | | | | No R54 model |
| | 2 | Residential Access 3+ | | | | |
| | 3 | Residential Access 1 or 2 | | | | |
| | 4 | None | | | | |
| Number of lanes | 1 | One | | 7.2 | 200% | Failed |
| | 2 | Two | 112.3 | 113.2 | 1% | |
| | 3 | Three | 27.5 | 22.1 | 24% | |
| | 4 | Four or more | 5.2 | 1.7 | 206% | |
| | 5 | Two and one | | | | |
| | 6 | Two and three | | | | |
| Lane width | 1 | Wide (≥ 3.25 m) | 50.1 | 144.5 | 65% | Failed<br><br>Measurement – calibrations wrong |
| | 2 | Medium (≥ 2.75 m to < 3.25 m) | 79.8 | 0 | | |
| | 3 | Narrow (≥ 0 m to < 2.75 m) | 15.1 | 0 | | |
| Curvature | 1 | Straight or gently curving | | | | No R54 model |
| | 2 | Moderate curvature | | | | |
| | 3 | Sharp curve | | | | |
| | 4 | Very sharp | | | | |
| Quality of curve | 1 | Adequate | 0.5 | 3.3 | 85% | Failed |
| | 2 | Poor | | | | |
| | 3 | Not applicable | 144.5 | 141.2 | | |
| Grade | 1 | 0 to < 7.5% | | | | No R54 model |
| | 4 | 7.5 to < 10% | | | | |
| | 5 | 10%+ | | | | |
| Road surface condition | 1 | Good | 112.4 | 144.5 | 78% | Failed |
| | 2 | Medium | 32.6 | 0 | | Misclassification |
| | 3 | Poor | | | | |
| Skid resistance/grip | 1 | Sealed – adequate | NA | | | No R54 model |
| | 2 | Sealed – medium | NA | | | |
| | 3 | Sealed – poor | NA | | | |
| | 4 | Unsealed – adequate | NA | | | |
| | 5 | Unsealed – poor | NA | | | |
| Delineation | 1 | Adequate | 145 | 144.5 | 100% | Pass |
| | 2 | Poor | | | | |
| Street lighting | 1 | Not present | 98.9 | 114.3 | 13% | Failed |
| | 2 | Present | 46.1 | 30.2 | 53% | |
| Pedestrian crossing facilities – inspected road | 1 | Grade separated facility – no ped fencing | | | | |
| | 2 | Signalised with refuge | | | | |
| | 3 | Signalised without refuge | | | | |
| | 4 | Unsignalised marked crossing with refuge | | | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| | 5 | Unsignalised marked crossing without a refuge | | | | |
| | 6 | Refuge only | | | | |
| | 7 | No facility | | | | |
| | 8 | Grade separated facility – ped fencing present | | | | |
| | 14 | Unsignalised raised marked crossing with refuge | | | | |
| | 15 | Unsignalised raised marked crossing without refuge | | | | |
| | 16 | Raised unmarked crossing with refuge | | | | |
| | 17 | Raised unmarked crossing without refuge | | | | |
| Pedestrian quality of crossing | 1 | Adequate | | | | |
| | 2 | Poor | | | | |
| | 3 | Not applicable | | | | |
| Pedestrian crossing facilities–- intersecting road | 1 | Grade separated facility – no ped fencing | | | | |
| | 2 | Signalised with refuge | | | | |
| | 3 | Signalised without refuge | | | | |
| | 4 | Unsignalised marked crossing with refuge | | | | |
| | 5 | Unsignalised marked crossing without a refuge | | | | |
| | 6 | Refuge only | | | | |
| | 7 | No facility | | | | |
| | 8 | Grade separated facility – ped fencing present | | | | |
| | 14 | Unsignalised raised marked crossing with refuge | | | | |
| | 15 | Unsignalised raised marked crossing without refuge | | | | |
| | 16 | Raised unmarked crossing with refuge | | | | |
| | 17 | Raised unmarked crossing without refuge | | | | |
| Pedestrian fencing | 1 | Not present | 144.6 | 145 | | Failed |
| | 2 | Present | 0.4 | 0 | | Misclassification |
| Speed management/ traffic calming | 1 | Not present | | | | No R54 model |
| | 2 | Present | | | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| Vehicle parking/friction | 1 | None | 144.8 | 144.2 | | |
| | 2 | One side | 0.2 | 0.3 | 67% | |
| | 3 | Two sides | | | | |
| Sidewalk – driver-side (RHS) | 1 | Physical barrier | 0.3 | 0 | | Failed |
| | 2 | Non-physical separation > 3 m | 0.7 | 0 | | Misclassification |
| | 3 | Non-physical separation > 1 m | 0.7 | 0 | | Misclassification |
| | 4 | Adjacent to traffic | 2 | 0 | | Misclassification |
| | 5 | None | 141.3 | 143.8 | 0.3% | |
| | 6 | Informal path >= 1 m | | 0.5 | | |
| | 7 | Informal path 0 to < 1 m | | 0.2 | | |
| Sidewalk – passenger-side (LHS) | 1 | Physical barrier | 10.2 | 0.4 | 2,450% | Failed |
| | 2 | Non-physical separation > 3 m | 0.2 | 0.6 | 67% | |
| | 3 | Non-physical separation > 1 m | 0.9 | 0.2 | 350% | |
| | 4 | Adjacent to traffic | 6.4 | 0 | | Misclassification |
| | 5 | None | 127.3 | 77.7 | 64% | |
| | 6 | Informal path >= 1 m | | 62.8 | | |
| | 7 | Informal path 0 to < 1 m | | 2.8 | | |
| Service road | 1 | Not present | 134.7 | 145 | 7% | Failed |
| | 2 | Present | 10.3 | 0 | | Misclassification |
| Bicycle facilities | 1 | Segregated bicycle path with barrier | | | | Failed |
| | 2 | Segregated bicycle path | | | | |
| | 3 | Dedicated bicycle lane on roadway | 2.7 | 0 | | Misclassification |
| | 4 | None | 140.4 | 144.5 | 3% | |
| | 5 | Extra wide outside (≥ 4.2 m) | | | | |
| | 6 | Signed shared roadway | 1.9 | 0 | | Misclassification |
| | 7 | Shared use path | | | | |
| Roadworks | 1 | No road works | | | | |
| | 2 | Minor road works in progress | | | | |
| | 3 | Major road works in progress | | | | |
| Sight distance | 1 | Adequate | | | | No R54 model |
| | 2 | Poor | | | | |
| School zone warning | 1 | School zone flashing beacons | | | | Failed |
| | 2 | School zone static signs or road markings | 0.2 | 0 | | Misclassification |
| | 3 | No school zone warning | | | | |
| | 4 | Not applicable (no school at the location) | 144.3 | 144.5 | | |

| Attribute | Cat ID | Category | Road length (km) | | Absolute difference | Comment |
|---|---|---|---|---|---|---|
| | | | R54 Model | Manual | Per cent | |
| School zone crossing supervisor | 1 | Crossing supervisor not present | NA | NA | | No R54 model |
| | 2 | Crossing supervisor present during school time | NA | NA | | |
| | 3 | Not applicable (no school at the location) | NA | NA | | |