AUTOMATING ROUTE MAPPING FOR PBS VEHICLES



M. COLEMAN
CPEng, B. Eng (Mechatronics), B Cs, MBA, NER APEC Engineer IntPE(Aus) RPEQ. Managing Director of Tiger Spider and a PBS Assessor with over 24 years experience in heavy vehicle technology, standards and policy.

S. BUXTON
Manager Network Access
Infrastructure Tasmania Division, Department of State Growth Tasmania. Simon has worked in the roads and bridges industry for 41 years in the UK and Australian in both the public and private sectors.

R IBRAHIM
B. Eng (Aerospace) Monash University (2016) with over 5 years experience consulting to the heavy vehicle industry.

Keywords: Performance Based Standards (PBS), Low-Speed Swept Path, Frontal Swing, Tail Swing

Topics: Intelligent Transport Systems (ITS) and traffic management integration | Heavy Vehicle Safety, Driver Safety, Heavy Vehicles as a Workplace.

Abstract

This paper presents a framework for a dynamic route mapping tool for Performance Based Standards (PBS) vehicles based on vehicle turning performance.

The overarching research question was:

It is possible to develop a robust, scalable, and objective route assessment methodology that provides a more granular level of swept path analysis (i.e., beyond the basic PBS performance levels) that can be codified into GIS data tables to support dynamic route maps of bespoke PBS heavy vehicles.

Specific goals for this work included:

1. Validating the necessary attributes which can be codified and added to DSG's Geospatial Information System to allow for the automation of road network maps for unique vehicles,
2. Optimizing and documenting the route assessment process methods to minimize the time required to undertake network assessments,
3. Minimizing the need for "engineering judgement" when completing network assessments to ensure they are completed in an objective, consistent and scalable way.

1. Introduction

The Department of State Growth (DSG) Tasmania sought to develop a mapping tool for the Tasmanian road transport industry that would generate a dynamic route map for Performance Based Standards (PBS) vehicles based on vehicle turning performance.

This tool is based on an automated mapping tool DSG successfully implemented for Special Purpose Vehicles (SPV) based on bridge impacts. The tool allows transport operators to input a vehicle's unique configuration: tyres, axles, axle weights and dimensions into an online portal which then automatically generates a bespoke network map applicable to that specific vehicle (Department of State Growth, 2022).

The web-based system allocates a unique vehicle ID based on vehicle configuration, axle weight and dimensions and generates a bespoke network map which provides access under a state-based gazette notice **(Commonwealth of Australia, 2019)**. Multiple vehicle IDs may be generated for each vehicle, allowing for a broader network when operating unladen. DSG wished to build upon this successful implementation and provide a similar tool for PBS vehicles. However, for longer PBS vehicles, geometric factors are a critical component of network suitability along with bridge impacts.

DSG anticipated that vehicles up to PBS Level 3B could potentially access the Tasmanian road network. This meant that PBS networks could potentially support vehicles as short as 12.5 m and up to 42 m overall length, with Low-Speed Swept Path (LSSP) turning performance ranging from as low as 5.4 m to 10.6 m (National Transport Commission, 2020; National Transport Commission, 2007)

The starting point for the system was based on the Traffic Design Low Speed Swept Path Analysis Guideline implemented by the Department of Transport Victoria (DOTV) which is used for assisting with access decisions for High Productivity Freight Vehicles (HPFVs') in Victoria.

A robust, scalable and objective route assessment methodology was developed to provide a more granular level of swept path analysis (i.e. beyond the basic PBS performance levels). The results were then to be codified into GIS data tables to generate dynamic road networks for bespoke vehicles based on their turn performance results and the turning capacity of the road network.

2. Methodology

The methodology included:

- Developing LSSP reference vehicles,
- Refining and developing LSSP route assessment method,
- Refining and developing GIS attributes table,
- Assessing target intersections in Northern Tasmania.

The development of the LSSP route assessment methodology was an iterative process that evolved after working through target intersections on the proposed PBS networks.

2.1 Development of LSS Reference vehicles

The goal of the review was to have swept path granularity to 0.1 m the accuracy of PBS swept path assessments. We, therefore, developed a suite of vehicles which ranged from swept paths of 5.4 m (PBS Level 1) to 10.6 m (PBS Level 3).

Whilst the PBS Level 1 limit is up to 7.4 m and should, in theory, allow for general access, there may be instances, especially on local roads, where road space is insufficient to adequately accommodate swept paths of up to 7.4 m. Therefore, consideration was given to vehicles based on Austroads design vehicles e.g., 12.5 m rigid trucks, 13.5 m and 14.5 m buses. Shorter, semi-trailers and truck and dogs were also considered for use as the basis of PBS Level 1 reference vehicles.

Given that overall width limits may likely increase to up to 2.6 m, we used 2.6 m wide vehicles as part of the route assessment process. This aimed to future proof the scheme and support a potential shift to vehicles designed to the wider global standard.

PBS Level 2 and 3 vehicles were based on a mixture of B-double and A-double designs. Reference vehicles were designed to maximize the LSSP in 0.1 m increasements and, in general, configured to maximize Frontal Swing (FS) (including Maximum of Difference (Mod) and Difference of Maximum (DoM)) and Tail Swing (TS) where appropriate. The design envelope was refined further to ensure that designs were not too impractical.

Table 1 - Reference Vehicles Summary

Vehicle Combination	Configuration	LSSP (m)	Project Group
Truck/Bus	12	5.4 – 6.5	Truck-Bus (LSSP: 5.4-6.5)
Prime Mover Semi	12s3	6.6 – 8.0	Prime Mover & Semi-Trailer (LSSP: 6.6 - 8.0)
B-Double	12s3s3	8.0 – 8.7	B-Double (12s3s3) - (LSSP: 8.0-8.7)
A-Double	12s3-2s3	8.8 – 10.6	A-Double (12s3-2s3) – (LSSP: 8.8 - 10.6)

2.2 Route assessment methodology

We started by reviewing the VicRoads guidelines and applying them to Assess target intersections in Northern Tasmania. We then refined the methodology based on:

- Consultation with DSG network access team,
- Consultation with DSG Geospatial team,
- Review of Tasmanian road rules and conditions, and
- any other local factors.

To provide structure for this process, we used a risk assessment framework that identified risks and the likely severity of heavy vehicle turning movements through an intersection. Where possible, we sought appropriate stakeholders to provide unique perspectives, e.g., PBS Assessor, GIS expert, network access/assessment expert, road rules expert, heavy vehicle driver, pedestrian, and light vehicle driver. The risk assessment process involved a desktop risk assessment to consider various turn movements through 2-3 sample intersections.

2.3 Geographic Information System (GIS) Attributes

GIS attributes were developed and refined based on initial work completed by DOTV and consultation with DSG network access and geospatial teams. We also completed a review of frameworks and tools developed to support dynamic route mapping, e.g., google maps APIs, GIS data protocols and transport agency network mapping examples. The following GIS attributes were implemented.

Intersection ID – A unique identifier for each intersection
Turn ID – The unique identifier for each turn within each intersection
Description – Describes the turn which outlines the road names and turn directions.
Swept Path – Result of swept path analysis. The theoretical capacity of the intersection.
SP Access – A Swept Path number DSG have applied to some vehicles based on experience.
SP Current – The current level of access provided, either 7.4 m (PBS L1) or 8.7 m (PBS L2).
SP Target – The desired level of access for the intersection.

2.4 Intersection Assessment

Intersections were selected by DSG and based on PBS Network demand and high-resolution aerial imagery coverage. The diverse set of intersection types enabled the reference vehicle methodology and GIS attributes to be assessed, see Figure 1.

Each intersection analysis served both as a worked example for future analysis and a data sample to feed into the GIS attributes table. The assessment was completed using Spider Path with Near Maps aerial imagery.

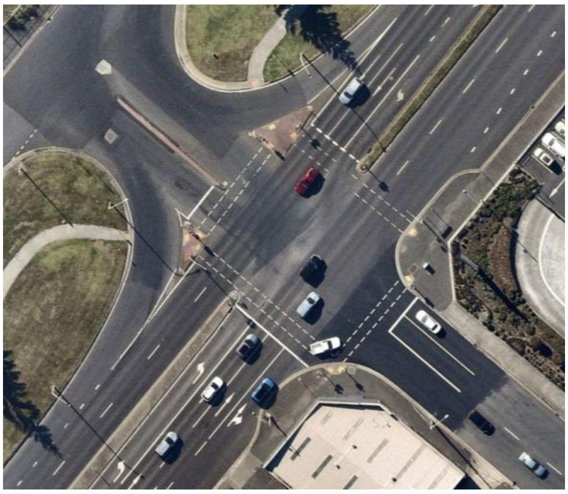
Vehicle performance of each combination was assessed and subsequently used for swept path mapping onto aerial imagery of Tasmanian intersections to determine the swept path capacity of each turn within each intersection, with results compiled into the GIS database. An example of the output is provided in Table 2.

Table 2: Assessed "Swept Path" values of Simple T-Intersection

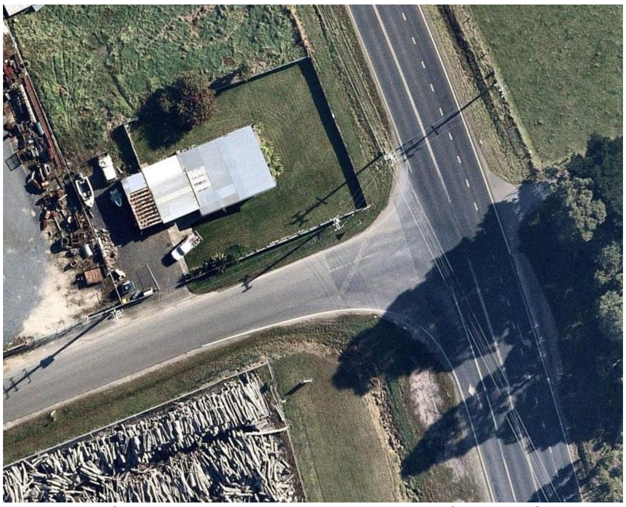
Item	Turn ID	Description	LSSP (m)
1	I1_A1_1	Stennings Rd - Bass Hwy (North Bound)	6.5
2	I1_A1_2	Stennings Rd - Bass Hwy (South Bound)	10.6
3	I1_A2_1	Bass Hwy (South Bound)	No Turn
4	I1_A2_2	Bass Hwy (South Bound) - Stennings Rd	9.6
5	I1_A3_1	Bass Hwy (North Bound) - Stennings Rd	8.7
6	I1_A3_2	Bass Hwy (North Bound) - Stennings Rd !CrossLanes!	10.4[1]
7	I1_A3_3	Bass Hwy (North Bound)	No Turn

[1] I1_A3_2 – Legally required a straddling manoeuvre

Simple 4-way Intersection – Bass Hwy / Reservoir Dr, Wynyard



Complex 4-way Intersection -Bass Hwy / Edwards St, Burnie



Simple T intersection - Bass Hwy / Stennings Rd, Wynyard

Complex T Intersection - Bass Hwy / Brickport Rd, Cooee

Roundabout - Bass Hwy / Calder Rd / York St, Wynyard

Bass Hwy / Maskells Rd / & weighbridge site, East Ulverstone

Figure 1 – Northern Tasmanian Intersections Assessed

3. Introduction of Collision Boundaries

To highlight route obstructions when making a route assessment, a boundary line drawing tool was developed to highlight collisions and determine the magnitude of encroachment, see figure

Figure 2: Boundary line visualisations are shown in red

The visual salience of this tool was to provide quicker objective judgement of invalid turns when generating LSSP values. Collision points allow for measuring the degree of encroachment better to determine the likely LSSP value for this turn. These objective measures were also foundational for extending automation capabilities into the LSSP assessment process, refer Figure 3.

In the existing implementation, all drawn boundary lines were treated as wall-to-wall interactions provided that the boundary is relevant to the turn (e.g., not intersecting the turn). To determine the LSSP, a first pass LSSP 10.6 m vehicle was used to draw a path where the optimal path is attempted, irrespective of encroachment. The defining factor of an optimal path was to use as much outward space as possible before making the turn.

Collisions represented with red line flashes mid turning | **Collision points (purple) visualise the degree of obstruction encroachment**

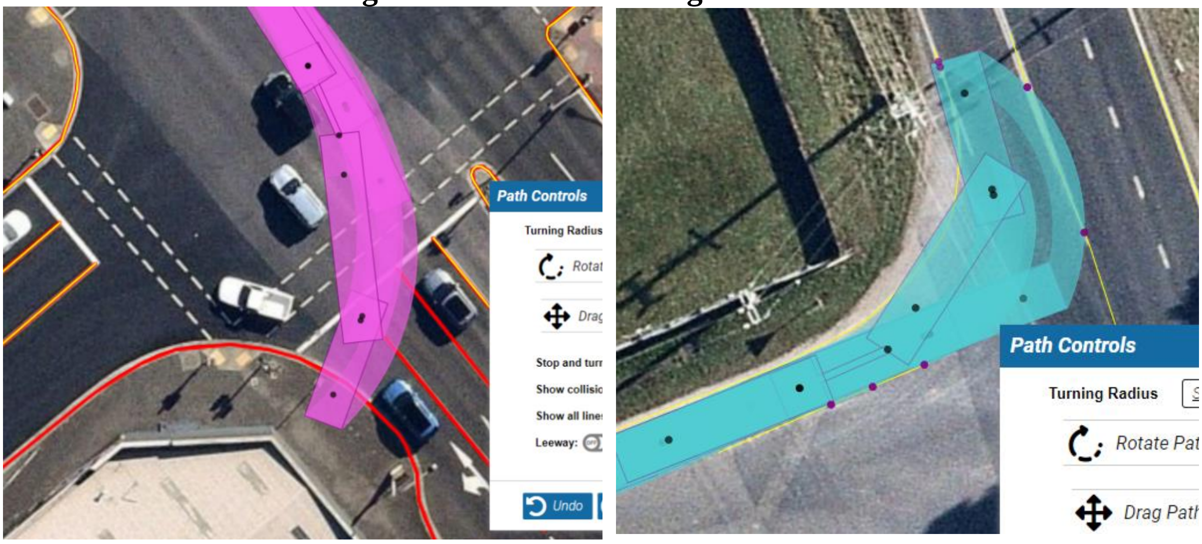


Figure 3 - Collisions representation with lines and expansion with collision points

In the existing implementation, all drawn boundary lines are treated as wall-to-wall interactions provided that the boundary is relevant to the turn (e.g., not intersecting the turn).

To determine the LSSP, a first pass LSSP 10.6 m vehicle is used to draw a path where the optimal path is attempted irrespective of encroachment. The defining factor of an optimal path is to use as much outward space as possible before making the turn. The largest swept path invalid encroachment width is used to estimate the next trial swept path. This is done by subtracting the width measurement from the vehicle's LSSP. Usually, an assessor strives to draw a perfectly optimal path. However, the level of expertise, experience and fine-tuning means that finding the perfect upper bound swept path. This is due to natural variations that occur in path micro choices when performing swept path drawings. In the interest of time, a degree of engineering judgement was used to determine if the encroachment was significant or negligible.

To successfully model more realistic turning behaviour, the assessor needed to understand the basic road rules and concepts of lane straddling, traffic signalling, risks to pedestrians along with the real impacts of Tail Swing and Frontal Swing.

Through, using the boundary line approach it was discovered that LSSP values may be too conservative if all boundaries are considered hard "wall" limits. By introducing soft boundaries combined with roadside furniture objects a more accurate assessment of network fit can be made. The categories are defined in the Table followed by visual examples in Figure 3 and Figure 4. There may still be a discussion about the concept of mountable curbs. However, mountable curbs may purely present the same attributes of a "road line".

Table 3 - Boundary Categories Definitions

Category	Description	Examples
Road Lines	Defined by common vehicle road rules (realistically encroached by trucks)	• Solid road lines
Curbs (Soft Constraint)	Frontal /Tail Swing may spill over this area, but tyres cannot (i.e. non-mountable)	• Curb islands (non-pedestrian & without fences) • Grass patches, roundabouts
Walls (Hard Constraint)	No part of the vehicle may encroach this area	• Fences/barriers/tall obstacles • Solid lane dividers in busy intersections • Pedestrian walkways, pedestrian Islands

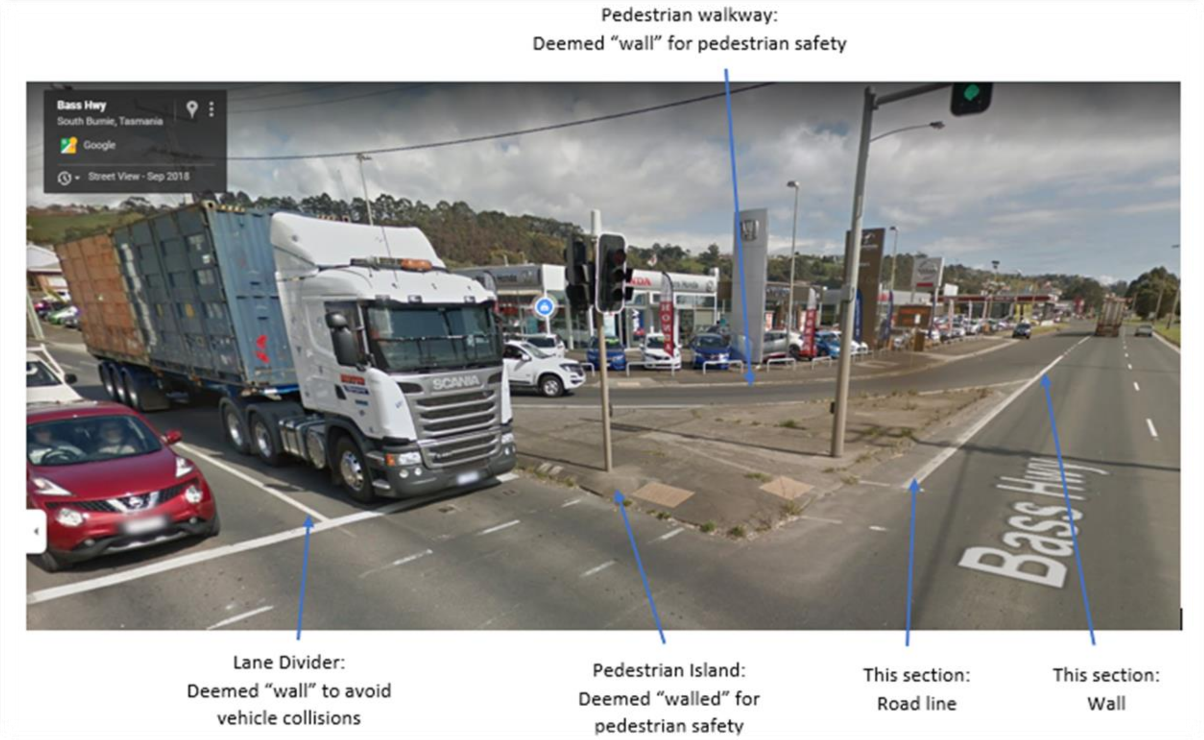


Figure 4 - Street View Perspective of Boundary Definitions

Figure 5 - Map View Perspective of Boundary Definitions

4. The Effect of Frontal Swing and S-Dimension on LSSP analysis

The reference vehicles had Front Overhangs (FOH) maximized to meet the new PBS Frontal Swing limit of 0.85 m. This resulted in reference vehicles with front overhangs larger that would be expected in practice.

Therefore, we sought to confirm that the oversized FOH would not change the outcome of a different vehicle with similar LSSP in a wall-to-wall analysis. Boundary lines were considered wall-wall boundaries, that is, the front of the vehicle could not penetrate the boundary. Tail swing behaviour (collision with a wall) was ignored in this study.

Both vehicles had an LSSP of 5.6 m; however, one had a FS of 0.85 m the other 0.7 m. To match the LSSP with reduced FS the trailer S-dimension was increased. We found that despite the increase in wheelbase/s-dimension for a reduced front overhang the wall-to-wall road space required was comparable. Therefore, LSSP was deemed a valid metric across vehicles with different FOH and frontal swing characteristics.

5. Tyre Path Visualisation (frontal swing over curbs)

In order to reduce the conservatism of swept path assessments we considered assessing curb-to-curb rather than wall-to-wall analysis. In this way, frontal swing could pass over the top of a curb boundary and provide a more realistic assessment of the vehicles in-service capability. To assess this potential, we added the outer steer tyre path to the swept path diagram as a separate black line.

This feature allows users to generate a more realistic vehicle turn representative of current trucks behaviour, allowing for a tighter and more accurate upper bound LSSP, see Figure 5.

Classic Swept Path **Frontal swing over curb**

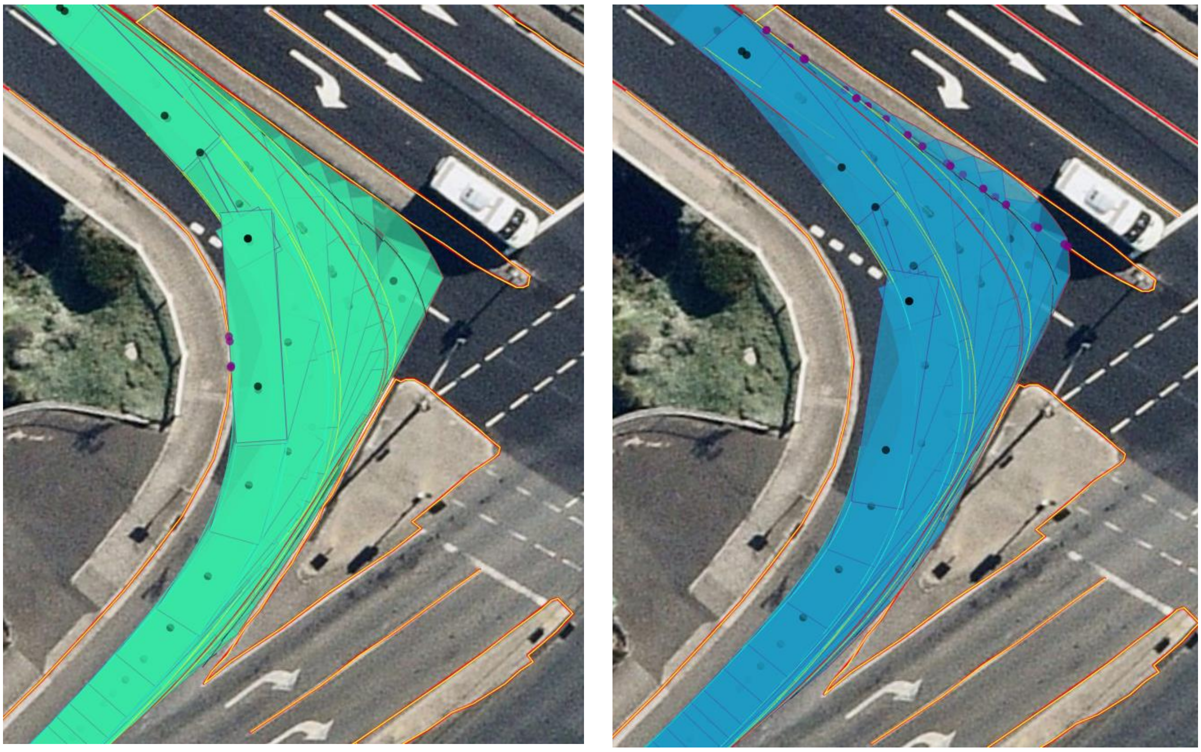


Figure 6 Left-hand turn with an LSSP 9.0m vehicle

Enabling vehicle frontal swing to overlap curbs would be dangerous if curb adjacent obstacles or Roadside Furniture (RSF) are not taken into consideration. It was proposed to categorise RSF as a separate boundary entity. Although they would almost equivalent attributes to a wall, the rationale lies in RSF being more subject to being added or removed compared to other boundary types, see Figure 6. Keeping them as a separate entity enables road managers to personally manage these inconstant road features and keep maps up to date and thus more relevant for analysis. To fit this property perhaps, it is suggested the use of scalable and droppable template shapes such as circles, ovals, squares, or rectangles be considered to represent them.

Ultimately the combined curb and roadside furniture concept can work in tandem for accurate and detailed LSSP. After this addition, road line type boundaries can be represented while unrealistic vehicle dynamics are ignored.

Further additions that could be made could include introducing a 3D Z-vertex parameter to represent the height of boundary objects, refer Table 4. This could be an alternative to cross-sectional assessment when looking at vehicles with oversized loads allowing the convenience of an all-in-one assessment procedure. RSF heights would need to be physically measured.

Figure 7 - Street View of Roadside Furniture (orange) with a curb (red)

Table 4: Proposed values Per Boundary Category

Boundary Category	Height (m)
Road lines	0
Curbs	0.1
Walls	∞

2. References

- BITRE. (2022a). *Australian aggregate freight forecasts – 2022 update.* Canberra: Bureau of Infrastructure and Transport Research Economics (BITRE).
- BITRE. (2022b). *Australian interstate, intrastate and capital city road freight forecasts – 2022 update.* Canberra: Bureau of Infrastructure and Transport Research Economics (BITRE).
- Commonwealth of Australia. (2019). *Tasmania Class 1 Special Purpose Vehicle Exemption Notice 2019 (No.1).* Brisbane: Commonwealth of Australia.
- Department of State Growth. (2022). *Heavy Vehicle Access Management System*. Retrieved from Class 1 Special Purpose Vehicles: https://hvams.stategrowth.tas.gov.au/spv