DEPARTMENT OF STATE GROWTH

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CONFIDENTIAL

Hobart City Deal Southern Projects

T3 Enforcement Concept of Operations Report

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Hobart City Deal Southern Projects
T3 Enforcement Concept of Operations Report

Department of State Growth

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EXECUTIVE SUMMARY

The Hobart City Deal Southern Projects seek to develop a northbound transit lane between Olinda Grove and Hobart/ Davey Street. This lane will work as a 'T3' Transit lane which means it is accessible only to private vehicles carrying three or more occupants, buses, taxis and emergency service vehicles. The Department of State Growth has identified that enforcement is critical to operating a successful and effective transit lane and will in turn promote the project objectives of modal shift to public transport and multi-occupancy vehicles.

This Concept of Operations Report has been developed to describe the characteristics of this proposed T3 enforcement system to illustrate how this system will function from an operational and road user perspective. This report is the primary outlet of Sub-project 5 – T3 Enforcement – Concept of Operations and supports the development of the Southern Outlet Transit Lane Concept Design prepared as part of Sub-project 1.

The term 'concept of operations' can vary across technical disciplines and industries. For this document the intent is to capture the current system, the changes proposed, and detail the anticipated system.

Enforcement of transit lanes is a complex problem with technical, policy, and legal elements that need to be solved. The enforcement system is an important element in maintaining compliance and operational effectiveness. This report is based on the T3 Enforcement Concept Design, where three enforcement sites using the technologies identified during the feasibility study stage are to be installed along the Southern Outlet corridor to identify the type of the vehicles using the T3 lane, and verify if the occupancy of private vehicles using the lane meets requirements (over three occupants). The proposed sites are as follows:

- The first site is a secondary enforcement site located at Chainage 560. This site will have automatic number-plate recognition (ANPR) devices installed.
- The second site is the primary enforcement site located at Chainage 1180. This site will have the occupancy rate detection devices which can identify the number of passengers in the vehicle and take photos to support the enforcement process. This site will also require ANPR devices to capture the number-late information.
- The third site is the other secondary enforcement site located at Chainage 2300 This site will have ANPR devices installed.

The proposed highly-automated T3 enforcement system:

- Identifies approaching vehicle and records key information (license plate)
- Assesses the number of occupants in the vehicle (taking images to support enforcement)
- Verifies the use of the T3 Lane through a secondary enforcement system (two locations)
- Automatically recommends warnings or citations as appropriate
- Detected infringements are reviewed by human operators for issuing of fines or warnings as appropriate.

Understanding the synergies between the potential of technology and traffic engineering concepts that guide understanding of road users, this Concept of Operations report, together with the Concept Design, will ensure a successful approach to operations and design that encompasses stakeholder requirements.

1 SCOPE

1.1 IDENTIFICATION

This concept of operations applies to the section of the Southern Outlet shown in Figure 1.1 below. This section is the location of the proposed T3 transit lane which will provide access for buses, emergency services and high occupancy vehicles (HOV) with three or more occupants. The Concept Design for the proposed T3 Lane is being developed as part of the Hobart Southern Projects (sub-project 1).

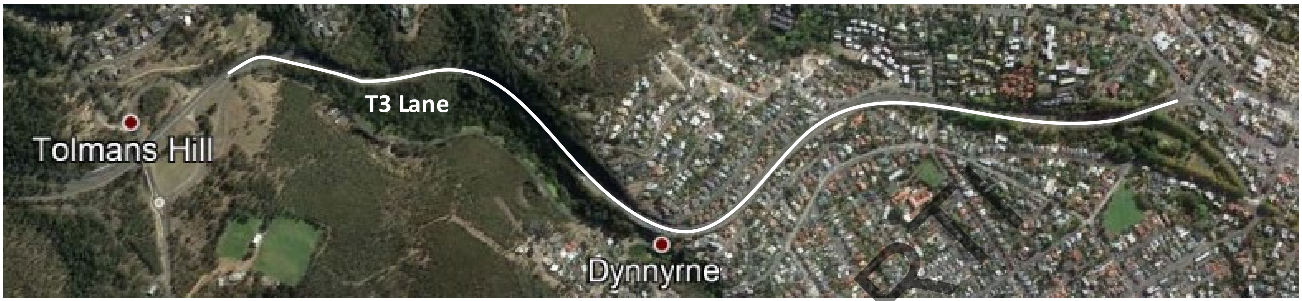

Figure 1.1 T3 Southern Outlet Area

This concept of operations will address the enforcement system recommended for use, which incorporates Indra's DAVAO HOV enforcement system (primary) and ANPR (secondary).

1.2 DOCUMENT OVERVIEW

This Concept of Operations is a working document that should be updated throughout the lifecycle of the project, as and when new information and requirements become clear – or aligned to each stage of design.

At this stage (preliminary design), only high-level information is available at this stage, and it is not possible to complete all sections. Where there is opportunity for further information, or it is not yet possible a status box will be put in place which indicates that further information will be added as design progresses, an example is shown below.

This is an example of a status box.

This Concept of Operations has been based on the Institute of Electrical and Electronic Engineers (IEEE) Standard 1362 (System Definition – Concept of Operations). This standard has been used due to the enforcement systems strong electronic components and requirements for multiple interfaces. The structure instructed by the standard has been mostly utilised for this document, with one additional section added to provide the Department of State Growth with greater information on the expected capital and operational expenditure (section 5.3.5).

This document will:

- Communicate the user's needs for and expectations of the T3 lane and enforcement system.

This document's intended audience is:

- Department of State Growth (project sponsor): to further understanding of how the system will work in practice and inform future development of the project and potential Requests for Quotations
- Potential contractors: to inform system design and outline functional requirements.

1.3 USE OF THE TERM CONCEPT OF OPERATIONS

The term 'Concept of Operations' can have different meanings within different technical disciplines or industries. While the use of IEEE 1362 has been used as a guide to help formulate this document, an equivalent level of detail has not been developed at this stage of the project and may not need to be developed for future stages.

1.4 SYSTEM OVERVIEW

THE SYSTEM

The proposed T3 lane for implementation on the Southern Outlet requires an enforcement system to verify the occupancy of private vehicles using the lane meets requirements (over three occupants). The enforcement system is an important element in maintaining compliance and operational effectiveness.

The system should – with a high degree of automation – enforce the rules of this T3 lane. This is expected to be aligned to the simplified process outlined in Figure 1.2 below.

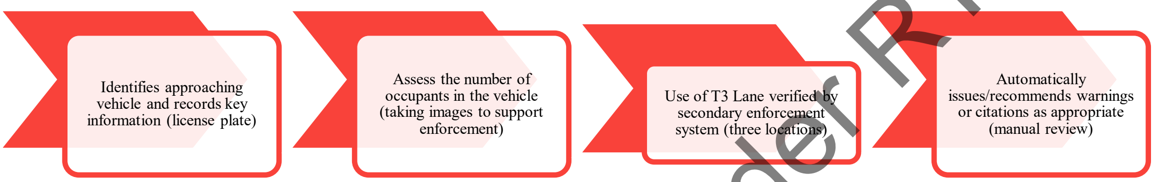

Figure 1.2 Simple system process

KEY STAKEHOLDERS

There are a number of key stakeholders impacted by the implementation of the T3 lane and associated enforcement system, these are:

- Department of State Growth (Project Sponsor)
- Emergency services (key stakeholder)
- Public transport operator (key stakeholder)
- Maintenance provider
- Department of Justice
- Road users (public)
- Road user representative groups (e.g. RACT)
- Taxi operators.

2 REFERENCED DOCUMENTS

2.1 REFERENCED DOCUMENTS

The following references and standards are found to be applicable to the proposed T3 enforcement system. In the absence of published standards for Tasmania, VicRoads standards have been used as they are developed and typically aligned to practice in Tasmania.

- Specification TCS 001 – Mast Arms, Joint Use Mast Arms, Joint Use Poles
- Specification TCS 011 – Universal Road Side Cabinet
- Specification TCS 043 – Electrical Distribution Cabinet
- Standard Section 732 – ITS Devices Installation
- Standard Section 734 – Electrical Installations
- Standard Drawing TC 1220 – Cable Pit Access Cover (Department of State Growth)
- General ITS Requirements (draft) (Department of State Growth)
- IEEE 1362.

3 CURRENT SITUATION

3.1 BACKGROUND, OBJECTIVES AND SCOPE

The Southern Outlet in this area currently operates as a regular two-lane highway, with an 80 km/h speed limit. A bus lane is in place for approximately 800 m on the approach to Davey Street, terminating approximately 270 m upstream of the intersection. Currently, there are is no electronic enforcement system in place for the bus lane and enforcement is carried out irregularly by Police.

3.2 OPERATIONAL POLICIES AND CONSTRAINTS

Normal road rules apply to the Southern Outlet's regular running lanes (non-bus lane), with this section of carriageway operating under an 80 km/h speed limit.

The section of bus lane is bound by the following operational policies and constraints:

- In operation 24/7
- Only available for use by buses, bicycles and emergency services
- Special purpose lane restrictions apply (Tasmanian Road Rules, Department of State Growth, 2017)
  - You can drive for up to 100 metres in special purpose lane **only** when:
    - You need to cross it to enter or leave the road
    - Avoiding a hazard in your lane
    - Overtaking a vehicle turning right.

LEGAL CONSTRAINTS

Initial stakeholder feedback from the Office of the Director of Public Prosecutions provided additional operational constraints and considerations for the T3 enforcement system, essential to the successful operation of an enforcement system. This includes:

- Evidence of the vehicle being driven in the T3 lane; this would be through witness of photographic evidence.
  - Photographic evidence needs to capture the vehicle at multiple points as they travel in the lane
  - In the absence of physical barriers, a minimum of two cameras are required
  - If two cameras were used, images would have to be of a high quality. A greater number of cameras would mean a lower quality image would be more acceptable.

3.3 DESCRIPTION OF THE CURRENT SITUATION

Currently, there are no automated systems in place along this stretch of the Southern Outlet relating to enforcement. The bus lane that is present for approximately 800 m has no enforcement system in place. As such, there is no associated cost other than regular maintenance of the pavement and line markings.

Some vehicle detection, primarily for queue or congestion detection, has been installed using radars is present on the inbound direction.

3.4 MODES OF OPERATION FOR THE CURRENT SITUATION

The current situation is in operation 24/7, with no changes to operation during normal circumstances. Under the current regime there are two applicable modes of operation; maintenance and incident response.

MAINTENANCE

Maintenance activities may be required for the pavement, roadside infrastructure (signs and vehicle barrier protection systems), electronic vehicle detection or verge vegetation. All maintenance is undertaken in accordance within defined Department of State Growth guidelines, which includes but is not limited to Traffic Control for Works on Roads (2014).

INCIDENT

In the event of an incident (such as crash, stopped vehicle, hazardous material spill etc.) on this section of the Southern Outlet the road operation may be altered significantly. Any alternations – such as the closing of lanes or carriageways – will be undertaken aligned to the responsible party's guidance and policies.

3.5 USER CLASSES AND OTHER INVOLVED PERSONNEL

This section will detail each 'user class'. A user class is distinguished by the ways in which users interact with the system.

System owner

The system owner is the Department of State Growth. The system owner is responsible for commissioning other user classes to perform system duties (such as maintenance, verification and operation).

Maintainer

Maintenance activities are likely to be infrequent in the current situation, due to a low level of maintainable infrastructure. Maintenance of the pavement and associated road signage is undertaken in accordance with the Department of State Growth's typical practices.

Police

The Tasmanian Police Force are currently responsible for the manual enforcement of road rules along this stretch of the Southern Outlet, including enforcement of the bus lane.

Public transport

Public transport operators and users currently benefit from use of the bus lane.

Private car users

Private car users utilise the regular running lanes on the carriageway and are currently prohibited from using the bus lane.

3.6 SUPPORT ENVIRONMENT

This section of the network is currently maintained by contractors who are commissioned by the Department of State Growth in their role as 'system owner', as well as direct managed works by State Growth.

The Tasmanian Police Force currently support operation of the bus lane by conducting manual enforcement.

4 JUSTIFICATION FOR AND NATURE OF CHANGES

4.1 JUSTIFICATION OF CHANGES

A number of factors have created a requirement for the development of an T3 enforcement system on the Southern Outlet. The Department of State Growth has identified a number of key project objectives for the overall Hobart City Deal – Southern Projects. These are:

- To achieve modal shift for commuters using the Southern Outlet (in favour of public transport)
- To improve public transport reliability along this corridor
- To encourage multiple occupancy of private vehicles during peak periods of travel
- To improve public transport and passenger experience for Kingborough and Huon residents.

The introduction of the T3 lane and associated enforcement system will contribute towards achieving all of the above project objectives by:

- Improving public transport reliability through a dedicated T3 lane
- Encourage multiple occupancy vehicles by allowing use of the T3 lane to improve journey times
- Encourage modal shift as public transport is likely to have improved journey time vs private car use.

The Department has identified that enforcement is critical to implementation success and effective operation of the transit lane and will in-turn promote the objectives of encouraging modal shift and multi-occupancy private vehicles.

4.2 DESCRIPTION OF DESIRED CHANGES

This section summarises the new capabilities, functions, processes and other changes that are proposed in response to the factors identified in section 3.

CAPABILITY CHANGES

The functions and features to be added for the proposed system to meet its objectives and requirements are:

- Ability to detect the occupancy of a vehicle
- Identification of vehicles
- Tracking of vehicle lane usage (i.e. is it consistently present in the T3 lane)
- Compiling of enforceable evidence of T3 lane misuse.

SYSTEM PROCESSING CHANGES

The proposed system introduces changes in the processing of data, including:

- Communication network expansion
- Recording of:
  - Vehicle occupancy
  - License plate
  - Time and date
- Storage, processing and reporting of enforceable evidence (Cross referencing of license plate information between primary and secondary enforcement sites).

INTERFACE CHANGES

Whilst the full scope of interface changes is not currently available, a high-level consideration of possible interface changes considers new interfaces between:

- Primary and secondary enforcement system to cross reference detection information and provide a recommendation for enforcement
- Following manual verification of the recommendation to enforce, an interface will be developed between the Department of State Growth (responsible for verification) and the Police (responsible for enforcement).

> The level of required interface changes is not clear at this stage. The system may be capable of integrating with an existing enforcement system interface between the Department of State Growth and Police or may require the development of a new interface. This section is to be updated as the project progresses.

PERSONNEL CHANGES

The primary enforcement system (HOV detection) requires support in the verification of its recommendations for enforcement. This will be done manually and may require the recruitment of additional resource(s), or the assignment of additional responsibilities to a current employee(s).

ENVIRONMENT CHANGES

The road environment around the proposed system is crucial to its successful operation. The Planning and Environmental report (PS117730-01-PLA-REP-001 RevA) identifies the Planning, Environmental, Heritage and Geotechnical properties of the land on which the proposed system will operate.

Changes required to the environment to support operation of the proposed system includes:

- Line markings; the T3 Separation report (reference) identifies a buffer type line marking as the most appropriate solution for supporting T3 enforcement
- Protecting infrastructure; assets introduced to the road environment as part of the deployment of the proposed system will require supporting infrastructure (such as vehicle protection barrier systems) aligned to Tasmanian guidelines (to be updated.

> As the proposed system introduces new assets to the Tasmanian state road network, a review of supporting infrastructure requirements should be conducted once the system is agreed upon and aligned to current best practice.

OPERATIONAL CHANGES

To support the proposed system, a range of changes to current operational policies, procedures, methods and daily work routines are required, including:

- Introduction of policy facilitating T3 operation and enforcement
- Establishment of a new education and enforcement procedure, encompassing:
  - Verification of enforcement recommendations (HOV detection images)
  - Issuing of education materials or citations relevant to the T3 lane.

SUPPORT CHANGES (changes in support requirements e.g. introduced new maintenance requirement, inspections, validation of images).

The introduction of new functions, processes, interfaces and personnel necessitates changes to the current support environment. Verification of HOV detection images has been classified as an operational change, as it a critical operational procedure allowing enforcement of the T3 lane.

Additional maintenance requirements are the core support change. The introduction of new assets, including detection systems, ANPR, pavement markings and supporting infrastructure brings a range of new maintenance requirements. These maintenance requirements are likely to be tiered, requiring varying levels of knowledge. This ranges from highly specialised skill sets for the set-up and calibration of the primary enforcement system to more common requirements such as those brought by pavement markings and vehicle protection barrier systems.

> Once elements of the system are agreed upon, a full review of component maintenance requirements will be possible. This section should be updated accordingly and a Maintenance and Repair Strategy Statement produced at the relevant project stage (detailed design).

4.3 PRIORITIES AMONG CHANGES

This section identifies priorities amongst changes and new features. Classification and prioritisation should help to guide the decision-making process during development of the proposed system. Changes classified as desirable and optional have been prioritised within their classes, this has not been done for essential features as they are all essential for the operation of a T3 enforcement system.

The majority of changes are classified as essential, with only one desirable change and no optional changes. This is due to the number of requirements that must be met in order to legally enforce the T3 lane (as specified in section 3.2). Additionally, there are maintenance and safety requirements that must be met to ensure the system remains operational and acceptably safe.

Table 4.1 Change priority

<table>
<tr><th>Classification</th><th>Priority</th><th>Change</th><th>Impact of not implementing</th></tr>
<tr><td rowspan="6">Essential features</td><td rowspan="6">N/A</td><td>Ability to detect occupancy of a vehicle (capability).</td><td>Unable to detect vehicle occupancy and enforce T3 lane rules. This may lead to widespread misuse and render the T3 lane ineffective without any enforcement alternative.</td></tr>
<tr><td>Detection of vehicle license plates (capability).</td><td rowspan="5">Unable to enforce T3 lane rules. This may lead to widespread misuse and render the T3 lane ineffective without any enforcement alternative.</td></tr>
<tr><td>Compiling of enforceable evidence (capability).</td></tr>
<tr><td>Storage of enforceable evidence (system processing).</td></tr>
<tr><td>Recording of (system processing):
— Vehicle occupancy
— License plate
— Time and data.</td></tr>
<tr><td>Cross referencing license plate information between primary and secondary enforcement system (system processing) (interface).</td></tr>
</table>

Classification	Priority	Change	Impact of not implementing
		Interface between Department of State Growth and Police to enable enforcement following image verification (interface change).	
		Allocation of resource to complete manual verification of HOV detection images (personnel).	
		Maintenance requirement (support).	System may not meet enforcement requirements. System may become non-operational due to poor maintenance.
		Line markings (environment).	Current line markings will be used. T3 lane would terminate where bus lane begins. Clarity for road users would be reduced, potentially impacting ability to enforce.
		Supporting infrastructure (environment).	This would be a significant departure from standard and be unacceptably unsafe for road users.
		Introduction of new policy supporting T3 lane operation and enforcement (operational).	T3 lane would not be recognised as legitimate and enforcement would not be possible.
Desirable features	1	New education and enforcement procedure (operational).	Fines would be incorporated into the Department's existing citation system. Education may not be possible. Lack of tailored messaging may impact operational effectiveness of the system.
Optional features	No changes have been classified as optional.		

4.4 CHANGES CONSIDERED BUT NOT INCLUDED

This section identifies changes and new features considered but not included, documenting the results of analysis activities.

- Inclusion of hard barrier separating T3 lane and regular lanes
- Manual enforcement
- Other enforcement systems as noted within the Technology Feasibility Study (Appendix C).

4.5 ASSUMPTIONS AND CONSTRAINTS

The below assumptions or constraints are applicable to the changes and new features identified in this chapter.
T3 enforcement assumptions include:

- A system with a high degree of automation is required rather than manual due to local resourcing and policy
- The speed limit is currently 80 km/h and will remain at that speed unless future VSLS change speed limits when operationally required.
- Police will remain responsible for the enforcement of speed limits and road rules
- Indra DAVAO system will be used for primary enforcement locations
- High quality images are required
- Multiple locations providing evidence are required.

Further constraints and assumptions are likely to become clear as the project progresses, and greater levels of stakeholder engagement are undertaken.

5 CONCEPTS FOR THE PROPOSED SYSTEM

This section describes the proposed system resulting from the desired changes as specified in section 3, providing a high-level overview of the operational features to be provided.

5.1 BACKGROUND, OBJECTIVES AND SCOPE

Hobart has strong jobs growth and a population increasing in line with the greater economic activity. As a car dependent city (83 per cent of all journeys to work are by car), it is expected that pressure on the road network will continue to increase. This, combined with heavily concentrated peak demand, will likely result in congestion and studies such as the 2010 Hobart Inner City Development Plan (and learnings from cities elsewhere) have demonstrated that the current commuter travel patterns are unsustainable. In response to this, the Hobart City Deal Southern Projects provides a reliable and cost-effective alternative transport system with a focus on prioritized rapid passenger transport as a competitive alternative to private car travel.

The overall project objectives (of which this system is a part) are:

- To achieve modal shift for commuters using the Southern Outlet (in favour of public transport)
- To improve public transport reliability along this corridor
- To encourage multiple occupancy of private vehicles during peak periods of travel
- To improve public transport and passenger experience for Kingborough and Huon residents.

The specific objectives of introducing a T3 lane are:

- Improving public transport reliability through a dedicated T3 lane
- Encourage multiple occupancy by allowing use of the T3 lane to improve journey times
- Encourage modal shift as public transport is likely to have improved journey time vs private car use.

This system will help to achieve these objectives by enforcing applicable policies and restrictions on the use of the T3 lane, maintaining the T3 lanes operational integrity (through effective enforcement) and helping reduce journey times and encourage modal shift.

The systems core objectives are:

- Enforce the T3 lane with a high degree of automation
- Achieve an acceptable false-positive rate (20 per cent false positives from automated system caught by manual review).

5.2 OPERATIONAL POLICIES AND CONSTRAINTS

There are a wide range of operational policies and constraints which are applicable to the proposed system, these have been categorised and are detailed below.

T3 LANE OPERATIONAL POLICIES AND CONSTRAINTS

- The lane will be operational 24/7, therefore the proposed system is required to able to detect and enforce 24/7 during varying light conditions (day and night) and a range of weather conditions (actual enforcement may be by time of day).
- Capable of detecting and distinguishing all vehicle types, including private cars, heavy goods vehicles, emergency services vehicles and public transport.

ENFORCEMENT POLICIES AND CONSTRAINTS

- System needs to be highly automated, manual enforcement is not an available option (although manual verification is permitted).
- Enforcement system is required to provide proof beyond reasonable doubt of lane misuse (at least two points that a vehicle has been present in the T3 lane).
- Capable of detecting license plates and vehicle occupancy in all weather conditions.
- Minimal involvement.

5.3 DESCRIPTION OF THE PROPOSED SYSTEM

5.3.1 THE OPERATIONAL ENVIRONMENT AND CHARACTERISTICS

The T3 lane will be in place along the Southern Outlet towards Hobart, beginning to the north of Olinda Grove junction and terminating at the intersection with Davey Street. Figure 5.1 shows the section of the Southern Outlet applicable to this enforcement system.

The subject section of the Southern Outlet provides significant challenges due to changing horizontal and vertical geometry. The reliability of intelligent transportation systems that rely on image recognition can be diminished by complex geometry. This geometry guided the proposed locations of the primary and secondary enforcement sites.

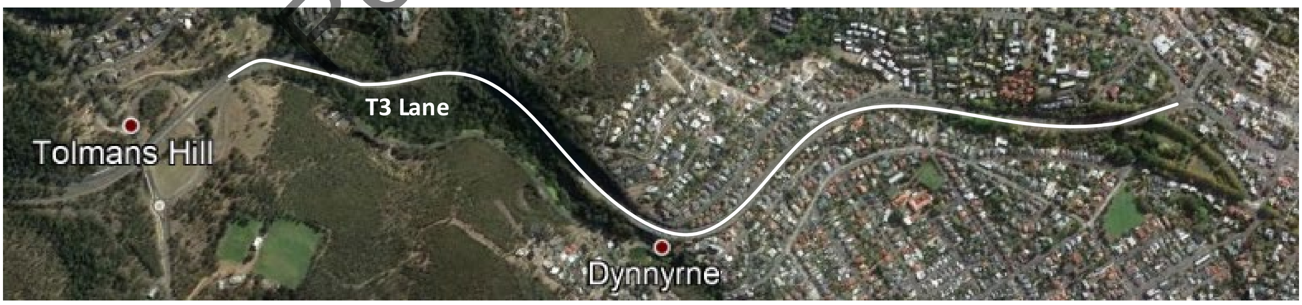

Figure 5.1 T3 Lane operational area

Detailed information on the Planning, Environmental, Heritage and Geotechnical properties of the environment can be found in PS117730-01-PLA-REP-001 RevA (Planning and Environment Report).

> Planning, Environmental, Heritage and Geotechnical requirements of the system will be detailed at a later project stage, once specific systems and supporting infrastructure are identified and recommended.

5.3.2 SYSTEM COMPONENTS (AND INTERCONNECTIONS)

This section details the core system components and their interconnections at a high level, to inform future design of the T3 enforcement system. These recommended components have been identified as a result of preliminary works carried out as part of the Technology Feasibility Study (Appendix C).

PRIMARY ENFORCEMENT SYSTEM

The primary enforcement system – proposed as Indra's DAVAO system – will be capable of detecting the number of occupants within a vehicle, the core access criteria for the T3 lane. This system will be positioned near the start of the T3 lane (aligned to operational policy), to capture all vehicles using the T3 lane from the beginning. This system should also be able to detect and differentiate between other permitted vehicles such as emergency services and public transport.

ANPR devices will be required at this site to capture the number plate information. It is understood that other deployments of DAVAO by Indra have been modified to meet specific project requirements and it is assumed that secondary data sources such as ANPR could be matched. If this 'data matching' is not feasible or cost efficient with the DAVAO product then, based on previous experience of similar projects, third party data fusion should be relatively straightforward.

There are very few technologies available that meet the requirements of this project and a collaborative approach with suppliers will likely need to be explored.

The primary enforcement site would also have the same ANPR as the secondary enforcement locations.

SECONDARY ENFORCEMENT SYSTEM

A secondary enforcement system is required to demonstrate that a road user has travelled along the T3 lane in contravention with access requirements (as there are permitted reasons for temporarily using the T3 lane as defined in section 3.2). This system will be comprised of ANPR cameras, which are connected to the overall system and capable of cross referencing against data from the primary enforcement system. There are a number of ANPR systems available, and this element of the project could be subject to a competitive performance-based process.

It is recommended that two secondary enforcement sites are deployed, the first a minimum of over 100 m downstream of the primary enforcement site, the second located over the final 800 m of the T3 lane.

The ANPR system and DAVAO system will need to be integrated for the enforcement operation.

ENFORCEMENT AND EDUCATION PROCESS

The enforcement and education process is driven by recommendations provided through a combination of recommendations from the primary and secondary enforcement systems. Firstly, these recommendations will be manually verified, to ensure only applicable enforcement and education materials are distributed. Once verified the enforcement and education process begins and appropriate materials/citations issued.

> A clear and transparent education and enforcement procedure should be developed, aligned to the overall project objectives and protecting the operational integrity of the T3 lane facility.

A high-level overview of system components and interconnections is shown in Figure 5.2.

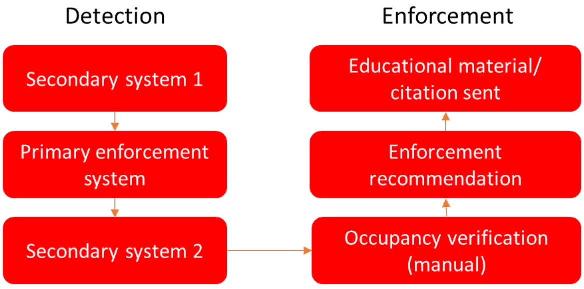

Figure 5.2 Overview of system components

5.3.3 INTERFACES TO EXTERNAL SYSTEMS OR PROCEDURES

The T3 enforcement system will have several interfaces to external systems or procedures, including:

- Enforcement system (with a new process and owner to be agreed upon)
- Tasmanian ANPR database; it may be possible for ANPR sites to be connected to any existing Police ANPR database to assist in their duties
- Department of State Growth; the system will be connected to the Department of State Growth's asset management system.

Stakeholder engagement at later stages of this project should identify any addition interfaces to external systems or procedures. Ultimate owner of the external systems will need to be determined before development commences to ensure all user requirements are encapsulated.

5.3.4 CAPABILITIES OR FUNCTIONS OF THE PROPOSED SYSTEM

The proposed system should be capable of:

- Detecting and recording the number of vehicle occupants in a car at the primary enforcement site
- Detecting and recording the license plate and type of vehicle at the primary enforcement site, including the ability to detect vehicles allowed to use the T3 lane (emergency services, public transport)
- Detecting and recording the license plate of vehicles at secondary enforcement sites along the T3 lane
- Cross referencing license plate and occupancy information from the primary and secondary enforcement sites, to provide the Department of Justice with confidence that misuse has occurred
- Initiating the enforcement and education procedure
- Flexible configuration for detection decision making
- Vehicle passenger occupancy detection algorithm that is able to be updated, modified, configured based on adaptive policy decisions.

5.3.5 COST OF SYSTEM OPERATIONS

The costs detailed in Table 5.1 below are a based on initial conversations with system suppliers (Indra) and WSP's experience of in the design and deployment of other, similar systems (ANPR). These costs are intended to provide an indication only of the expected cost of system operations over a one-year period. Note that the installation and supporting infrastructures such as gantries are not included in this table; they have been included in the civil cost estimate for the Southern Outlet Transit Lane (Concept Design).

Table 5.1 Indicative cost of system operations

System component	Cost type	Description	Cost estimate	Maintenance Cost (2 years) – no renewal cost included	Based upon
Primary site					
Indra DAVAO HOV detection system	Capital expenditure	Including all components and excluding system integration or centre application	[redacted]	Included	Indicative cost from supplier (Indra)
ANPR system	Capital expenditure	ANPR system	[redacted]	[redacted]	Previous experience in deployment of ANPR. (e.g. CEOS ANPR system)
Operational expenditure	Operational expenditure	Annual	[redacted]	N/A	Indicative cost from supplier (Indra)
Secondary sites					
Secondary enforcement system x 2 Using ANPR cameras	Capital expenditure	ANPR system	[redacted]	[redacted]	Previous experience in deployment of ANPR. (e.g. CEOS ANPR system)
Operational expenditure x 2	Operational expenditure	Annual	[redacted]	N/A	Previous experience in deployment of ANPR. CEOS ANPR system
On-going new staff training	Operational	Annual	[redacted]	N/A	Assume 2 new workers trained p.a. at a 2-day workshop and 1 day supervised. $250/hr training x 24 hrs. This does not include travel cost.
Enforcement and community education process					
The set-up of a new enforcement and community education process	Capital expenditure (first year)	Annual	[redacted]	N/A	Assume one part-time employee working for a year; budget for advertising via radio

The cost of system operations will become more accurate as the project progresses and further engagement with potential suppliers and stakeholders is conducted.

5.3.6 OPERATIONAL RISK FACTORS

A preliminary assessment of operational risk factors for the proposed enforcement system is detailed in Appendix A.

5.3.7 PERFORMANCE CHARACTERISTICS

Performance characteristics of the system will be detailed at a later project stage.

5.3.8 QUALITY ATTRIBUTES

Quality attributes of the system will be detailed at a later project stage.

5.4 MODES OF OPERATION

This section describes the various modes of operation for the proposed system, and the anticipated operation of the system during each mode.

REGULAR OPERATION

Under regular operation the system should be fully operational, with primary and secondary enforcement sites both live.

DEGRADED OPERATION

If one (of two) secondary enforcement sites is non-operational, the enforcement system is still capable of detecting T3 lane misuse and following education/citation procedure. However, secondary verification that a road user has misused the lane will only be possible from one site.

MAINTENANCE

Maintenance procedures will be carried out in line with the Department for State Growth's guidelines and requirements. It is recommended that during maintenance of the secondary enforcement sites, one is always kept live and operational (if within maintenance guidelines for lane closures), as this facilitates enables enforcement activities to be carried out.

More comprehensive guidance on operation during maintenance will be completed at a later stage of this project.

TRAINING

While somewhat dependent on the eventual technology selection, most image recognition systems require either a settling in or training period to provide feedback to the detection algorithms.

5.5 USER CLASSES AND OTHER INVOLVED PERSONNEL

This section will detail each 'user class'. A user class is distinguished by the ways in which users interact with the system.

SYSTEM OWNER

The system owner will ultimately be the Department of State Growth. The system owner is responsible for commissioning other user classes to perform system duties (such as maintenance, verification and operation).

TRAINER

The system supplier is expected to provide training to the Department's staff, maintenance operatives and reviewer – anyone involved in the day to day operation of the system. The trainer should have an expert knowledge of the system and be experienced in delivering training.

REVIEWER/VERIFICATION

To optimize system performance, human review is required of instances where the system has detected potential misuse. This verification procedure should reduce the likelihood of false-positive sanctions being issued and help the system improve and become more accurate over time. This will be the responsibility of the Department of State Growth, or their appointed contractor.

MAINTAINER

Maintenance and calibration activities are expected to be required on both scheduled and non-scheduled basis. Maintainers will be required to have the skill level and competencies required to carry out their duties. It is anticipated that different levels of specialist knowledge will be required for different system components/failures – the roles and responsibilities of maintenance operatives should be clearly detailed and agreed upon.

ROAD USER – PRIVATE CAR USER

Car users will interact with the system through the use of the T3 lane. Their interaction will be limited to being captured by enforcement sites and receiving/not receiving enforcement and education materials.

ROAD USER – PUBLIC TRANSPORT

Public transport (buses) are granted access to the T3 lane to assist in their day to day operation and help encourage modal shift. They will use the T3 lane for priority access to Davey Street.

ROAD USER – MAINTENANCE OPERATIVES

Maintenance operatives require access to the T3 lane to carry out maintenance procedures and inspections. Access should be safe and aligned to current guidelines and standards. There may be a need for maintenance vehicles to be registered with the Department for State Growth to stop erroneous enforcement and education materials being distributed.

ENFORCEMENT AND EDUCATION PROCESS FACILITATOR

The responsibility of issuing enforcement and education actions will be upon the Police/Department of Justice, in line with current practices. However, the process and tiered approach (education then citation) will be developed by the Department of State Growth to align to the overall project objectives.

5.6 SUPPORT ENVIRONMENT

The system will require support concepts and a structured support environment to facilitate smooth day to day operation.

Repair or replacement criteria

If the system were to require repair or replacement through issues or faults as a result of faulty hardware, software or any other component or service delivered by the supplier it is expected the supplier will promptly provide repair or replacement services.

Maintenance levels

Scheduled, and non-scheduled maintenance of the enforcement system is expected. The below assumptions are aligned to typical maintenance requirements for similar ITS equipment:

- Number of scheduled maintenance visits per annum:
  - Four for devices with critical optical components (e.g. image recognition for ANPR and vehicle passenger occupancy)
  - Two for devices with non-critical optical components (e.g. CCTV cameras)
  - One for other ITS devices
- Number of non-scheduled maintenance visits per annum – unknown, to be determined in partnership with eventual equipment suppliers.

Legislative support

It is anticipated that legislative changes will be required to enable the enforcement of the T3 lane. This will include support from the Department of Justice in implementing the required changes in legislation. A review of legislative/regulatory changes is detailed in Appendix B.

6 OPERATIONAL SCENARIOS

6.1 OPERATIONAL CONCEPT

The system schematic is shown in Figure 6.1.

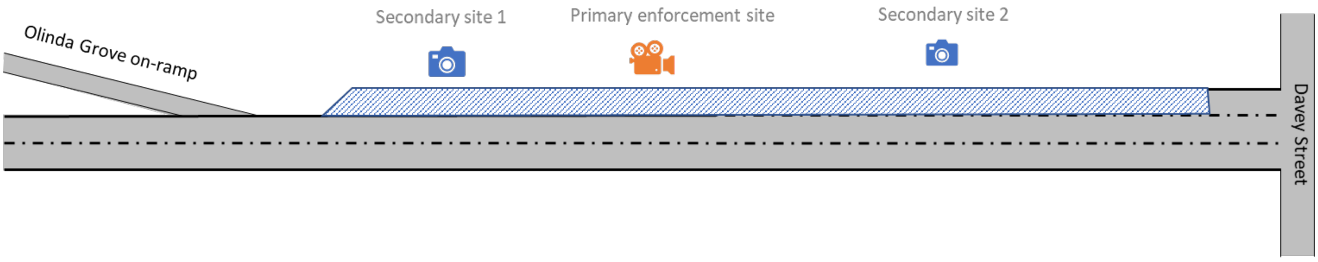

Figure 6.1 System schematics

For vehicles other than buses, emergency service vehicles and maintenance vehicles, the system may operate similar to the flowchart shown in Figure 6.2. This decision tree would be expected to be workshopped with internal political, community engagement, legal, and technical stakeholders. For example, vehicles entering after the initial warning but before the middle primary enforcement could be issued with fines instead of just a warning.

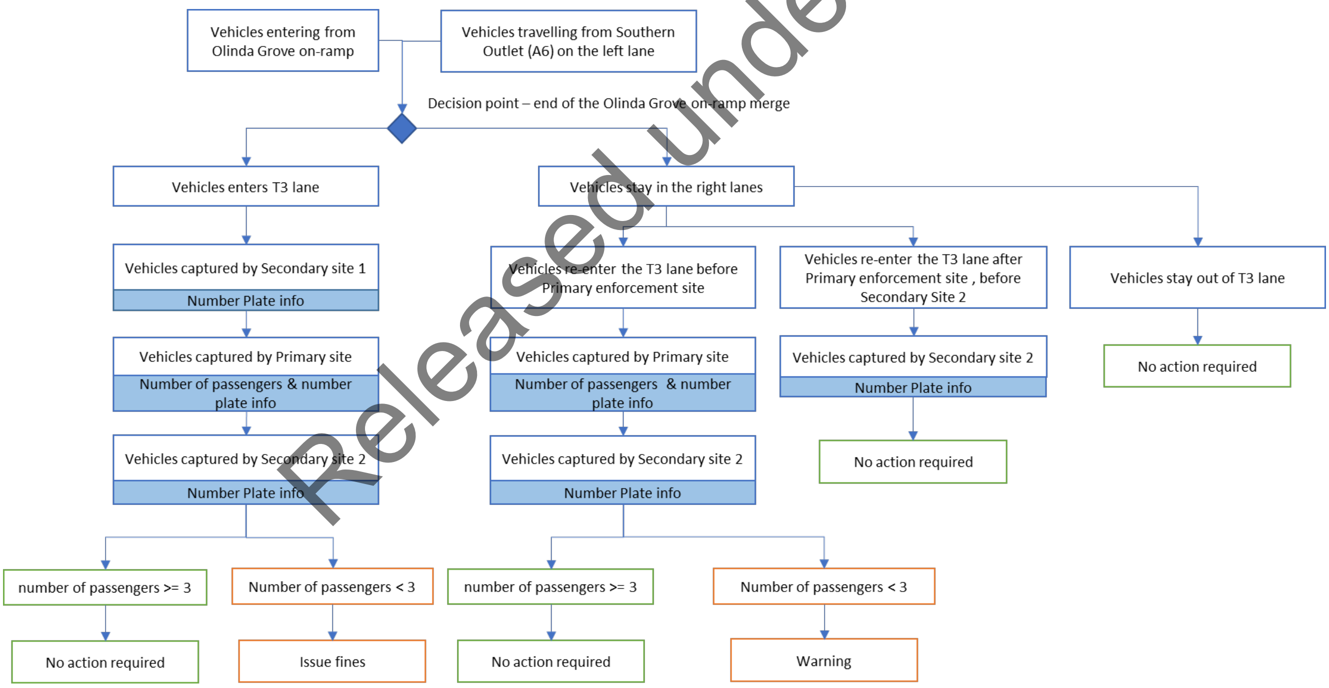

Figure 6.2 System operation flowchart

6.2 SCENARIO ONE

SCENARIO DESCRIPTION

A HOV with three occupants is driving along the Southern Outlet towards Hobart. The driver recognises their vehicle meets requirements for use of the T3 lane and remains in lane one joining the T3 lane at the start, just downstream of the Olinda Grove on-ramp. The vehicle continues to drive the full length of the T3 lane, exiting at Davey Street.

OPERATIONAL RESPONSE

As the vehicle passes the first secondary enforcement site, the number plate information is recorded and timestamped. As the vehicle passes the primary enforcement location, the number of occupants and registration plate is recorded and timestamped. The primary enforcement site recognises that the vehicle meets the requirements for use of the T3 lane. As the vehicle passes the second secondary enforcement location its registration plate is logged again and cross referenced with number plates recorded as compliant by the primary enforcement location and the other secondary enforcement location. As the approved number of passengers is returned, no further enforcement actions are undertaken.

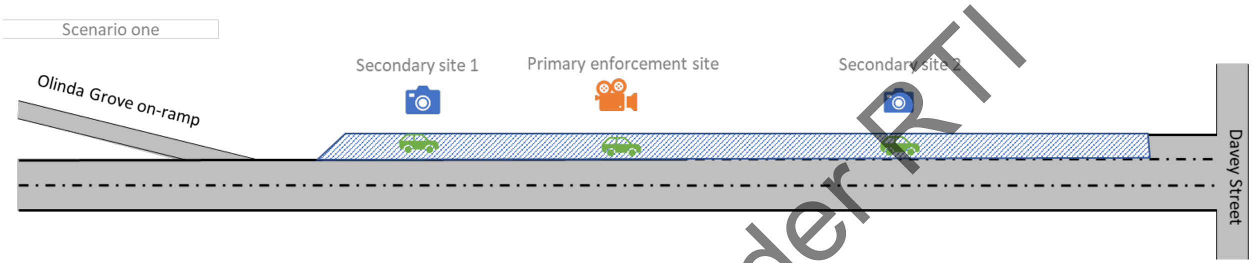

Figure 6.3 Scenario one operational schematic

6.3 SCENARIO TWO

SCENARIO DESCRIPTION

A HOV with three occupants is driving along the Southern Outlet towards Hobart. Traffic is light and the vehicle continues along the Southern Outlet in the normal, non-restricted running lanes. At approximately ch. 1800 the vehicle joins the T3 lane, travelling the remaining length and exiting at Davey Street.

OPERATIONAL RESPONSE

The vehicle passes the first secondary enforcement location in a normal running lane, as such no detection of number plate was taken by the first secondary enforcement system. Joining the T3 lane at approximately ch. 1800 the vehicle then passes the primary enforcement location, where its registration plate is logged, and number of passengers counted. The two registration logs are then cross referenced with each other, which returns a positive result as the number of passengers are equal to or more than three. No further enforcement actions are undertaken.

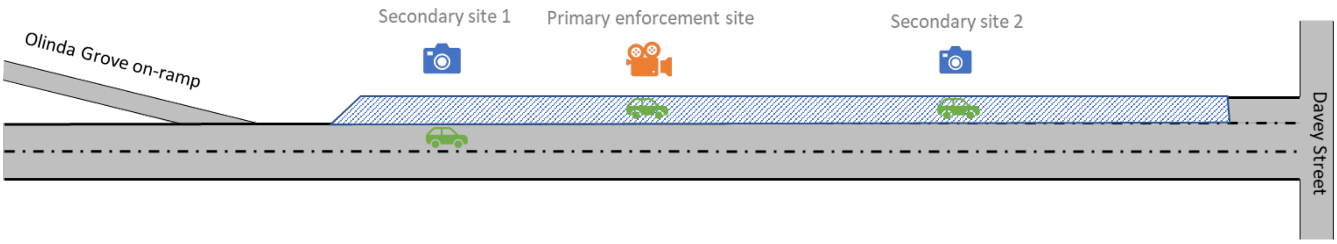

Figure 6.4 Scenario two operational schematic

6.4 SCENARIO THREE

SCENARIO DESCRIPTION

A vehicle with less than three occupants is driving along the Southern Outlet towards Hobart. Travelling in lane one (verge-side) the vehicle continues on its path and joins the T3 lane at the start, just downstream of the Olinda Grove on-ramp. The vehicle continues to drive the full length of the T3 lane, exiting at Davey Street.

OPERATIONAL RESPONSE

The vehicle passes the first secondary enforcement site and its number plate is recorded. The vehicle passes the primary enforcement location in the T3 lane, as such the enforcement system records the number of occupants (non-compliant) and the vehicles registration. As the vehicle passes the secondary enforcement location its registration is again recorded and cross referenced with the primary enforcement systems logs and the first secondary number plate logs. This shows that the vehicle was recorded as non-compliant and the enforcement process begins. The images taken by the primary enforcement site are verified by a human operator, who confirms there are less than three occupants in the vehicle. Then the operator, acting under delegated authority, issues a warning or fine to the registered driver of the vehicle. The scale of fines would be set by the regulatory authority. Warnings may detail the cost of possible future fines and contain educational material on the objectives and rules of the T3 lane. If the infringing vehicle left the T3 lane before secondary site 2 then a policy decision will need to be configured at the system level.

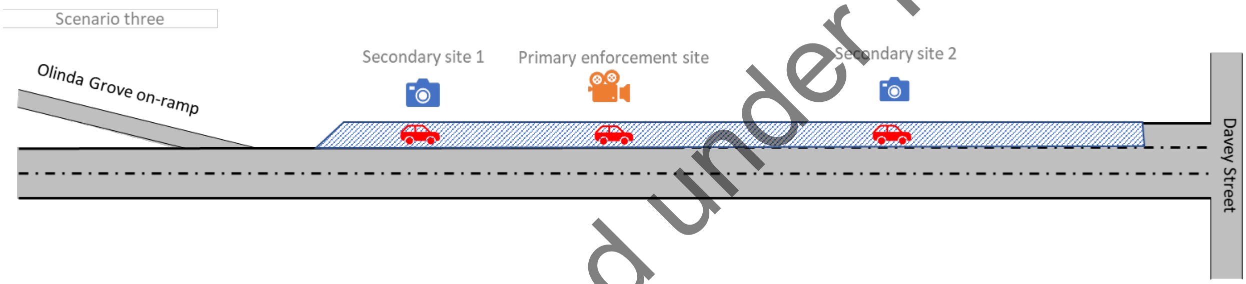

Figure 6.5 Scenario three operational schematic

6.5 SCENARIO FOUR

SCENARIO DESCRIPTION

A vehicle with less than three occupants is driving along the Southern Outlet towards Hobart. Traffic is light and the vehicle continues along the Southern Outlet in the normal, non-restricted running lanes. At approximately ch. 1800 the vehicle joins the T3 lane, travelling the remaining length and exiting at Davey Street.

OPERATIONAL RESPONSE

The vehicle passes the first secondary enforcement location in a normal running lane, as such no detection of vehicle registration was captured at the first secondary enforcement location. Joining the T3 lane at approximately ch. 1800 the vehicle then passes the primary enforcement location, where its registration plate is logged and the number of passengers is checked. Then the vehicle passes the second secondary enforcement location and its registration information. The images taken by the primary enforcement site are verified by a human operator, who confirms there are less than three occupants in the vehicle. Then the operator, acting under delegated authority, issues a warning or fine to the registered driver of the vehicle. The scale of fines would be set by the regulatory authority. Warnings may detail the cost of possible future fines and contain educational material on the objectives and rules of the T3 lane.

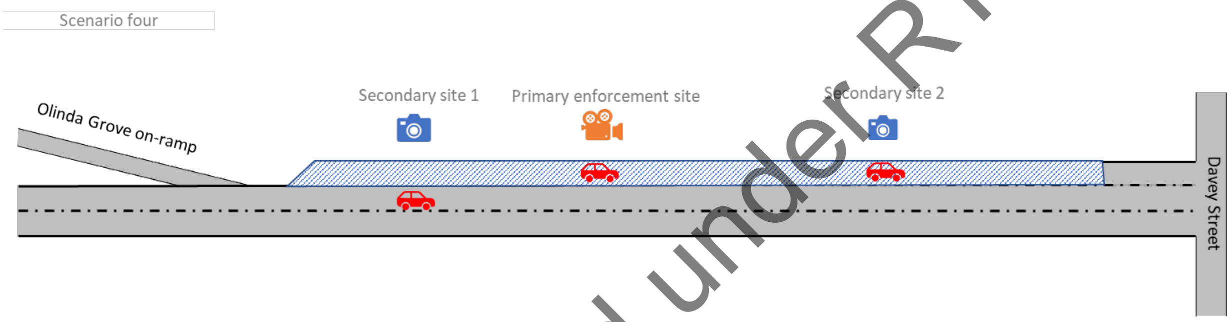

Figure 6.6 Scenario four operational schematic

6.6 SCENARIO FIVE

SCENARIO DESCRIPTION

An vehicle, with unknown number of passengers, travels on the normal lane and for some reason, decides to join the T3 lane towards the end and passes the secondary enforcement site 2.

OPERATIONAL RESPONSE

As the vehicle passes the second secondary enforcement location, the registration plate is recorded and logged. As this is the only information of this specific vehicle, it is not possible to know the number of passengers in the vehicle, and where the vehicle joins the T3 lane, therefore no enforcement action is required.

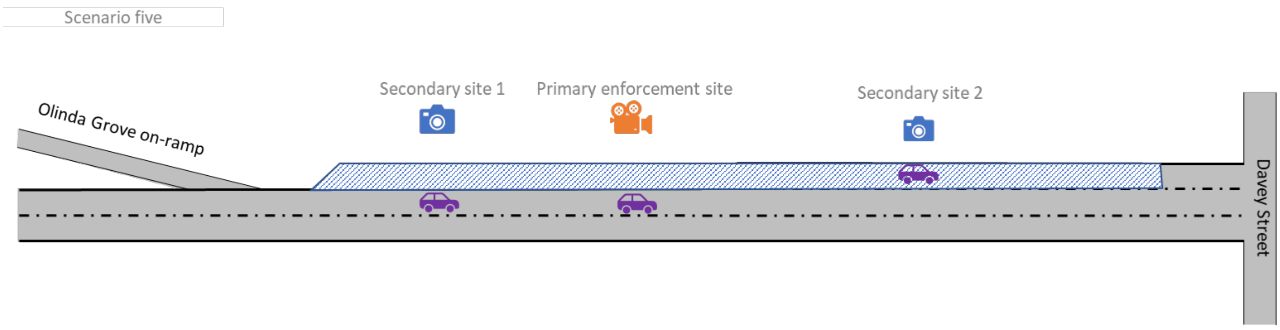

Figure 6.7 Scenario five operational schematic

6.7 SCENARIO SIX

SCENARIO DESCRIPTION

An emergency vehicle (police, ambulance, fire etc.) is driving along the Southern Outlet. The vehicle joins the T3 lane at the start, just downstream of Olinda Grove. The emergency vehicle continues along the length of the T3 lane, exiting at Davey Street.

OPERATIONAL RESPONSE

As the emergency vehicle passes the first secondary enforcement location, the registration plate is recorded and logged. The secondary enforcement system recognises that the vehicle meets the requirements for use of the T3 lane (recorded as an emergency vehicle). As the vehicle passes the primary enforcement location and the second secondary enforcement location its registration plate is logged and the system again recognises that the vehicle meets the requirements for use of the T3 lane (recorded as an emergency vehicle). No enforcement action is required.

6.8 SCENARIO SEVEN

SCENARIO DESCRIPTION

The maintenance work does not require the switching off of any of the enforcement sites and the vehicle enters T3 lane at various points due to the requirement of maintenance work.

OPERATIONAL RESPONSE

The system will operate as normal. Its registration number will be logged into the system before the vehicle goes to site, and the system will take the registration plate out of the processing procedure, similar to the emergency service vehicles. The vehicle's registration number will be removed from the system once the maintenance work is done.

6.9 SCENARIO EIGHT

SCENARIO DESCRIPTION

The maintenance work needs one or several of the enforcement sites to be switched off, or partial closure of the T3 lane.

OPERATIONAL RESPONSE

The system will stop operation and resume once the maintenance work is done. This should be carefully undertaken with a grace period instated either side of the maintenance works.

6.10 SCENARIO NINE

SCENARIO DESCRIPTION

The vehicle passenger occupancy detection system is returning too many false positives, or a manual review of approved vehicles has an unacceptable number of non-compliant vehicles.

OPERATIONAL RESPONSE

The system will need to be recalibrated or the algorithm re-trained. This will likely require involvement and additional costs with the system supplier unless specified within commercial arrangements.

7 SUMMARY OF IMPACTS

This section describes the operational impacts of the proposed T3 enforcement system on users, developers and the support and maintenance organisations.

7.1 OPERATIONAL IMPACTS

The operational impact of the proposed system can be split into lower-level subclauses to help describe the anticipated operational impacts. These subclauses and impacts are summarised below.

INTERFACES

Development of new interfaces between:

- Primary enforcement and secondary enforcement system
- Overall enforcement detection systems and enforcement and education process
- Expansion of the existing communication network infrastructure
- Additional systems to be integrated into the State Growth ITS VLAN/security systems/other network management tools.

CHANGES IN PROCEDURE

- New enforcement and education procedure including:
  - Image verification
  - Issuing of enforcement and education materials
- Maintenance, monitoring and recalibration of specialist technologies.

OPERATIONAL BUDGET

It is expected the Department of State Growth's operational budget for state roads will increase, with costs for the operational expenditure of the primary system alone totalling an approximated $1m USD. These costs were provided indicated by the detection system supplier and with the reference system that the costs were sourced from servicing a high capacity toll road in the United States this installation, with lower performance requirements, is expected to be lower.

OPERATIONAL RISK

Anticipated changes in operational risk are detailed in Appendix A.

7.2 ORGANISATIONAL IMPACTS

The organisational impacts on the user, support and maintenance agency during operation of the system are detailed below.

MODIFICATION OF RESPONSIBILITIES

The Department of State Growth will be ultimately responsible for the operation of the proposed system.

JOB POSITIONS

The introduction of the T3 enforcement system introduces a number of new roles including:

— Verification of recommended enforcement actions

— New maintenance responsibilities and amendments to existing contracts.

TRAINING

Training will be implemented for those who interact with the system including:

— Verification training

— Maintenance/system repair training.

7.3 IMPACTS DURING DEVELOPMENT

It is expected that the development and works required for the new system will impact all users of the Southern Outlet, as lane closures will be required during works, impacting traffic flow.

8 ANALYSIS OF THE PROPOSED SYSTEM

This section provides an analysis of the benefits, limitations, advantages, disadvantages, and alternatives considered for the T3 enforcement system.

8.1 SUMMARY OF IMPROVEMENTS

The proposed system introduces a range of new capabilities including:

- Ability to detect the occupancy of vehicles using the T3 lane
- Additional ANPR capabilities
- Enforcement of T3 lane (and previous bus lane rules).

It is expected these new capabilities will provide benefits to public transport and high occupancy vehicles by reducing travel time/journey time and improving journey time reliability.

8.2 DISADVANTAGES AND LIMITATIONS

The complex and highly specialised nature of the primary enforcement system will require specialist knowledge to conduct some repairs and calibration activities. This is a disadvantage as it is likely to negatively impact the time taken to respond to an issue with the primary enforcement system, as such resource is unlikely to be readily available.

8.3 ALTERNATIVES AND TRADE-OFFS CONSIDERED

This section details the alternatives and trade-offs considered in respect to the operational alternatives, rather than design alternatives.

Physically separating the T3 lane from other lanes was considered but discarded as it significantly reduces the flexibility of the route to manage roadworks and incidents, particularly on the T3 lane.

Increasing or decreasing the number of detection sites were considered with the final number and location settled through a collaborative workshop.

A system based on manual enforcement by Police was rejected by judicial and road safety stakeholders as difficult and unsafe to implement.

A softer approach to enforcement that uses a less rigorous level of technology could also be considered. This method would involve detection (e.g. through high-resolution CCTV) and education of non-compliant drivers, escalating to cost penalties for repeat offenders.

APPENDIX A

OPERATIONAL RISK

A1 OPERATIONAL RISK ASSESSMENT

This section details a preliminary assessment of operational risk factors for the proposed enforcement system. This risk assessment should be developed throughout the lifecycle of the project and updated when any changes to the system, or operating environment are made. Table A.1 details risk levels based on the assessed consequence and likelihood.

Table A.1 Risk matrix evaluation table

Likelihood	Insignificant	Minor	Moderate	Major	Severe	Catastrophic
Almost certain	C	B	B	A	A	A
Very likely	C	C	B	B	A	A
Likely	D	C	C	B	B	A
Unlikely	D	D	C	C	B	B
Very unlikely	D	D	D	C	C	B

Table A.2 describes the risk tolerability requirements.

Table A.2 Risk tolerance and responses

Risk rating	Risk description	Response
A	Very high – generally intolerable	Very high risks are generally intolerable and should be avoided except in extraordinary circumstances. An alternative solution should be found and all necessary steps taken to reduce the risk below this level.
B	High – undesirable	High risks are undesirable. It is highly unlikely an undesirable risk would be accepted. This can only be tolerated if it is not reasonably practicable to reduce the risk further, that is so far as is reasonably practicable (SFAIRP) is demonstrated and the risk is acceptable to the Department of State Growth. High risks are considered to be on the verge of being unacceptable and all credible options to reduce or eliminate the risk shall be considered.
C	Medium – tolerable	Medium risks are tolerable if it is not reasonably practicable to reduce the risk further. It is essential that where risk has health, safety or environmental consequences the risk should be reviewed to determine if the risk can be reduced further and whether all reasonable and practicable controls have been considered or applied, or both and a demonstration of SFAIRP is provided. Additional treatment measures should be sought if significant benefit can be demonstrated and/pr there is an additional treatment measure which is recognised as good practice in other like environments.
D	Low – broadly acceptable	Low risks are considered to be broadly acceptable. Where the risk has health, safety or environmental consequences control measures should be effective, reliable and subject to appropriate monitoring. If options for further risk reduction exist and costs are proportionate to the benefits, then implementation of such measures should be considered. The risk and its treatments should be subject to appropriate degrees and forms of monitoring to ensure it remains at this level.

Table A.3 details the operational risk assessment for this system.

Table A.3 Operational risk assessment

Risk	Likelihood	Severity	Risk score	Mitigation
Primary enforcement system Technical failure (standard)	Unlikely – equipment failures are accounted for in the calculation of maintenance and are not expected to occur regularly as the system has been deployed previously	Minor – enforcement may not be possible; however, maintenance contractors are expected to have skill set required to address standard faults.	D	Ensure skill set of maintenance contractors is relevant and suitable. Development of a Maintenance and Repair Strategy.
Primary enforcement system Technical failure (complex)	Unlikely – equipment has been developed, tested and deployed globally. Confidence in the system is provided by Indra.	Major – enforcement will not be possible, and it is unlikely that the required skill set is readily available to remedy a complex failure. This may leave the T3 lane without enforcement until resource can be found.	C	Ensure a clear and fully understood Maintenance and Repair Strategy is in place with escalations for more complex requirements.
Secondary enforcement system – technical failure	Unlikely – ANPR equipment is in widespread use globally and in Australia.	Minor – full enforcement may not be possible (depending on the number of failures), however maintenance contractors are expected to have the skill set required to address ANPR faults.	D	Ensure skill set of maintenance contractors is relevant and suitable. Development of a Maintenance and Repair Strategy.
Issuing of erroneous citations/ educated materials	Very Unlikely – whilst no system is 100% accurate, there are a number of verification steps before the issuing of a citation, including: — Manual checking of vehicle occupancy images — Cross referencing with ANPR to user show driven along HOV lane.	Moderate – there may be some reputational damage, especially is erroneous issuing is widespread. Additional cost may be incurred investigating such instances.	D	Develop clear training process for verification of HOV images. Conduct extensive testing of the system prior to implementation.

APPENDIX B

LEGISLATIVE/REGULATORY CHANGES

B1 LEGISLATIVE/REGULATORY CHANGES

This appendix details key legislative or regulatory changes required to support the operation of the Southern Outlet T3 lane. At this early conceptual stage it outlines key issues and potential changes to legal, regulatory and processes that may need to be reviewed in parallel to the technical procurement and implementation of T3 enforcement technologies.

Processes

- Maintenance of new and complex systems.
- Integration of 3rd party systems (Indra) with existing State Growth ITS LAN or similar.
- Security of personal information (systems and staff reviewing/using personal information).
- Guidance and policy for issuing of warnings and/or fines.
- Guidance for edge cases.
- Engagement/use of police enforcement.

Legislation

- The existing legislation for T3 lanes predates this project. Review to ensure it supports the proposed system, technology and regulatory processes.

Regulatory

- Agreed regulatory delegation or approvals to empower staff to make regulatory decisions related to enforcement including issuing of fines and official warnings.

APPENDIX C

TECHNOLOGY FEASIBILITY STUDY

MEMO

TO:	[redacted] – Project Director, Department of State Growth
FROM:	[redacted] – ITS Lead, [redacted] – Project Manager
SUBJECT:	**Hobart Southern ProjectsT3 Enforcement – Technology Feasibility Study**
OUR REF:	PS117730-TAP-MEM-002
DATE:	**22 January 2020**

SUMMARY

Effective enforcement of the proposed T3 transit lane on the Southern Outlet is critical to optimising the transit lane's usage and realise the project objective of encouraging the use of public transport and High-Occupancy Vehicles (HOVs) along this constrained corridor.

A review of research, trials, literature and industry feedback identified that worldwide, manual enforcement is the most commonly used enforcement method. In some areas (e.g. California), technology is deployed alongside manual enforcement to aid in the identification of vehicles claiming HOV status. Whilst there have been numerous studies and trials into highly automated HOV enforcement solutions, none have been found to be mature enough to be accepted as wholly appropriate for enforcement. WSPs' experience indicates that a less mature solution results in higher ongoing cost due to re-calibration, highly specialised maintenance requirements, and the increased risk of faults – including false-positive results which require additional manual checking.

Due to the unavailability of a mature, proven system, WSP recommends a combination of manual enforcement and a technological solution for the Southern Outlet T3 lane. The technology aspect would act as a 'first filter' to aid the enforcement agents in identifying and pulling out non-compliant vehicles. This would help raise detection rates above that of a manual-only approach. When considering technology solutions, a proof of concept trial may provide confidence in capability and reduce the risk of overinvestment.

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1. INTRODUCTION

The Tasmanian Government's *Hobart Transport Vision* (Infrastructure Tasmania, January 2018) seeks to provide Hobart's residents and visitors with "*a reliable and cost effective alternative transport system with a focus on prioritised rapid passenger transport as a competitive alternative to private car travel*". To achieve this, the Department of State Growth is developing a design for a T3 Transit Lane on the Southern Outlet inbound towards Hobart. This transit lane is planned for the sole use of buses, taxis, hire cars, bicycles, emergency vehicles and T3 high occupancy vehicles (HOV) - private vehicles with three or more occupants.

By moving more people in fewer cars, the potential benefits of transit lanes include lower journey times, improved transit reliability as buses can maintain their schedules, better access for emergency vehicles, reduced vehicle emissions and help realise the potential societal/social benefits of car sharing. However, a transit lane is only as successful as its level of compliance. Regular and extensive misuse may engender public cynicism and result in reduced support for the facility (Schijns & Eng, 2006). Enforcement technology is one element of many that will support a successful transit lane. Other elements may include public education or larger financial penalties that act as a disincentive.

To be successful in achieving its objectives, the transit lane may not require complete compliance. Similar technology projects to improve road network efficiency have found tolerance in levels of compliance to realise maximum benefit. A balance between enforcement aims, transit lane objectives, and practicality must be made when evaluating compliance enforcement solutions.

Enforcement of HOV requirements is a complex problem with technical, policy, and legal elements that have been addressed globally to varying levels of success. This technology feasibility study aims to detail current and emerging practices and technologies for the enforcement of a Transit (T3) lane and provide advice on the most appropriate system. WSP conducted the study utilising:

- Desk based research, including;
  - National and international case studies
  - National and international research papers and studies
- Engagement with industry, including conversations with potential suppliers
- Engagement with WSP transport experts globally.

The study focuses on key themes both nationally and internationally. Supporting evidence from case studies or research are highlighted in call-out boxes.

2. CURRENT ENFORCEMENT

In our review, WSP found that there are three general types of HOV enforcement – manual enforcement, combined manual and technology-based enforcement, and technology-based enforcement – which are defined below.

MANUAL ENFORCEMENT

Manual enforcement is usually carried out by the police or highway patrol (or equivalent), as they hold the requisite statutory authority to issue fines for traffic offences. However, the method of enforcement and level of deterrent varies globally. Manual enforcement usually consists of:

1. Visual check of vehicle occupancy
2. Pursuit of a vehicle believed to not meet the HOV lane requirements
3. Issuing of infringement notice and accompanying fine.

MANUAL AND TECHNOLOGY-BASED ENFORCEMENT

As some technologies have advanced since the introduction of HOV lanes, manual enforcement can also be complemented with the use of some technologies (e.g. toll transponders). In practice, the use of technology acts as a 'first filter' to road users, discouraging misuse – with manual enforcement remaining the larger part of the enforcement method.

TECHNOLOGY-BASED ENFORCEMENT

An enforcement solution which is largely reliant on technology to carry out the majority of enforcement tasks, with manual work reduced to less than 50% of the workload.

The nuances of the systems outlined above are discussed further in sections 3.1, 3.2 and 3.3.

2.1 AUSTRALIA

The use of HOV lanes throughout Australia has become more widespread in recent years, with lanes available for private cars (non-busway lanes) across multiple cities and several states. The city locations and HOV requirements in place are detailed in Table 2.1 below.

Table 2.1 HOV facilities for private vehicles in Australia

STATE	CITY	HOV REQUIREMENTS
Victoria	Melbourne	T2
New South Wales	Sydney	T2 and T3
Queensland	Brisbane	T2 and T3
Queensland	Gold Coast (Southport)	T2 and T3

Austroads Guide to Traffic Management, Part 9 Traffic Operations (2019) states that, at the time of publication, no automated method of detecting vehicle occupancy with sufficient accuracy exists; the technological challenges and other issues have limited automated technologies from supplementing or replacing manual enforcement.

Melbourne Eastern Freeway HOV lane

A T2 transit lane on the Eastern Freeway in Melbourne has been in operation for over 15 years, operating over morning peak periods. Whilst a 2007 survey found that the T2 lane delivered travel time benefits of up to five minutes (up to nine minutes at the height of peak time), and despite once weekly enforcement, approximately 35% of vehicles observed were private vehicles without passengers (misuse). It should be noted that the case study notes that "*the relative success of the Eastern Freeway T2 lane relies on the regular enforcement undertaken by Victoria Police*" (Australian Transport Council, 2009).

Brisbane HOV lane enforcement

Between May and October 2011, the Queensland Department of Transportation and Main Roads (QDOTMR) investigated the use of transport officers as a method of on-road HOV lane enforcement. Prior to the study, enforcement was the responsibility of the Queensland Police Service (QPS), therefore, the QPS had to balance HOV enforcement with other high priority responsibilities. This resulted in a drop in the number of infringements issued from 5,319 in 2003 to 3,000 in 2008 and therefore were unable to undertake the increased enforcement effort required by the trial. As such policy was amended to grant enforcement powers to transport officers.

The trial focused on an intense period of enforcement over one week (four to five days), followed by a four week break before additional random enforcement over the remainder of the enforcement period. Results showed violation rates to decrease by 6% to 10% over the trial, and showed decreased travel times for HOV users, increased throughput and limited, if any impacts on other travellers on the network (QDOTMR, 2011).

Figure 1 - Melbourne Eastern Freeway T2 HOV Lane (Hoddle Street)

2.2 INTERNATIONAL

HOV lanes are in use globally, In Europe, HOV lanes utilise manual enforcement similar to Australian enforcement practices.

A647 HOV Lane – Leeds, United Kingdom
A T2 HOV lane was introduced on the A647 towards Leeds, United Kingdom in May 1998. Enforcement on the scheme was and remains a manual process (despite a technology trial discussed later). Initially, regular police enforcement (by motorcycle) proved effective in the opening year and typically violation levels were approximately 2%. However, the enforcement method was altered to random policing by patrol vehicle and occasional policing by 'beat' officers (on foot) at traffic signals which saw violation rates rise to up to 10% (Leeds City Council, 2010).

Figure 2 - Road sign for A647 T2 HOV lane in Leeds, UK

The number of HOV lanes across North America, and in particular the United States, is much higher than anywhere else globally, due to the prevalence of higher capacity multi-lane freeways. The United States has hundreds of facilities nationwide[1] and the prevalence of facilities has resulted in attempts to introduce elements of technology and automation into the enforcement process.

[1] The actual figure is unavailable due to the non-publication of results for a US Department of Transportation study into HOV facilities nationwide.

In a number of areas – including Washington D.C., Houston and Seattle - a ‘HERO’ program has been introduced to assist with enforcement. Such program provides a central facility – a phoneline, app or website – for road users to report HOV lane violators, triggering an education process where the education materials are sent to the accused violator. These materials and the sender would usually escalate as more accusations are received by the HERO program, building to letters from the Police and Highway Patrol. Whilst the HERO program introduces an element of community enforcement, reports to made to the state are not enforceable with fines and are therefore not a suitable sole method of enforcement.

Washington State HERO Program – Washington, United States
HOV lanes are commonplace in Washington State, with various operational regimes across the I-5, I-90, I-405 and state routes 16, 167 and 520. The HERO program has been in place here since 1984 and has since grown into a nationally recognized program and is used as an example for other US states. The escalating warning system adheres to the following approach: first time – educational brochure, second time – a letter from Washington State Department of Transport and third time – letter from Washington State Patrol. In 2018 over 64,000 registrations were reported via the HERO program, with 33,481 brochures issued and 1,086 letters mailed to drivers. Whilst it is unlikely to be the only contributary factor it is of note that the average violation rate in Washington State is 5-10%, which is lower than the U.S. national average of 10-15%.

Figure 3 - Road sign for HERO program in the United States

Literature found the majority of real-world technology-based trials to have been conducted in the United State, which is unsurprising given the number of facilities. Systems including the use of cameras, infrared and sensors have been trialled with limited success.

I-880 Automated Enforcement Trial – San Francisco
The Metropolitan Transportation Commission (MTC), the agency responsible for the management of transportation in the San Francisco Bay area recently conducted a trial of automated enforcement technologies on the I-880 HOV lane. Three companies met the MTCs criteria for participation. In this trial, Indra’s High-Occupancy Vehicle Detection System (DAVAO) was found to achieve the highest overall system accuracy rate, with 88% accuracy. Results for all participants ranged from 78-88% accuracy. However, false-positive results – where vehicles were found to be violators by the system but were actually compliant – were found to be between 5-6% of results. On the I-880, this would result in approximately 50,000 false-positives per month, costing up to US$3 million per year to manually review images before fines are issued. It is understood the MTC is now shifting its focus towards the testing of applications rather than infrastructure and will shortly be running an app pilot across approximately 500 vehicles.

3. POTENTIAL AND EMERGING TECHNOLOGIES

This section details potential and emerging technologies that seek to provide highly automated solutions for HOV lane enforcement, including information found on any pilots, trials or results of real-world performance testing.

3.1 VIDEO SYSTEMS

Some technologies have been developed where video cameras are set up to take images of passing vehicles, usually in an overhead (front) and verge mounted (side) configuration. Images are then securely processed through a machine learning algorithm, or similar software to identify the number of occupants within a vehicle.

Systems such as this have been trialled several times, with a few common challenges. In one trial in Southern California false alarm rates ranged from 21% to 51% for the system, with the trial concluding small children and sleeping adults were a large contributary factor to the unacceptably high false-alarm rates (TDOT, 2018). A video systems case study is detailed in the San Francisco I880 case study box below.

Conduent Vehicle Passenger Detection System – Video systems case study
A system has been developed and known to the market for a number of years, named the Vehicle Passenger Detection System – by Conduent (formerly Xerox). The system utilizes front and side cameras to take images of vehicles and passes these images through an AI based algorithm which detects the number of occupants within a vehicle. Conduent' own pilots show the system to be 95.1% accurate for T3 enforcement. It should be noted, it is believed this system was also part of the MTCs testing of systems on the I-880. Although the data for this trial is not readily available, it is known that the highest performing technology at the trial (Indra), achieved 88% accuracy. Therefore, it can be concluded Conduent's performance in this trial was lower than this.

Figure 4 - Mobile deployment of Conduent Vehicle Passenger Detection System during a trial

3.2 INFRARED SYSTEMS

A variation on the image-based video systems, infrared has been regularly considered as an option for the automated enforcement of HOV lanes. The key idea is that restricting image detection to infrared bands can enhance correct occupancy detection through the manipulation of the relative spectral properties of objects and humans within the vehicle.

There are challenges to the technology - a recent study assessing the suitability of sensor/detection types for HOV lane enforcement found that the type of glass/material used for the windshield and side windows has a significant effect on detection capability (Minnesota DOT, 2017).

Infrared systems case study

A system utilizing infrared technology, named ‘Cyclops’ or ‘dtect’ was developed in the UK, and tested on the Leeds A647 HOV (T2) lane in 2005. The system, which ran in conjunction with the system developer, reported a 95% accuracy rate. However, even with the high accuracy rate, this pilot highlighted that challenges remained in creating an infrared system that works under overcast lighting conditions or at dusk. The Cyclops system had an associated capital cost of approximately US$170,000 per single lane (VDOT, 2009).

Research note: the system developer’s website, where information was cited in research papers, is no longer live. Further investigation showed the company to have been liquidated, with credit owed over £230,000 – according to accounts and liquidation information on Companies House.

Figure 5 - Cyclops / dtect system in situ during testing on the I-15

3.3 TOLLING TRANSPONDERS

Tolling transponders are common place globally. Utilised for easy charging of toll roads the transponder emits a signal to a toll receiver, automatically charging the person registered to the transponder. In the case of HOV enforcement, a transponder may be utilized as a complementary enforcement technology, rather than the main method of enforcement by requiring users to pre-register and indicate their status as a HOV which allows additional enforcement by checking if the indicated HOV status is correct.

Tolling transponders case study

Current practice in California combines manual enforcement methods with toll transponders which are required for charging to travel along the toll road. Conversations with industry peers at Caltrans – California Department of Transportation – indicated that the system is extremely effective, with very few violations. This system works with a switch on the transponder (HOV on / HOV off), which communicates with technology at a gantry site on the toll road. A beacon mounted on the gantry flashes different colors (white/green) for HOV and non-HOV indicated vehicles. A California State Trooper (enforcement agent) then manually checks a sample of vehicles for violators and issues the corresponding penalty. Enforcement is conducted on a daily basis.

Figure 6 - Example of HOV tolling transponders

3.4 MOBILE PHONE TECHNOLOGY

Utilising mobile phones, and specifically Bluetooth for HOV detection appears to be an emerging enforcement proposition. By creating a platform for users to register, systems can detect the number of signals in any given vehicle, verifying its actual occupancy. Alternatives, such as Bluetooth beacons, are offered to those without smart phones.

The requirement for an application on a smart phone may adversely impact some user groups, such as the elderly who are less likely to have smart phones. While alternatives may be offered the system introduces an extra barrier to use of the HOV lanes, this may detract from efforts to encourage a shift towards carpooling, as traditionally the less barriers to use, the higher the uptake.

GoCarma – Mobile Phone technology case study
In North Texas, GoCarma is being implemented and replacing the traditional manual enforcement system. The app works by users registering their phones, and the number of registered persons in a vehicle is detected by the application as it travels along the HOV lane. Users without a phone are able to request a free Bluetooth beacon instead. Officials claim the system to be 98.4% accurate (Leszcynski, 2018). Interestingly, the introduction of this system has removed the traditional enforcement process of issuing fines for offenders, instead the app will issue warnings to non-compliant vehicles, with repeat offenders being banned from using the HOV lane. GoCarma claim its algorithms work to stop people who try and cheat the technology (McLoud, 2018) – however, no studies or information on pilots were found to be available.

It is important to note that this is being implemented on existing toll roads, where users are familiar with a registration process for use and are rewarded for HOV use with a 50% discount on the toll price – a major differentiator when comparing potential compliance on public roads. It is reported the program will cost an estimated US$24 million over 10 years.

4. WHAT HAS WORKED

This section will focus upon the key themes of what has been seen to be most effective and may be considered best practice for HOV enforcement.

Manual Enforcement

Standard practice globally is found to be manual enforcement, and all current active forms of enforcement include a manual element. In the majority of jurisdictions, the responsibility for manual enforcement sits with the police department, as legislatively they are traditionally the only ones with enforceable powers. Case studies such as the Brisbane HOV lane management study documents efforts to address the additional strain placed on police when attempting to balance other policing work with HOV enforcement. Here, the introduction of new powers for transport officers through changes to policy and legislation facilitated increased enforcement presence and increased compliance.

Whilst manual enforcement has been shown to be effective in enforcing HOV lanes in some cases, there are examples of poor compliance where manual enforcement is used. Therefore, holistic consideration should be given to other techniques and themes which influence the effectiveness of a manual enforcement method (deterrents, education, frequency of enforcement), some of which are discussed further below.

Combined Enforcement

The practice of combined enforcement – combining some technological element with manual enforcement – has been shown to be effective, particularly in the case of utilising tolling transponders and manual enforcement (see Caltrans case study). Although it should be noted, that in this case study the level of manual enforcement was very high (on a daily basis), which may have been the primary driver for its' success. Feedback also indicated that the strong relationship between Caltrans and State Troopers is a key element to the systems success.

Strong deterrents

The level of deterrent against misuse of HOV lanes plays an important role in the attempt to have only genuine HOV vehicles in the T3 lane. Deterrents may include fines, points on a license or education materials and letters. HOV lanes – worldwide lessons for EU practitioners (Schijns & Engs, 2006) note that the two US cities with violation rates below 2% - Los Angeles and Houston – feature a combination of a commitment to enforcement, fine levels that are effective deterrents (minimum US$490 in California (Caltrans, 2018)), and physical provisions allowing enforcement to take place (wide shoulders, buffers etc.).

Changes to policy/legislative powers

Policy and legislative powers are a key element of any enforcement system. Without adequate provision in place, enforcement would not be possible. This document focuses upon the policy / legislative changes that may optimize a HOV enforcement system, rather than those required for its implementation.

A key theme identified throughout literature on HOV lanes is the additional strain on resource brought about by manual enforcement methods; however, changes to policy and legislative powers can help to reduce this. One way this may be done is to grant an alternative party powers to enforce HOV lanes and issue fines for misuse. There is precedent on the Australian network, as shown by the Brisbane HOV lane case study where traffic inspectors were granted to requisite powers. Whilst done initially to facilitate the study into the impact of higher levels of enforcement (a positive benefit was realized), the powers were made permanent following the trials success (QDTMR, 2011).

5. WHAT HASN'T WORKED

This section discusses themes found throughout the literature review of systems, processes and technologies that do not perform to a standard acceptable for enforcement of a HOV lane.

Wholly technology-based solutions

The literature regularly points towards the need for a highly automated, technology-based enforcement solution in order to improve violation detection rates, act as an increased deterrent, and reduce pressure on parties responsible for manual enforcement (usually police). However, studies have consistently shown that a fully automated system not to be readily available for use, and those systems currently claiming to be effective to not be wholly practical for implementation.

As noted within the MTC trial case study, a recent trial of the most accurate systems currently available produced results ranging between 78-88% accuracy in real-world trials (note for many providers, claims are often made of higher accuracy – usually recorded in a controlled environment). Combining the accuracy results with system false-positive results (where manual checking would be required of images) of approximately 5-6% for the most accurate provider – the technological solutions would still require a high level of manual labor, reducing their suitability. It's also of note that following this study, the MTC – servicing the highest number of HOV lanes in the US (88 as of the latest study) (U.S Department of Transportation Federal Highway Administration, 2009) – have shifted their focus from fully automated camera systems towards other methods of enforcement, such as the use of mobile beacons.

It is also accepted that the automated enforcement of T3 lanes, where detection of rear seat passengers is required is the most challenging for technology-based systems. Conversations with industry confirmed that the this, along with a number of variables in HOV detection such as sleeping passengers, young passengers, and use of dummies, were prohibitive to the realization of a system that meets requirements for automatic HOV enforcement. It is of note that this feedback was from one of the world's largest defence, security and systems provider (IDEMIA), considered a global leader in similar technologies.

Low levels of manual enforcement

Some studies focused on the level of manual enforcement required to ensure maximum benefit is realized. All of these studies concluded that low levels of enforcement were producing sub-optimal results, either as a baseline or as part of the study. Reasons for low levels of enforcement ranged from resource availability, to the design of HOV lanes (central, with no area for enforcement).

The Leeds A647 case study showed that initial, semi-regular enforcement resulted in good compliance however when enforcement regularity ceased compliance was seen to worsen. Additionally, feedback from Caltrans indicated they had very low levels of violation, due to daily manual enforcement (complemented with some technology in some areas).

6. OTHER CONSIDERATIONS

This section aims to provide notes on other considerations and themes found during this study that are important to the decision-making process for enforcement. Thoughts captured below are based on literature reviewed around HOV lane enforcement, and WSPs understanding from experience with similar ICT/ITS projects in Victoria and globally.

One general observation concerns the environment and in which many automated systems have been trialled or deployed, and their similarities in that they are seen to fit into one of, or a number of the below:

- Extensive HOV network in place (some places in the U.S. have had such lanes for over 30 years);
- Extensive tolling infrastructure already in place;
- HOV lanes also running as High Occupancy Tolling (HOT) lanes, where paid single occupancy vehicles also access the lane;
- HOV infrastructure operated in conjunction with toll operators.

These parameters show a difference in the drivers for HOV lane enforcement for these areas, where financial recuperation plays a larger part for toll operators seeking to protect their product (efficient and 100% compliant lanes) or for public bodies who burden high operational enforcement costs due to extensive HOV networks.

The highly automated solutions identified by this study are seen to be 'immature', in that they are not widely deployed and there is little evidence as to their success in real-world scenarios. This should be taken into account when the time comes to consider cost more fully, as immature systems may require unknown levels of reworking, re-calibration and refinement to meet system requirements – the level of which is increased by the amount of physical infrastructure and complex hardware.

The legislative aspect of enforcement is also critical. Any system which acts as the sole source of truth must provide evidence which is considered accurate and reliable enough to stand up in a court of law, and to not create additional administrative burden by issuing incorrect fines. It should be noted there is Australian precedent for enforcement of T3 lanes, but none for automated solutions.

Tasmania added legislation supporting Transit Lanes on 25 November 2019 with a penalty of $840. The equivalent offence in New South Wales has a penalty of $2,200. While an increase in penalties may improve compliance it may impact public acceptance of the scheme.

7. RECOMMENDATIONS

This literature review has shown that there is a lack of mature, fully automated enforcement solutions for T3 enforcement that has been proven to work effectively in real-world scenarios. The slow, or lack of, uptake of systems following trials indicates there remain blockers to the deployment of these systems. The context of their use is also an important consideration - trials conducted have been on large freeways and toll roads in the United States, where there are very high traffic flows which makes the prospect of automated enforcement much more attractive and financially feasible. A summary of enforcement options is included in Appendix A.3.

Considering this, WSP recommends a combination of technology and manual is utilised for T3 enforcement on the Southern Outlet. The technology aspect of this solution would act as a 'first filter', to aid the enforcement agents in identifying and pulling out non-compliant vehicles, which would help raise detection rates above that of a manual-only approach. When considering technology solutions, a proof of concept trial may provide confidence in capability and reduce the risk of overinvestment.

It is important to note that decisions on any enforcement solution should consider the whole life cost of the transit lane's operation and other, vital elements for a successful system such as education and awareness. WSP's experience indicates that the less mature a solution, the higher the ongoing cost due to re-calibration, highly specialised maintenance requirements and increased risk of faults.

8. NEXT STEPS

The scope for Hobart Transport Vision Southern Projects sub-project 5 is to develop a Concept of Operations for the proposed T3 enforcement solution. The scope was set out under the assumption technology-based enforcement solutions were suitable for deployment. Therefore, WSP proposes a meeting/workshop with the Department of State Growth and other relevant stakeholders to discuss outputs of this feasibility study and identify the appropriate enforcement option to advance.

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A.2 ABBREVIATIONS AND ACRONYMS

ABBREVIATION / ACRONYM	EXPANSION
HERO	A reporting system for road users across the United States
HOV	High Occupancy Vehicle
ITS	Intelligent Transport Systems
MTC	Metropolitan Transport Commission
QDOTMR	Queensland Department of Transport and Main Roads
QPS	Queensland Police Service
T2	Transit lane for vehicles with two or more occupants
T3	Transit lane for vehicles with three or more occupants
TDOT	Tennessee Department of Transportation

A.3 OPTION MATRIX

ENFORCEMENT METHOD	GLOBAL EXPERIENCE	ENFORCEMENT	CAPITAL EXPENDITURE	OPERATIONAL EXPENDITURE	LEGISLATIVE CHANGES
Manual enforcement (Police)	Manual enforcement is the most widely used practice globally due to the lack of appropriate automated systems	Police carry out enforcement manually from the roadside, with the power to issue fines for misuse	Low – additional enforcement infrastructure not specifically required. Cost associated with designing HOV lane to facilitate manual enforcement (place for police to park and pull over offenders)	Medium – main operational expense is police labour and the issuing of fines, noting expenditure is a sliding scale based on the amount of enforcement conducted	No changes required
Manual enforcement (other)	Manual enforcement is the most widely used practice globally due to the lack of appropriate automated systems	Nominated body (i.e. traffic inspectors) carry out enforcement manually from the roadside, with the power to issue fines for misuse	Low – additional enforcement not specifically required. Cost associated with designing a HOV lane to facilitate manual enforcement (place for inspectors to enforce from and pull over offenders)	Medium – main operational expense would be the employment of additional resources for enforcement, noting expenditure is a sliding scale based on the amount of enforcement conducted	Additional legislative changes required to give requisite powers (noted there is precedent in QLD) – if enforcing body not to be Police
Automated technology (infrared)	Limited global experience in the deployment of infrared systems. Some pilots have been recorded however no system appears in use widely.	Enforcement would be automated, however manual checks of images may be required to filter out false positive results.	High – research shows the capital cost of such systems to be high e.g. Cyclops (not available) at approximately US$170,000 per lane	Medium to high – this has been given a conservative estimate as immature technologies is likely to require substantial recalibration and amendments. Additionally, there will be cost associated with checking of results for false positives	Approval and appropriate legislation would be required to allow to automated enforcement
Automated technology (video systems)	Limited global experience in the deployment of video systems. Several trials have been run by with varying results. The Conduent/ Xerox system claims 95.1% accuracy, however didn't achieve higher than 88% in a recent MTC trial.	Enforcement would be automated, however manual checks of images may be required to filter out false positive results.	High – whilst there is not a figure available from this research for estimated cost. Experience globally with such technologies indicates that the capital expenditure is likely to be high	Medium to high – this has been given a conservative estimate as immature technologies is likely to require substantial recalibration and amendments. Video systems are likely to require more refinement than infrared, due to their more complex nature. Additionally, there will be cost associated with checking of results for false positives	Approval and appropriate legislation would be required to allow to automated enforcement
Combined manual and technology	Common place in some areas where there are a high proportion of HOV lanes / toll lanes such as California, US	Usually manual enforcement is the largest aspect, with technology assisting manual enforcement to increase violation detection	Medium – dependent on infrastructure required to for the technological element. There may be some cost involved in the development/piloting of such systems	Medium – main operational expense is additional resources for manual enforcement. Complementary technology is likely to be a mature system or familiar technology requiring a lower level of maintenance and re-calibration than fully automated systems.	Baseline changes to allow enforcement of T3 lanes in Tasmania

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