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Rural Junction Active Warning System (RJAWS) Lite - Design Guide

CASR213

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Report documentation

REPORT NO.	DATE	PAGES	ISBN	ISSN
CASR213	21 January 2025	53	978 1 925971 47 7	1449-2237

Document Control

Version	Date	Initials	Amendments
1.0	2 Aug 23	CS	First publication
1.1	17 Jul 24	CS	- Changed various photos incl. cover to VMS option of major road sign - Revised diagrams to show VMS option of major road sign - Revised Section 4.3.1 to reflect approval of VMS - Included Wi-Fi option in Table 2.1 and Section 4.1.4 - Revised erroneous equation in Appendix A.2
1.2	21 Jan 25	CS	- Summary of input values added and values revised in Appendix A - Addition of L_{min} label to Figure 4.3

Title

Rural Junction Active Warning System (RJAWS) Lite - Design Guide

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Funding

Grant funding was provided to the City of Onkaparinga by the Minister for Infrastructure and Transport under the Community Infrastructure Grants Program. This project was commissioned by the City of Onkaparinga as the recipient of this grant.

Abstract

This is a design guide for the Rural Junction Active Warning System (RJAWS) Lite, an infrastructure treatment for improving safety at intersections along high-speed regional roads. In this design guide is provided the information necessary to design, operate and evaluate RJAWS Lite. While detailed information is provided, it is not meant to be prescriptive. Rather, it is intended to guide the designer to use their own judgement in designing the treatment such that it performs according to the intended role and achieves the expected outcomes. Experiences gained through the development and evaluation of RJAWS Lite and similar treatments are used to inform this guide.

Available From

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

Keywords

Rural Junction Active Warning System, RJAWS, intersection safety

Summary

Non-signalised intersections along the high-speed roads that are commonly found in regional and remote locations present a high level of safety risk. This risk is due to the high speeds of vehicles as they traverse the intersection, and the relatively low-level of control placed upon drivers as they navigate the intersection. The large collision forces induced by the high speeds of vehicles in these crashes commonly result in severe outcomes. While effective safety treatments exist for mitigating harm at intersections along high-speed roads, the high cost of these treatments makes them prohibitively expensive for all but a minority of locations.

This design guide is for the Rural Junction Active Warning System (RJAWS) Lite intersection safety treatment. RJAWS Lite is a low-cost treatment that can improve safety at intersections along high-speed regional roads. The low cost of RJAWS Lite makes it an ideal solution for intersections where more expensive treatments cannot be justified on economic grounds, and at intersections where a temporary solution is sought before funding for a more expensive and permanent solution can be found.

In this design guide is contained the information necessary for the successful design, construction and operation of RJAWS Lite. Additionally, procedures for evaluating the treatment to quantify its safety benefits are also provided. The following information is presented:

- Design philosophy
- Background regarding the treatment’s development
- Intended operating environment
- Intended functionality
- Technical design
- Signage design
- Operational guidance
- Operational performance
- Testing requirements
- Maintenance requirements
- Decommissioning
- Evaluation procedures

While this guide provides an extensive source of information for the design and operation of RJAWS Lite, it is not intended to act as a prescriptive standard or specification that must be adhered to. Instead, it is intended to guide the designer to use their own judgement in designing the treatment such that it performs according to the intended role and achieves the expected outcomes. Experiences gained through the development and evaluation of RJAWS Lite and similar treatments are used to inform this guide.

Table of Contents

1. Introduction

The Rural Junction Active Warning System (RJAWS) Lite is an intersection safety treatment for improving road safety at high-speed non-signalised intersections. In this design guide, the purpose and function of RJAWS Lite are described, and information required to design, operate and evaluate the treatment are provided. This guide is not intended to act as a prescriptive standard or specification that must be adhered to. Instead, it is intended to guide the designer to use their own judgement in designing the treatment such that it performs according to the intended role and achieves the expected outcomes. Experiences gained through the development and evaluation of RJAWS Lite and similar treatments are used to inform this guide. Despite the RJAWS Lite being effectively an Intelligent Transport System (ITS), this design guide purposely does not provide specific technical requirements expected from such types of technologies, which should adhere to the existing regulations for ITS systems (e.g. ITS regulations outlined in Government of South Australia 2019, 2022).

1.1. Design philosophy

Design gap

Non-signalised intersections along the high-speed roads that are commonly found in regional and remote locations present a high level of safety risk. This risk is due to the high speeds of vehicles as they traverse the intersection, and the relatively low-level of control placed upon drivers as they navigate the intersection. Most crashes at these locations are a result of mistakes: it is common for drivers to misjudge or misunderstand the situation under which they are placed, leading to errors that in turn lead to the occurrence of a crash. Within the hundreds of crash investigations that the Centre for Automotive Safety Research (CASR) has undertaken in South Australia, two types of errors have commonly been identified with these crashes: (1) a driver entering the intersection and colliding with another vehicle after having initially slowed and looked for other vehicles (commonly referred to as a “look but did not see” crash); and (2) a driver not having recognised the need to give way and entering the intersection from the minor road at speed (commonly referred to as a “run-through” or “blow-through” crash).

The large collision forces induced by the high speeds of vehicles in these crashes commonly result in severe outcomes. As an example of the role that speed plays in determining crash severity, the risk of a fatal or serious injury outcome is 1.3% when a right-angle crash between two vehicles occurs at a collision speed of 50 km/h. This risk rises to 23.7% at a collision speed of 80 km/h and 75.8% at a collision speed of 100 km/h (Doecke et al*.* 2020).

Most safety treatments for high-speed non-signalised intersections aim to reduce the <u>likelihood</u> of a crash occurring. Examples of these treatments are improved sight lines/distance, reinforced signage, improved lighting, auxiliary turning lanes, channelisation and staggering of cross-roads. Despite the improvement in safety that these treatments may provide, none can be 100% effective and so a residual of crashes will remain. For these remaining crashes the same risk of resulting in fatal or serious injuries still exists, as the underlying risk of severe outcomes has not been addressed. On the other hand, there exists treatments that aim to reduce the <u>severity</u> of crashes when they do occur, as well as reducing their likelihood. Examples of these treatments are roundabouts and the Rural Junction Active Warning System (RJAWS), upon which the RJAWS Lite treatment was conceived. However, these treatments can be prohibitively expensive: RJAWS and interstate equivalents in their most recent versions can cost near to or in excess of $500k, while rural roundabouts can cost several million dollars. These high costs can only be justified at a minority of locations.

This leaves a gap in our ability to improve safety at intersections: there are few inexpensive intersection safety treatments that can substantially reduce the risk of fatal and serious injuries by treating both the likelihood and severity of crashes. RJAWS Lite is aimed towards filling this gap by providing a low-cost, technology-driven intersection safety treatment that reduces both the likelihood and severity of crashes at non-signalised intersections along high-speed roads. While RJAWS Lite is intended to be used at any suitable intersection, it may be particularly applicable to intersections controlled by local governments, who are less likely to be able to afford more expensive intersection treatments.

Safety outcomes

RJAWS Lite is aimed at reducing both the likelihood and severity of crashes at non-signalised intersections along high-speed roads in regional and remote areas. This is achieved with two safety systems: (1) a major road speed advisory and (2) a minor road run-through prevention. Both systems operate independently but use the same equipment to function.

The major road speed advisory is intended to reduce the likelihood and severity of crashes by warning drivers on the major road of traffic entering the intersection from the minor road(s) and advising them to reduce their speed as they traverse the intersection. This is achieved through the use of a modified advanced warning sign with flashing lights or Variable Message Sign (VMS) that illuminate when the speed advisory is required. A successful outcome consists of an appreciable reduction in travel speed along the major road when the major road speed advisory is activated. Reducing speed is the most effective tool that road designers can use to reduce the severity of crashes at intersections. Reducing speed along the major road is most important as this is generally where high speeds that lead to high severity crashes occur. It is therefore vital that speed be appropriately managed through effective application of the major road speed advisory. A heightened alertness and improved reaction time by a major road driver may also result.

The minor road run-through prevention is intended to reduce the likelihood of crashes by warning drivers along the minor road that they may be at a risk of running through the intersection. This system is intended as a last-chance warning for drivers who may not be aware that they are approaching an intersection at which they are required to give way to other traffic. This is achieved by illuminating a ring of flashing lights bordering the Stop or Give Way control sign. A successful outcome is to see a reduction in the number of vehicles that “run-through” the intersection.

Design outcomes

A successful implementation of RJAWS Lite should see the safety outcomes achieved while maintaining the following design outcomes:

1. **Low-cost**, including for the design, installation, operation and ongoing maintenance of the system. The expected design life of the system and its componentry should also be considered.
2. **High levels of reliability**, noting that the lower up-front costs of designing and installing RJAWS Lite may come with a trade-off against the very high levels of reliability and integrity that are typically expected of ITS infrastructure by state road agencies. RJAWS Lite

integrates static signage into the treatment, and this signage should provide redundancy if a failure with the electronic equipment occurs.

3. **Off-grid installation**, meaning that the system does not rely on physical connections to outside infrastructure, such as the electric grid, to function. Limiting such connections reduces the cost and simplifies the installation process.
4. **Minimising installation of below-ground infrastructure**, which in turn can reduce the cost and limit disruption experienced during the installation process.
5. **Back-to-base communication**, allowing operators to remotely monitor and control the operation of the system and log any appropriate data.
6. **Portability**, as in some situations RJAWS Lite is intended to perform as an intermediary treatment until a more permanent solution can be found. The system should be designed such that it can be removed and reinstalled at a different location with minimal cost and time.

RJAWS Lite incorporates two distinct systems (see *Safety outcomes* above). Dependent on the needs of a particular location, the two systems can be installed together, or one system may be installed without the other.

1.2. Background

The Rural Junction Active Warning System (RJAWS), upon which RJAWS Lite was conceived, was first installed in South Australia at four 3-leg intersections in 2018; three in 80 km/h speed limit zones and one in a 100 km/h speed limit zone (Mongiardini et al. 2021). A further fifth installation occurred at a 4-leg intersection within an 80 km/h speed limit zone in 2021. Note the name changed to Rural Intersection Active Warning System (RIAWS) for the 4-leg installation. Similar installations have been undertaken in New Zealand and Victoria, with the prior New Zealand examples being used as a key reference when designing the first RJAWS treatments in South Australia.

The South Australian RJAWS and RIAWS installations have been evaluated and show positive results. An evaluation of the RJAWS treatments showed a reduction in average travel speed of between 11.3 and 22.1 km/h on the major road when the systems were activated, corresponding to a reduction of the expected average casualty risk of between 42% and 65% compared to before the installation of RJAWS (Mongiardini et al. 2021). Similar results are expected for the RIAWS installation. An evaluation of crash and injury reductions due to the installation of RJAWS and RIAWS has not yet been conducted, owing to the novelty of the treatments.

Despite the positive results of the RJAWS and RIAWS trials in South Australia, the applicability of the treatment is somewhat limited by the cost of installation, with the latest examples in South Australia and interstate costing several hundred-thousand dollars per intersection. These costs are in-part due to the need to install underground services to power and connect the different parts of the system, and the increased complexity of the system as more advanced technology has been sought to detect vehicle movements. The cost of RJAWS and RIAWS can prohibit their installation at lower volume intersections, where the high cost may not be warranted, and for local governments, who are unlikely to be able to afford the treatment.

To facilitate the use of the RJAWS/RIAWS concept across a larger spectrum of the road network, the Centre for Automotive Safety Research (CASR) at the University of Adelaide partnered with SAGE Automation to develop RJAWS Lite. Taking the objectives of RJAWS/RIAWS as the starting point, the concept was redeveloped with the goals of lowering the cost and reducing the time and complexity required to install the system. To achieve these goals, off-grid power and mobile network communications were utilised. Solar was chosen as a power source due to its low cost, simplicity and ease with which it could be adapted for RJAWS Lite. Mobile network communication was chosen for its ability to facilitate reliable wireless connections between the different parts of the system and to allow for back-to-base communications providing live updates on the condition of the system. Radar was chosen in place of inductive loops to detect traffic, avoiding the need for installation of physical sensors in the road surface and their consequent wired connection to the rest of the system. As part of this redevelopment process, an additional system, named the minor road run-through prevention, was developed to utilise the same power, communication and vehicle detection equipment while providing the additional benefit of reducing the risk of run-through crashes, which can be a common occurrence at regional and remote intersections.

In 2021, funding was sought through the Australian Government's Road Safety Innovation Fund grant scheme, administered by the Office of Road Safety, and a trial of RJAWS Lite in South Australia commenced, with in-kind support provided by the Department for Infrastructure and Transport (DIT). This trial was completed on 30 June 2023. The Australian Government trial comprises the installation of RJAWS Lite at six 3-leg intersections across South Australia. In 2022, the City of Onkaparinga engaged CASR and Sage Automation to develop and deliver the first RJAWS Lite installation at a 4-leg intersection, with CASR subsequently evaluating the performance of the system. It is noted that this is considered a semi-permanent installation, as the brief called for the option to remove RJAWS Lite to make way for a more permanent solution in the future. This system was installed at the intersection of Field St/Olivers Rd/Chalk Hill Rd in McLaren Vale, South Australia.

As RJAWS Lite transitions from a trial stage to becoming a standard treatment, it is desired that the design and installation process move to the competitive market. This design guide was developed to facilitate this transition and allow for the consistent application of RJAWS Lite on City of Onkaparinga and, more broadly, South Australian roads.

2. Intended operating environment

RJAWS Lite is intended as an intersection safety treatment under certain operating environments. These operating environments are discussed in Table 2.1 and

Table 2.2. RJAWS Lite has been trialled at a limited number of locations and as such the intended operating environments have been informed by this limited application of the treatment. While some limitations to its operating environment are obvious or well understood, such as its application at only non-signalised intersections, others are not and may need to be explored as part of future installations. Where these limitations are not well-understood, they have been noted in Table 2.1 and

Table 2.2. These limitations are also informed by the design of RJAWS Lite that has been trialled so far, such as those limitations associated with the use of mobile network communication, solar power and vehicle detection radars. Changes to the design may change the environment within which RJAWS Lite can operate.

Table 2.1
Summary of operating environments intended for RJAWS Lite (1 of 2)

Factor	Suitable environment	Notes
Communication	Locations with suitable mobile network coverage	RJAWS Lite has been trialled using mobile network communication. Note that communication over different networks, such as the cellular 4G, NB-IoT or LTE-M networks, may affect the choice of suitable locations. The limitations of range beyond the populated areas of South Australia have not yet been tested, as RJAWS Lite has so far been tested in locations close to greater Adelaide. Wi-Fi has been used as an alternative for communication between the different components of the treatment. Use of Wi-Fi could extend the areas of operability for the treatment, though back-to-base communications for the remote monitoring and control would still rely on cellular communications.
Traffic volumes	Low to moderate traffic volumes	Substantially high traffic volumes on the minor road may inhibit the effectiveness of RJAWS Lite; too many activations of the major road speed advisory flashing lights/VMSs may make redundant their dynamic nature. In this case, other treatments or static reduced speed advisory/speed limit signs on approach to the intersection may be economically justified. Very low minor road traffic volumes may also make activation a rare event, which could lead some drivers to misunderstand the purpose of the treatment. RJAWS Lite is not intended to be installed at intersections with very low traffic volumes, where the safety benefit of the treatment may be substantially outweighed by its economic cost; or at intersections with very high traffic volumes, where higher cost treatments may be economically justified by their greater safety benefits.
Roadside environment	Non-built up roadside environments	RJAWS Lite has been trialled on roads with limited roadside access, no pedestrian facilities and little infrastructure (such as lighting and overhead/underground utilities). Use within built up roadside environments has not been tested and the limitations of such application are not understood.
Intersection type	3-leg and 4-leg intersections	RJAWS Lite has been trialled at both 3-leg and 4-leg intersections. Use at intersections with more than four legs has not been tested and the limitations of such application are not understood.

Table 2.2
Summary of operating environments intended for RJAWS Lite (2 of 2)

Factor	Suitable environment	Notes
Intersection control	Stop-controlled, give way-controlled and non-controlled intersections	RJAWS Lite has been trialled at both stop-controlled and give-way controlled intersections. Its use at non-controlled (3-leg) intersections is possible, though installation of the minor road run-through prevention system requires the use of a Stop or Give Way control sign. RJAWS Lite is not intended to be used at intersections with signalisation or roundabout control.
Intersection channelisation	No/limited channelisation	RJAWS Lite has been trialled at intersections with no or limited channelisation. Though plausible, its use at intersections with substantial channelisation has not been tested.
Intersection geometry	Few limitations	RJAWS Lite has been trialled at locations with acute, perpendicular, and obtuse intersection geometries. Note that some intersection geometries, such as that shown in Figure 2.1, may require an adjusted design. For the intersection shown in Figure 2.1, the minor road radar could not be located on the same pole as that containing the control sign.
Approach geometry	Straight or with minor to moderate curvature	RJAWS Lite has been tested at intersections where the approach roads are either straight or have minor to moderate horizontal and vertical curvature. The extent of curvature which can be facilitated is due to the ability of the vehicle detection radars to detect vehicles at an appropriate range. Use of other vehicle detection equipment may change these requirements, though this has not been tested.
Number of lanes	2-lane/2-way on all approach roads	RJAWS Lite has been trialled on 2-lane/2-way roads. RJAWS Lite was not intended for use on multi-lane roads and modification of the concept is likely to be required to facilitate its use on such roads.
Auxiliary lanes	Auxiliary turning lanes on the major or minor road may be present	RJAWS Lite has been trialled at intersections with auxiliary right turn and left turn lanes on the major road. While it has not been trialled at intersections with auxiliary turn lanes on the minor road, this is unlikely to impede its use.
Speed limit zone	High speed limit zones	RJAWS Lite has been trialled in both 80 km/h and 100 km/h speed limit zones. RJAWS Lite is not intended for use in low speed limit zones due to the limited effect it is likely to induce in such locations.
Overhead vegetation	Low levels of foliage	RJAWS Lite has been trialled at locations with low and high levels of foliage. Its use at locations with high levels of foliage can result in lower reliability, due to premature depletion of the batteries and the inability to recharge them during inclement weather conditions or shorter winter days. Note that tolerance to foliage will depend on several factors such as the power consumption of the system, both due to background consumption (e.g. communication systems) and dynamic consumption (e.g. flashing lights/VMS); capacity of the batteries; and wattage of the solar panels. Note that use of non-solar power sources may facilitate installation at high foliage locations, though this has not been tested.
Weather	All weather conditions	RJAWS Lite has been trialled during both fine and inclement weather conditions. The main limitation during inclement weather conditions is the ability to maintain electrical capacity due to the reduced charging provided by the solar panels.

Figure 2.1
Location of an RJAWS Lite trial installation on a curved major road and with a non-perpendicular minor road approach. Note unusual location of the minor road radar (marked as an "X"), necessitated by the minor road geometry (source: Location SA map viewer, Government of South Australia)

RJAWS Lite is designed to target specific crash types. As such, its use at intersections that are susceptible to or with a history of these crash types is preferable. The crash types that may be affected by RJAWS Lite are discussed in Table 2.3. Note that ancillary affects, such as a reduction in severity of pedestrian or head-on crashes owing to lower speeds when the system is activated, could occur but are not herein discussed.

Table 2.3
Crash types expected to be affected by the presence of RJAWS Lite(grouped by DCA code)

DCA code*	Crash type description	Expected effect
110-113, 116	Vehicles from adjacent directions (cross traffic, right far, left end, right near, left near)	Reduction in likelihood and severity. A reduction in likelihood is expected due to the lower vehicle speeds and improved reaction times, and therefore greater ability to react on activation of the major road speed advisory, and due to the expected reduction in run-through events on activation of the minor road run-through prevention. A reduction in severity is expected due to the lower impact speeds achieved when either the major road speed advisory, minor road run-through prevention, or both are activated.
130	Vehicles in same direction (rear end)	Increase in likelihood. Crashes of this type could potentially be increased upon activation of the major road speed advisory, owing to the vehicle in front reducing speed in response to the system. It is not expected that the severity of these crashes will be severe, owing to the low closing speeds and the inherently low severity associated with the impact configuration (Doecke et al. 2020)

*DCA codes taken from Government of South Australia (2020)

The major road speed advisory system and minor road run-through prevention system target similar crash types, though the errors that lead to these crash types are rather different. A discussion of these differences and what considerations need to be made to account for these are discussed below.

2.1. Major road speed advisory

The main benefit of the major road speed advisory is to reduce the speed of vehicles that are travelling straight through the intersection on the major road. This reduction of speed is expected on activation of the system when the presence of a vehicle approaching the intersection from the minor road is detected. Collision speed and the severity of a crash are directly correlated (Doecke et al. 2020). As most minor road vehicles are expected to be travelling at a low speed at the time of a crash (except in the event of a run-through event), the combination of lower speeds of both colliding vehicles is expected to substantially reduce the severity of crashes compared to when one vehicle (the major road vehicle) collides at a much higher speed.

A reduction in likelihood of crashes is also expected as the driver of the major road vehicle may have a heightened sense of awareness and will have more time to react to a crash situation before the collision occurs, possibly avoiding the collision altogether.

2.2. Minor road run-through prevention

The main benefit of the minor road run-through prevention system is to reduce the likelihood that vehicles will “run-through” the intersection from the minor road (i.e. traverse the intersection at speed without appreciably slowing). Crash investigations conducted by CASR have highlighted that run-through crashes are often the result of a driver either being unaware of the intersection or being unaware that they are approaching the intersection from the minor road, where they are required to give way to other traffic. The warning provided by the flashing lights bordering the control sign on activation of the minor road run-through prevention system is designed to alert the driver to the presence of the intersection and the need to give way. In doing so, the system is expected to reduce the likelihood that a driver will perform a run-through and therefore reduce the likelihood that a crash may result.

3. Intended functionality

RJAWS Lite consists of two separate safety systems. Both systems can operate independently but use some of the same equipment to function. These two systems are the major road speed advisory (similar in function to the original RJAWS treatment) and the minor road run-through prevention. Note that one or both of the systems can be activated at the same time. Dependent on the needs of a particular location, the two systems can be installed together, or one system may be installed without the other.

3.1. Major road speed advisory

The major road speed advisory alerts drivers to reduce their speed when traversing the intersection along the major road when a crash with a minor road vehicle is possible. The alert is provided via flashing lights/variable message sign (VMS) that illuminate when a minor road vehicle is detected as approaching the intersection (Figure 3.1). This alert is provided for all vehicles on the major road, given the presence of a minor road vehicle.

Figure 3.1
Example of a major road speed advisory sign with flashing lights (left) and variable message sign (VMS) (right)

The operational sequence of the major road speed advisory system is shown in Figure 3.2. This figure shows a four-leg intersection. An identical operational sequence is used for a three-leg intersection.

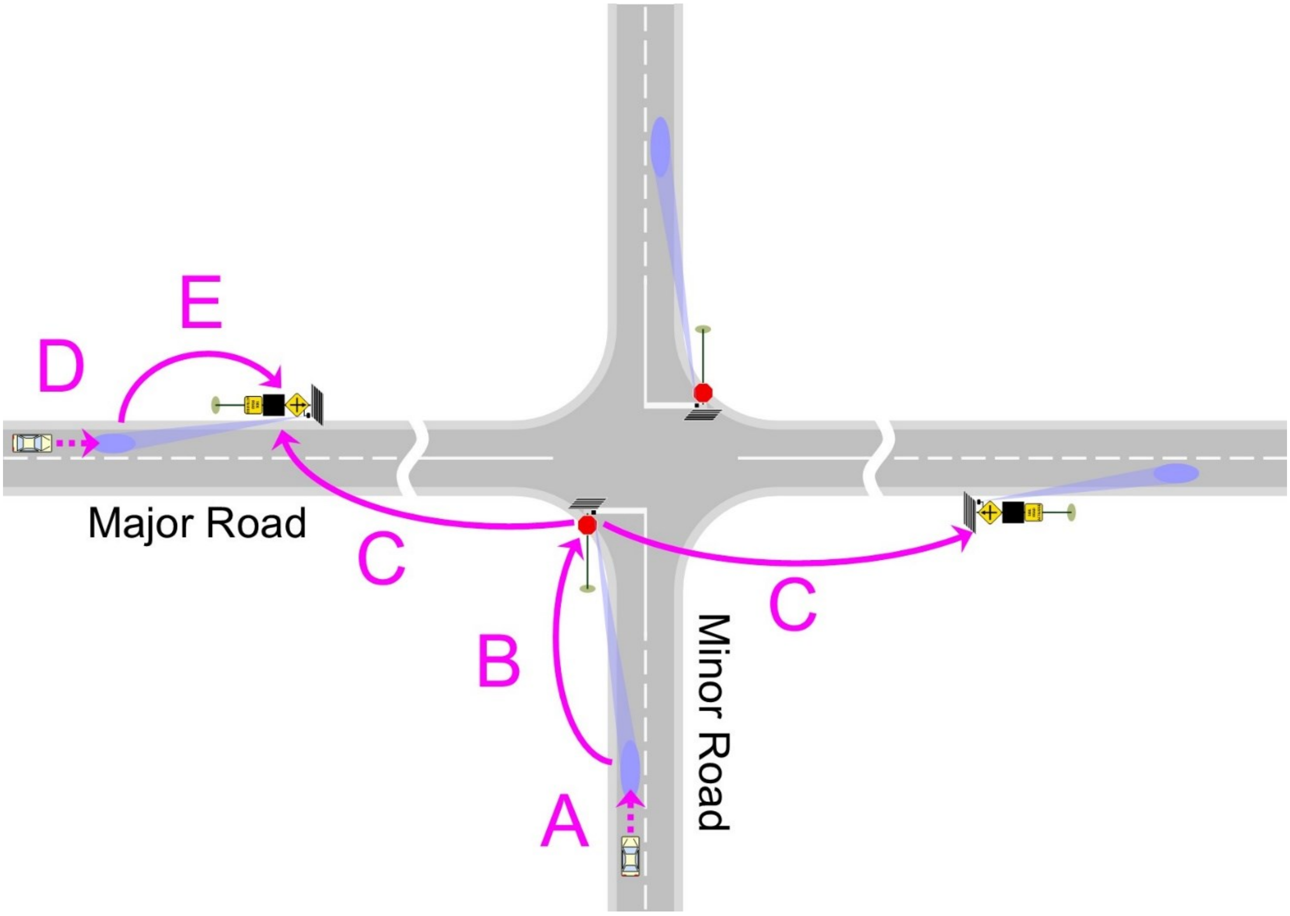

Figure 3.2
Diagram of the operational sequence of the major road speed advisory system

A. A vehicle on the minor road approaches the intersection and passes through the detection zone of the minor road radar
B. The minor road radar detects the vehicle on the minor road
C. The major road speed advisory signs are armed, but activated only in presence of through traffic (see note below)
D. Traffic is detected on the major road approach by the major road radar (mounted to the same structure as the major road speed advisory signs)
E. Flashing lights/VMS on the major road speed advisory sign are activated for a pre-defined duration.

Note: The major road detection equipment is used to reduce battery usage by only activating the flashing lights/VMSs on the major road speed advisory signs if a vehicle on the same major road approach is present. In the case that this battery-saving system is not used, flashing lights/VMSs on both major road speed advisory signs are activated at step C.

3.2. Minor road run-through prevention

The minor road run-through prevention is used to alert drivers that they are approaching the intersection along the minor road at a higher than appropriate speed and may therefore be at a risk of not stopping or adequately slowing before they traverse the intersection (Figure 3.3). This alert is provided via flashing lights around the control sign.

Figure 3.3
Examples of control signs with flashing lights activated for minor road run-through prevention systems

The operational sequence of the minor road run-through prevention is shown in Figure 3.4. This figure shows a four-leg intersection. An identical operational sequence is used for a three-leg intersection.

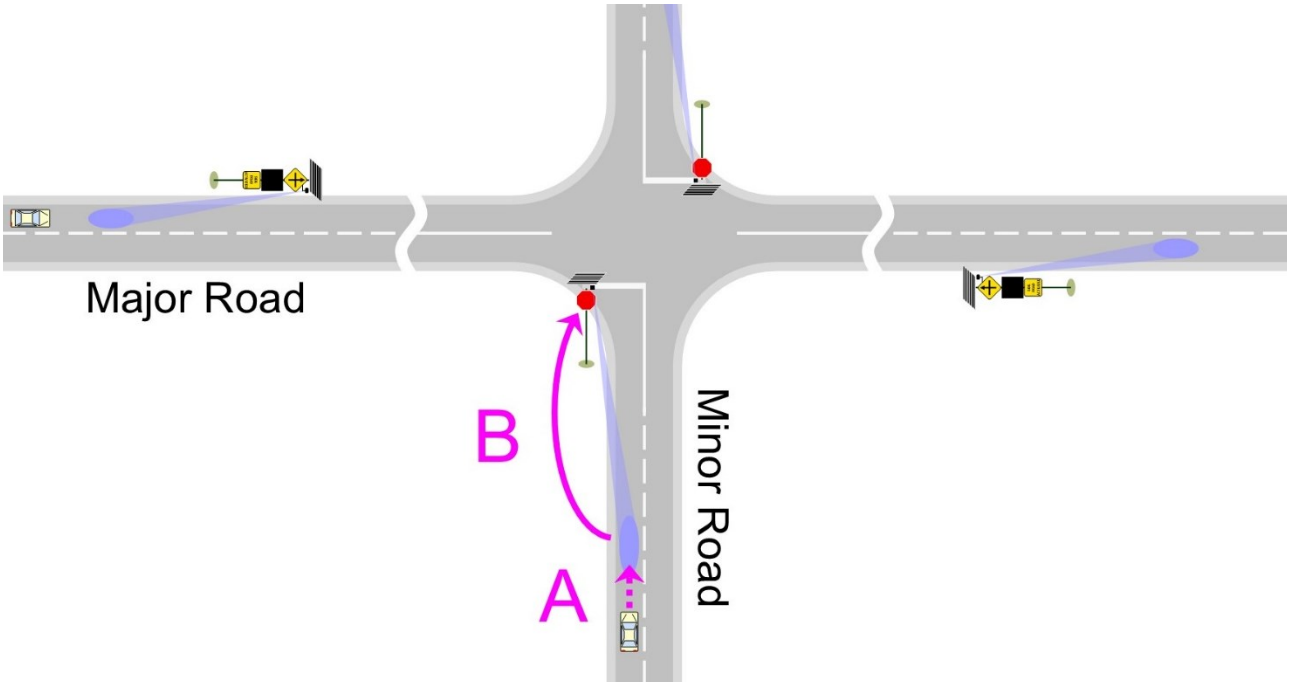

Figure 3.4
Diagram of the operational sequence of the minor road run-through prevention system

A. A vehicle on the minor road approaches the intersection and is detected as it passes through the detection zone of the minor road detection equipment. The vehicle is detected travelling at a speed above the threshold speed (see Section 4.2 for details) set to activate the flashing lights around the control sign

B. Flashing lights around the minor road control sign are activated for a pre-defined duration.

4. Design

4.1. Hardware requirements

RJAWS Lite is an overlay information system – it adds a level of information and warning for road users without changing the primary form of control at the intersection where it is installed. Intersections with RJAWS Lite installed should be able to function independently of whether the RJAWS Lite equipment is working. This provides a level of redundancy, In the event of a system failure, the risk to road users should not increase above that of an intersection without RJAWS Lite.

4.1.1. Roadside furniture

Previous trials of RJAWS Lite have utilised sleeved frangible poles to support the signs and equipment. Depending on the part of the treatment, the pole(s) may have solar panels, radar, communications equipment, computational equipment, flashing lights/VMSs and/or signs installed on them. Sleeved frangible poles allow for quick installation using non-destructive excavation methods and provides ease of deinstallation/reinstallation should the treatment be moved to another location.

Roadside furniture should be designed to reduce the incidence of vandalism while allowing for ease of access for maintenance (see Section 7). In previous trials, this has been achieved by:

- Placing all equipment at a height above ground level that is inaccessible without a ladder
- Where possible, enclosing equipment in lockable enclosures
- Placing furniture in locations where a vehicle can be parked and used to protect personnel from passing traffic
- Placing furniture in locations where a ladder can be safely used.

Previous trials of RJAWS Lite have used poles and equipment that are up to six metres tall. Many power lines are near this height from the ground. Careful consideration needs to be made where RJAWS Lite is proposed for installation around power lines. Minimum clearances should be adhered to during both construction and operation (e.g. Government of South Australia 2011). Consideration should be given to the safe clearance needs of installation and maintenance personnel and equipment, in addition to that of the installed infrastructure.

The installation of any roadside furniture creates additional risk of injury to road users. It is important that the net risk due to installing RJAWS Lite be lower than the risk at the same location without RJAWS Lite. The increased risk due to the installation of roadside furniture should be countered by a greater reduction in risk due to the operation of the treatment itself. It is important to consider the additional risk of installing roadside furniture, including from their physical presence and from any visual obstructions they may create. Frangible poles should be used unless there are specific reasons why they are not suitable. In such a case, the risk of using non-frangible poles should be carefully considered. The installation of equipment on the poles may create an additional hazard, due to the additional weight of the equipment, that may present a greater severity of outcome if a vehicle collides with a pole. If the risk associated with the installation of poles is deemed too high, the use of roadside barriers to shield road users from collision with the poles may need to be considered.

Requirements for additional roadside furniture, such as additional road signs if the location to be treated is not currently to an acceptable level of design, should also be considered.

4.1.2. Vehicle detection

Previous trials of RJAWS Lite have utilised radar to detect vehicles. Radar allows vehicle detection to occur without the need for extensive roadworks, such as what would be required for the use of inductive loops. However, radar also requires careful setup and alignment to ensure adequate and reliable vehicle detection. Radar may not be suitable for all locations, as roadside objects or the road alignment may not allow for a clear line of sight. Occlusion by traffic crossing the path of the intended target may also be an issue in some circumstances. Other methods of detecting vehicles are available and may be considered if they are in-line with the design philosophy (see Section 1.1) and comply with the design and operational requirements (see Section 4.2).

4.1.3. Power supply

Previous trials of RJAWS Lite have utilised solar power to supply electrical power for the treatment. Solar panels are installed at the top of each frangible pole to supply power to the equipment (radar, communications, computation, flashing lights/VMSs) that is installed on that pole. Other methods of supplying electrical power may be considered if they are in-line with the design philosophy (see Section 1.1) and comply with the design and operational requirements (see Section 4.2).

Power supply should be able to provide reliable operation of the treatment. While outages due to a lack of electrical supply may occasionally occur, the needs of the system should be carefully considered so that outages under reasonably foreseeable circumstances do not occur. Consideration of all foreseeable operational conditions should be made when determining the appropriate design of the power supply, including weather conditions and the position of the sun respective to the solar panels which may be shaded by trees or buildings at certain times of the year. It is important to consider the dynamic nature of the weather and sun position, which can change considerably between seasons.

Power input should be enough to compensate for all power consumption over a 24-hour period. The wattage of the solar panels needs to be sufficient to supply enough electricity to restore batteries to their “full” voltage by the end of the daylight period. It is understandable that this may not always be feasible, such as under extreme weather conditions. The battery capacity should be enough to maintain power supply for a reasonable amount of time without reliance on any charging from the solar panels. What constitutes a reasonable amount of time should be specified for each installation, based on cost and reliability considerations. For example, a location where reliability is paramount will require a greater cost outlay to supply higher capacity batteries.

Power consumption of most equipment (radars, communications, etc.) is reasonably deterministic. Activation of flashing lights/VMSs represents the most variable source of power consumption and will be dependent on the number and length of activations. Capacity should be enough to power activation by a reasonable percentage of minor road vehicles plus a margin of safety. What is reasonable depends on the site conditions and operation of the treatment. For example, if battery saving is not used for the major road speed advisory flashing lights/VMSs, then all minor road vehicles should be considered. If battery saving is used, then the percentage of minor road vehicles considered should represent the proportion of minor road vehicles that are estimated to coincide with the presence of a major road vehicle.

4.1.4. Communications

Reliable communication should be achieved between the different parts of the treatment and remotely with the control centre. Early trials of RJAWS Lite have utilised the LTE-M cellular network for communications. These trials have operated near the metropolitan area of Adelaide. According to a Telstra internet of things (IoT) network coverage map (Telstra 2023), both LTE-M and NB-IoT cellular networks should be able to service locations within the City of Onkaparinga's jurisdiction. Wi-Fi communication between the different parts of the treatment has been used for later trials. While imposing a higher up-front cost, Wi-Fi should improve reliability between the different parts of the treatment and reduce the ongoing cost of cellular connections. Cellular connection is still required between the RJAWS Lite and the control centre, as Wi-Fi is not feasible for such long-distance communication. When choosing the type of communication to employ, the up-front cost of Wi-Fi should be weighed against the potential reliability gains that can be obtained compared to using cellular-based communication. Other methods of remote communications may be considered if they are in-line with the design philosophy (see Section 1.1) and comply with the design and operational requirements (see Section 4.2).

Communications between the different parts of the system should guarantee constant communication with negligible lag time and minimal risk of connection loss. Remote communications with the control centre should at a minimum allow for the periodic reporting of system faults and system performance (e.g., battery voltage). Periodic or live performance data and the ability to remotely adjust operational parameters may also be desirable. During previous trials of RJAWS Lite, live remote communications reported data on vehicle detections, vehicle speeds, flashing light/VMS activations and battery performance. The level of data reported to the operator should be specified for each installation, based on the foreseeable needs of the installation. Locations used for trial purposes will likely require the reporting of a much greater depth of data. Locations not used for trial purposes should at least report minimum data to allow for the timely identification of faults and inadequate system performance.

4.2. Design and operational guidance

4.2.1. Design speed

All values in this section, with some exception, have previously been calculated using a design speed equal to the speed limit + 10 km/h (Austroads 2021) or target speed + 10 km/h. The exception are:

- Calculation of the maximum distance at which the major road speed advisory sign should be placed from the intersection (L_{max}). Here, a design speed of the speed limit is used for quantifying the initial speed of a major road vehicle as it approaches the intersection, as this leads to a more conservative value than if a higher speed value is employed.
- Calculation of the gate threshold speeds for activation of the minor road run-through prevention flashing lights. Using higher gate threshold speeds increases the risk that some vehicles at risk of running the control will not be detected and hence will not activate the flashing lights.

These exceptions have been previously made to adopt a more conservative design. The designer should consider the needs of each installation and base the design speed on that which promotes safe operation of the treatment.

4.2.2. Vehicle detection

In previous trials, vehicle detection was achieved using radar. As such, the detection of vehicles is henceforth discussed by means of radar. The use of other vehicle detection technology would also be acceptable, provided the vehicle detection requirements can be met.

Major road

In previous trials, battery-saving was employed for the major road speed advisory by using radars mounted adjacent to the major road speed advisory signs to detect vehicles along the major road and only activating the major road speed advisory sign flashing lights/VMSs when a vehicle was present. To achieve this, vehicles were detected at a distance on approach to the major road speed advisory signs. When a vehicle is present, the flashing lights/VMSs are activated for a limited length of time, allowing the driver of the passing vehicle to see the activation of the flashing lights/VMS. The distance at which vehicles are detected and hence the flashing lights/VMSs are activated should allow for the adequate decision time of a driver to be maintained (see Section 4.2.3 and Table 4.1). The use of radars for battery saving may not be required if the power supply is adequate to meet the demand of illuminating the major road speed advisory flashing lights/VMSs for each minor road vehicle detection. The cost of increased solar panel/battery capacity to allow for this, relative to the cost of this additional radar system, should be considered. Battery saving should only be considered where a substantial number of minor road vehicle detections will not coincide with vehicle presence on the major road.

The radar mounted adjacent to the major road speed advisory signs was also trialled at one location as a means of detecting vehicles turning right from the major road. This was done to provide additional warning when a right turn was being conducted from the major road, in addition to the manoeuvres from the minor road. This was facilitated by redirecting the major road radars to face the intersection, detecting traffic at a distance of approximately 36 metres from the intersection. Vehicles detected as travelling below 50 km/h (in an 80 km/h speed limit zone) were deemed to be turning and hence the major road speed advisory sign flashing lights were activated. Note the use of this function at a four-way intersection does not allow for the discrimination of left and right turning vehicles. This trial was unsuccessful as activation of the flashing lights occurred too late for the driver of an oncoming major road vehicle (that on a potential collision course with the right turning vehicle) to see them. While this could be rectified by detecting right turning vehicles at a location further from the intersection, discriminating between turning and non-turning vehicles by their speed would not be possible – at such a point, turning vehicles have not yet started to reduce their speed by a substantial amount. This feature is a desirable addition to RJAWS Lite and should be considered for future installations, should a feasible way to detect right turning vehicles be found.

Minor road

The minor road radar serves two functions. First, it acts to detect the presence of vehicles approaching the intersection from the minor road and activate the flashing lights/VMSs on the major road speed advisory signs. Second, it acts to detect the speed of vehicles approaching the intersection from the minor road and activate the minor road run-through prevention flashing lights.

To activate the major road speed advisory sign flashing lights/VMSs, the radar should be directed such that vehicles approaching the intersection from the minor road are detected at a suitable distance. This distance will be determined by several factors, including the road geometry, vehicle speeds and the distance required for correct placement of the major road speed advisory signs from the intersection (L_{max}, see Section 4.2.3). The type of radar chosen should be reliable at the necessary range.

To activate the minor road run-through prevention flashing lights, the radar should be directed such that vehicles approaching the intersection from the minor road are detected at a suitable distance. The radar should be angled so that it can reliably detect and track the speed of an approaching vehicle. Tracking of a minor road vehicle has previously been achieved by setting up “gates” at five or ten metre increments, at a distance of no greater than where normal deceleration starts and up to a point at which the radar line-of-sight is lost – generally a distance of about 30 metres from the control line. At each gate, a threshold speed is set. If a vehicle exceeds the threshold speed for a gate, the minor road run-through prevention flashing lights are activated. The threshold speeds are firstly set by determining a maximum desirable coefficient of deceleration above which the flashing lights are activated. An example of a coefficient of deceleration and its associated threshold speeds are shown in Figure 4.1. Previous trails have used a coefficient of deceleration of 0.26 (Austroads 2021). Once set using the coefficient of deceleration method, the threshold speeds for each gate can be fine-tuned by observing the proportion of minor road vehicles that trigger an activation. The threshold speeds can be raised or lowered to allow a specified proportion of activations. In previous trials, a limit of approximately 10% of minor road vehicles (causing activation of the flashing lights) was used to fine-tune the threshold speeds. Note that the objective here is to detect and warn drivers that are of a risk of running through the control sign, not just vehicles that are approaching at a speed faster than that considered normal. The method therefore used to set the threshold speeds should be pragmatic with an insight into the plausible behaviour of those who are at risk of running through the intersection.

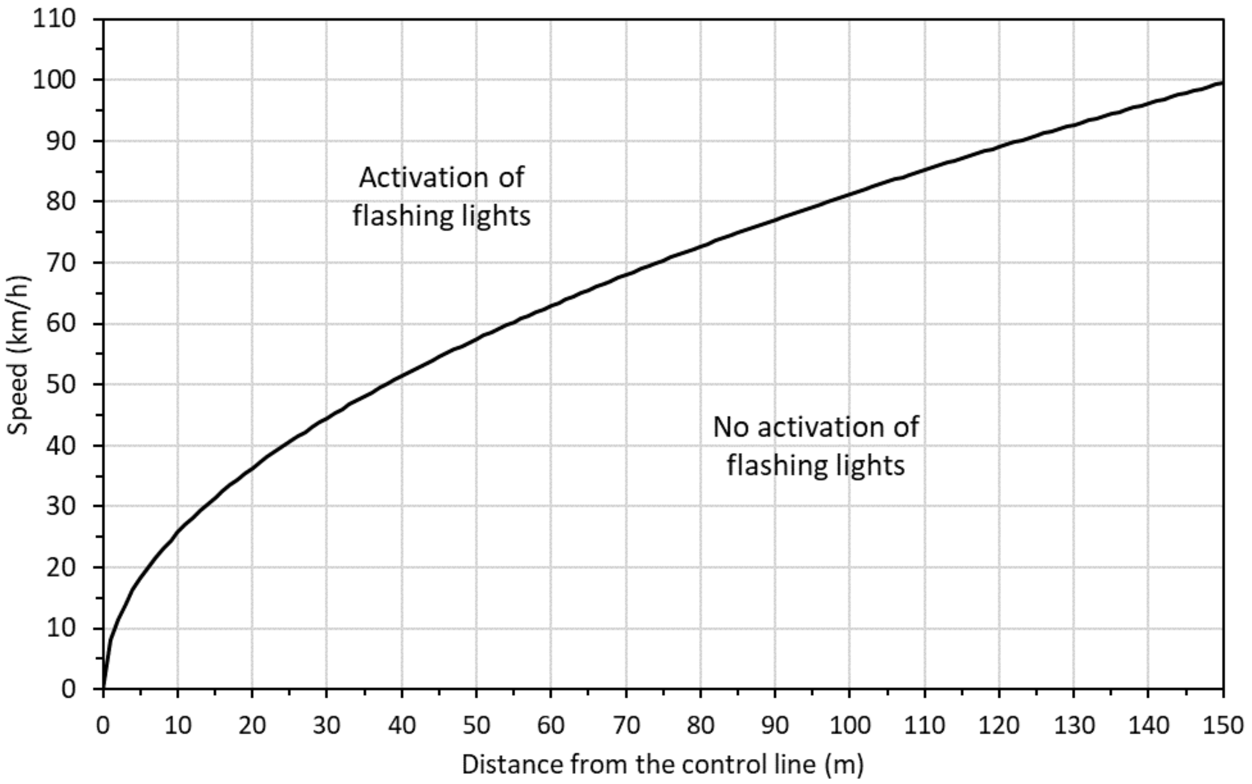

Figure 4.1
Example threshold speeds for activation of the minor road run-through prevention flashing lights, using a coefficient of deceleration of 0.26, assuming zero gradient

4.2.3. Sign location

The guidance provided in this section is general in nature. Placement of signs should be undertaken considering the aspects discussed below, as well as location specific aspects such as road geometry and sight lines. Access for maintenance purposes should also be considered – where safe access cannot be given, the need for barriers to shield roadside workers may need to be considered.

Road signs should be located in accordance with the relevant standards and guidelines; namely *Australian Standard 1742.2* (Standards Australia 2022), Austroads *Guide to Road Design Part 4A* (Austroads 2023), and the Department for Infrastructure and Transport *Manual of Legal Responsibilities and Technical Requirements for Traffic Control Devices* (Government of South Australia 2021). Locations outside of those specified in the above standards and guidelines may require additional approval.

Major road speed advisory signs

Note that Standards Australia (2022) provides different locations for warning signs based on the amount of speed reduction required by a driver. As RJAWS Lite is a novel treatment and the major road speed advisory signs are uncommon to other types of warning signs, it is unclear as to what category of speed reduction should be used. It is suggested that, on activation, the major road speed advisory signs may lead to a moderate level of speed reduction and therefore the respective category in Standards Australia (2022) should be adopted.

There are several other considerations that should be made when locating the major road speed advisory signs. These are:

- The distance necessary for a driver to react and slow in accordance with the advisory speed (determined by calculating L_{min})
- The coordination of timing between the detection and then arrival of a minor road vehicle at the intersection and the ability of a driver on the major road to see and react to the major road speed advisory (determined by calculating L_{max})
- The size of the signs, which can obstruct the major and minor road drivers' view of one another's vehicles. Consideration should be given to the obstruction of sight lines created by the signs and their placement should not obstruct visibility within the minimum gap sight distance and safe intersection sight distance (Austroads 2023).

L_{min} and L_{max} can be determined through analysis of the theoretical requirements for effectively locating the major road speed advisory sign, as detailed below. The distance at which the major road speed advisory sign is placed from the intersection (L) should be between L_{min} and L_{max}.

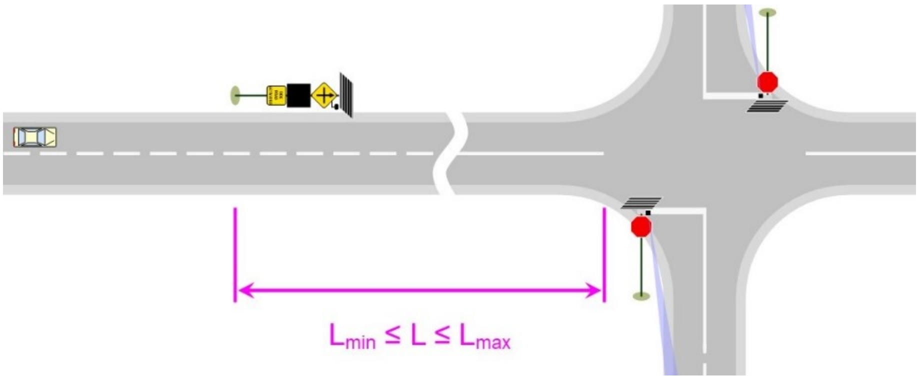

Figure 4.2
The major road speed advisory sign should be placed at a distance (L) from the intersection

Minimum distance (L_{min})

The major road speed advisory signs should be located at a distance from the intersection such that a driver on the major road, on activation of the flashing lights/VMS, can react and safely slow in accordance with the advisory speed before traversing the intersection (L_{min}). Previous trials of similar systems have shown that most vehicles will slow to a fraction of that advised (Mongiardini et al. 2021). Therefore, the target speed of vehicles on activation of the major road speed advisory is pragmatic. It is recommended that the target speed be no higher than 10 km/h above the advisory speed – in-line with the upper limit of speed reductions reported by Mongiardini et al. (2021). For example, the maximum target speed for an intersection in an 80 km/h speed zone with a 50 km/h advisory speed should be no greater than 60 km/h. Example calculations for L_{min} are shown in Appendix A. For previous trials, L_{min} has been calculated using a coefficient of deceleration (d) of between 0.15 (comfortable deceleration for a bus) and 0.26 (comfortable deceleration on sealed roads) (Austroads 2021). A value of d in the lower end of this range is suggested as it is likely to better reflect the rate of deceleration that will be adopted by most drivers on approach to the intersection when the flashing lights/VMS are activated (E.g., slowing with minimal active braking). This is also considered to be less likely than higher rates of deceleration to lead to rear end collisions (i.e. due to heavy braking by a leading vehicle). While a higher value of d may be adopted, the higher risk of rear end collisions should be considered and weighed against the benefit of its adoption. However, it has also been noted through experience that adopting a higher value of d may be necessary to fulfill the requirement of L_{max} when a minor road radar with a reduced range is used.

Maximum distance (L_{max})

When locating the major road speed advisory signs, there needs to be coordination so that the flashing lights/VMSs are activating at the time necessary to warn vehicles on the major road that have the potential to collide with the minor road vehicle. The significant risk here is that a sign will be placed too far from the intersection, so that when the lights are activated, a major road vehicle at risk of colliding with the minor road vehicle will have already passed the sign. The maximum distance at which the major road sign should be placed from the intersection can be determined by calculating L_{max}. L_{max} is dependent on the values for L_{DT} and L_{AT}. A graphical representation of the timesteps considered when calculating L_{max}, L_{DT} and L_{AT} are shown in Figure 4.3, with descriptions for coordination given in Table 4.1. Example procedures for calculating these values are shown in Appendix A.

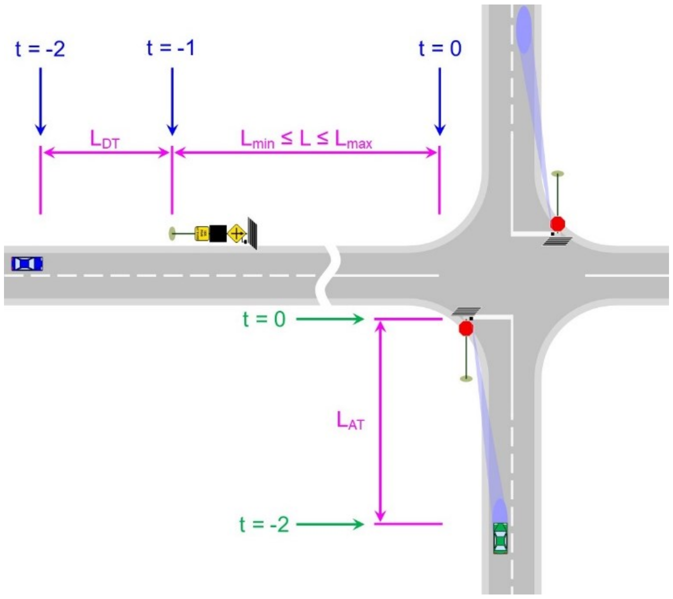

Figure 4.3
Graphical representation of the timesteps considered when determining placement of the major road speed advisory sign

Table 4.1
Timesteps considered for coordination of the minor road and major road vehicles when determining placement of the major road speed advisory sign

Timestep	Minor road vehicle	Major road vehicle
t = -2	The minor road vehicle is detected by the minor road radar at a distance (L_{AT}) as it approaches the intersection. In previous trials, it has been assumed that the minor road vehicle is decelerating at a constant rate. The approach time (AT) is the time required for the minor road vehicle to reach the intersection after detection from the minor road radar	The major road vehicle approaches the major road speed advisory sign, at a distance (L_{DT}) corresponding to the decision time (DT) required for the driver to observe and react to the advisory speed displayed on the sign
t = -1	-	The major road vehicle passes the major road speed advisory sign, at a distance (L_{max}) from the intersection, corresponding to the response time (RT) required for the driver to slow to the target speed at which it will traverse the intersection
t = 0	The minor road vehicle arrives at the intersection. In previous trials, it has been assumed that the minor road vehicle is travelling at a low speed (e.g. 20 km/h) when it traverses the control line. This is chosen as a conservative value, which decreases the time required for the minor road vehicle to reach the intersection	The major road vehicle arrives at the intersection, having slowed to the target speed

Activation of the major road speed advisory flashing lights/VMSs should occur at least a minimum distance before the major road vehicle passes the sign (L_{DT}). This distance corresponds to the decision time (DT) required for the driver to observe and react to the flashing lights/VMSs.

The maximum distance at which the major road speed advisory sign should be placed from the intersection to allow for coordination (L_{max}) is dependent on several factors: initial speed; advisory speed (or target speed); decision time; minor road radar detection distance; and major and minor road vehicle deceleration characteristics. Ideally, RJAWS Lite should be designed to compensate for a minor road vehicle that does not slow at all on approach. However, this can result in the major road advisory speed sign being placed infeasibly close to the intersection. Instead, it is suggested that RJAWS Lite be designed to allow coordination with a vehicle that is slowing for the intersection.

The distances of L_{max}, L_{DT} and L_{AT} are related through the time periods required for a car to travel their respective distances. These are RT, DT and AT, respectively. The relationship used to determine each distance can be expressed by the following equation

$$AT \geq DT + RT$$

where AT is the time required for the minor road vehicle to reach the intersection after being detected by the minor road radar; DT is the decision time required for the driver of the major road vehicle to observe and react to the major road speed advisory flashing lights/VMS; and RT is the response time required for the driver of the major road vehicle to slow to the speed at which it will traverse the intersection (the target speed). Example graphs from the calculation of L_{AT}, L_{DT} and L_{max} are shown in Figure 4.4 and Figure 4.5. Note that these graphs are for an intersection with speed limits of 80 km/h on all approach roads, a target speed of 60 km/h and zero grade on all approaches. A design speed of 80 km/h is used for the major road vehicle while a design speed of 90 km/h is used for the minor road vehicle (see Section 4.2.1 for reasoning).

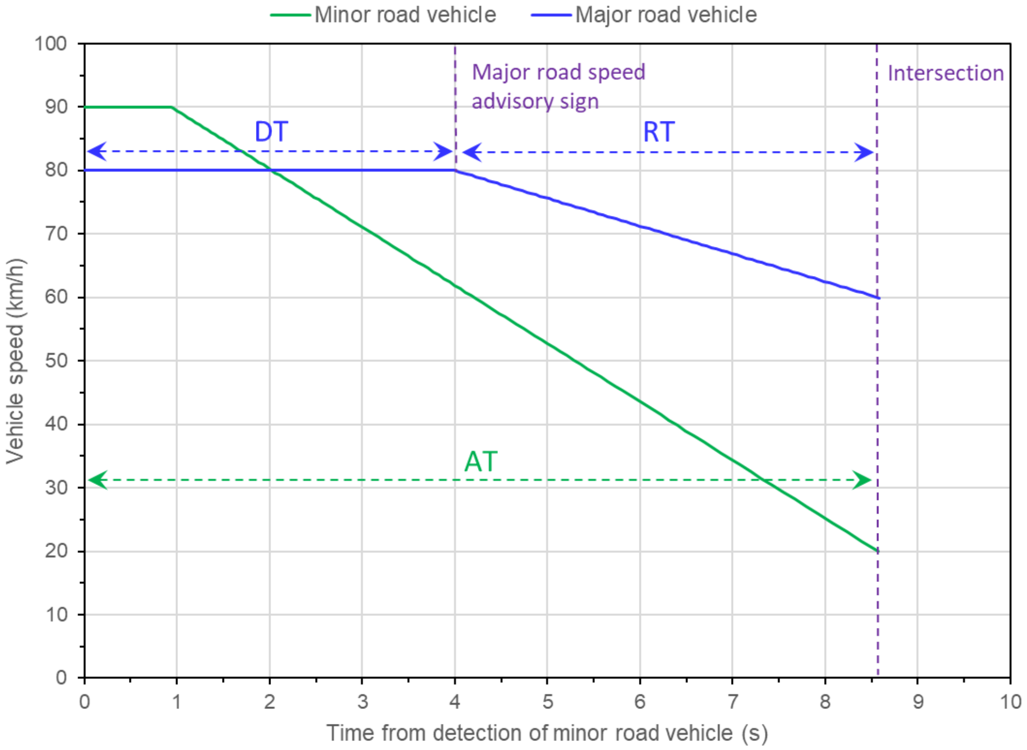

Figure 4.4
Example showing the speed trajectories of the major and minor road vehicles when coordinated to meet at the intersection at the same time

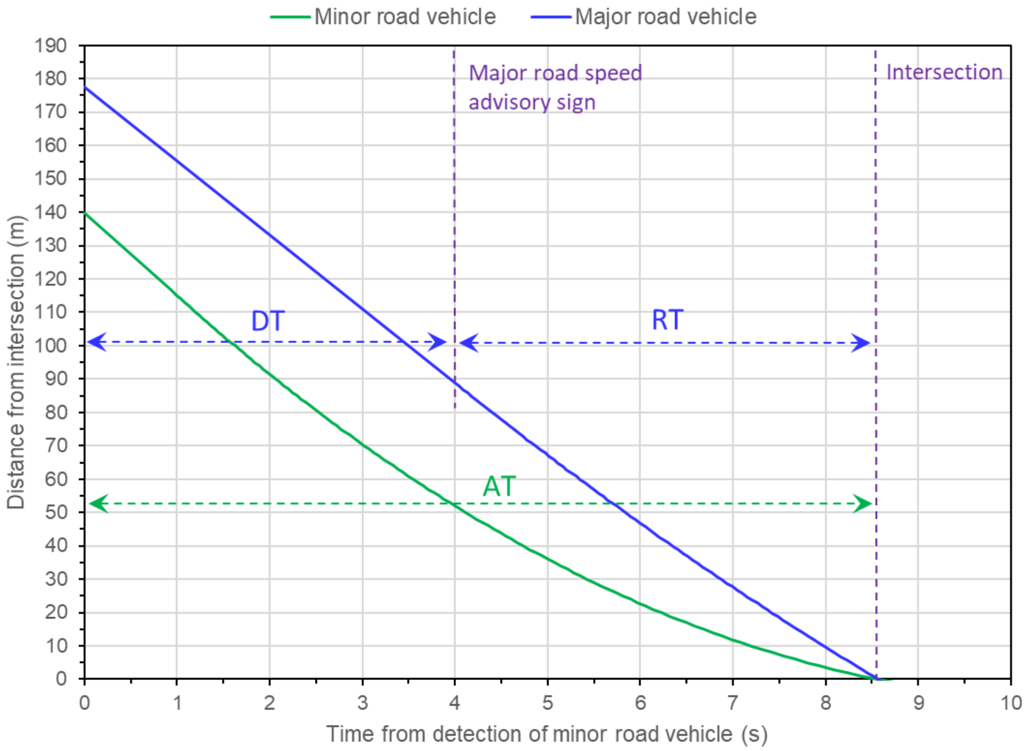

Figure 4.5
Example showing the spatial trajectories of the major and minor road vehicles when coordinated to meet at the intersection at the same time

Minor road run-through prevention

The minor road run-through prevention signage consists of the control sign with imbedded flashing lights. This should be placed within the bounds for locating a control sign as specified in the relevant documents (e.g. Austroads 2023; Standards Australia 2022).

In previous trials, the minor road radar has either been mounted on a separate pole, located opposing the terminating road of a three leg intersection, or on the same pole as is mounted the control sign. The former configuration was chosen for evaluation requirements and is unlikely to be used for further installations. Note that this configuration suffered from radar “noise” created by the presence of traffic on the major road obscuring the radar’s line of sight. For either configuration, the pole must be placed so that the minor road radar has an uninterrupted view along the minor road on approach to the intersection, to a distance required by the vehicle detection requirements (see Section 4.2.2).

Additional signage

RJAWS Lite should be considered as an overlay treatment. The signage specific to RJAWS Lite is intended to replace specific signage at a standard non-signalised intersection. The following signage is intended to be replaced.

- The major road speed advisory signage replaces the primary W2-1 Cross Road or W2-4 (L or R) Side Road Intersection signs.
- The minor road run-through prevention signage replaces the primary R1-1 Stop or R1-2 Give Way control signs.

Other signage should be in accordance with the relevant requirements (e.g. Austroads 2023; Standards Australia 2022). The need for additional advanced warning signs, sign duplication and other additional treatments should be considered.

In locations where RJAWS Lite has not yet been installed and where there is a perceived need to inform drivers of RJAWS Lite, signage explaining the operation of RJAWS Lite may be considered. Such signage has not been used in previous trials.

4.3. Sign design

4.3.1. Major road speed advisory

The Department for Infrastructure and Transport (DIT) has approved the use of major road speed advisory signs that either employ flashing lights or a variable message sign (VMS). While either sign variation can be used, only one variation should be employed per intersection (i.e., either both major road speed advisory signs employ flashing lights or both employ VMSs). It is preferable that all intersections with RJAWS Lite within close proximity of one another employ the same sign variation.

DIT has approved the use of two variations of signs that employ flashing lights for both 80 km/h and 100 km/h speed limit applications. These signs, TES 17795 and 17796, respectively, are shown in Figure 4.6. The sign incorporates a modified advisory speed sign, a Side Road Intersection or Cross Road warning sign, a target board and a TES 18580 flashing light assembly. The advisory speed shown to drivers is 30 km/h below the speed limit. This sign arrangement has been used for previous trials.

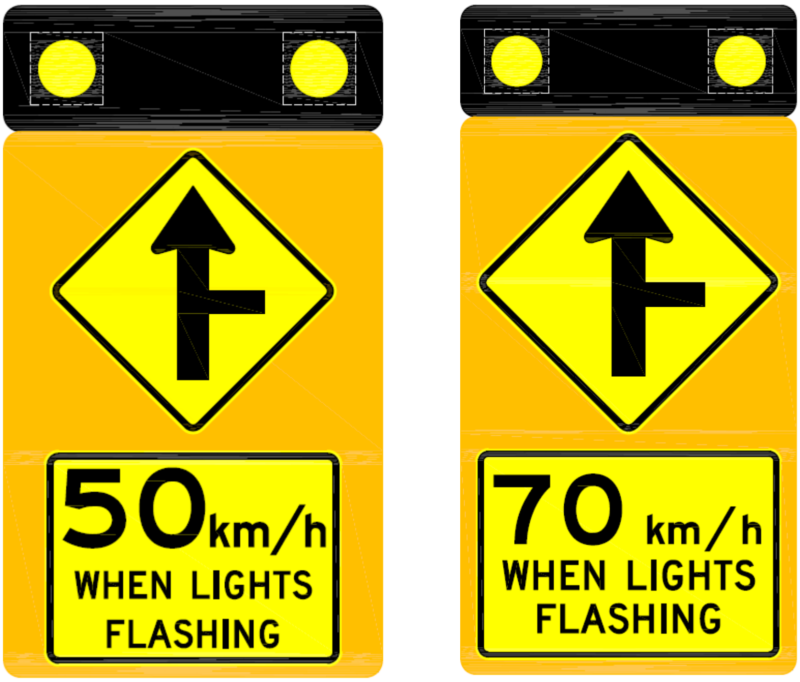

Figure 4.6
Major road signs approved for use by DIT: TES 19975 (left) and TES 19976 (right). Images are not to scale. Note these examples incorporate a W2-4(L) Side Road Intersection sign.

DIT has also approved the use of an alternative major road speed advisory sign that employs a VMS (Figure 4.7). For this design, a standard Side Road Intersection or Cross Road sign can be coupled with a VMS that displays the advisory speed when activated. The addition of a “side road activated” sign is employed to inform drivers of the treatment’s operation. The advisory speed shown to drivers is 30 km/h below the posted speed limit. This design of the major road speed advisory sign has been employed for permanent installations within the City of Onkaparinga Council.

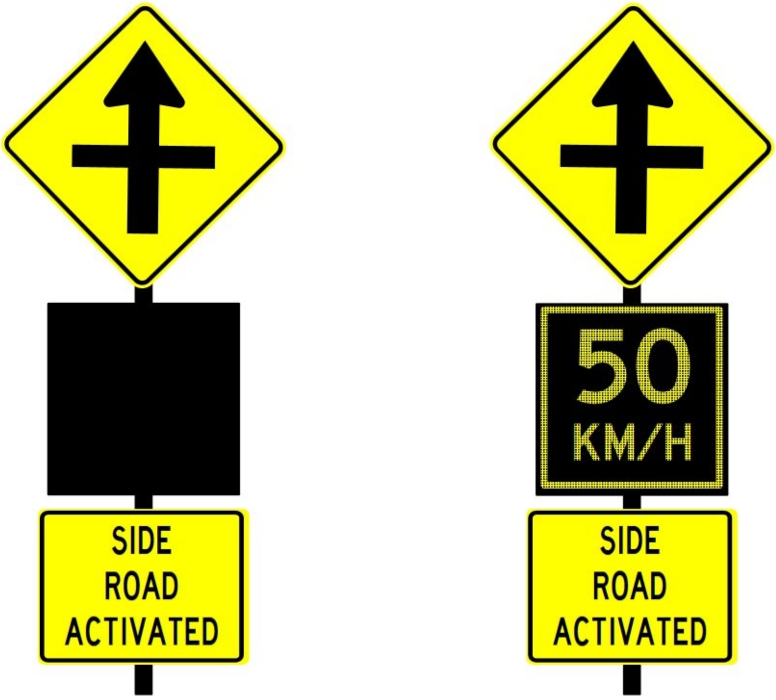

Figure 4.7
Alternative major road speed advisory sign (W2-1 Cross Road sign) using a VMS in-place of flashing lights - VMS in off mode (left) and “on” mode (right). .

Several limitations of the major road speed advisory signs that employ flashing lights (Figure 4.6) may be overcome with the use of this alternative VMS designFigure 4.7, including:

- Reducing the overall size of the sign compared to the static sign with flashing lights, which is substantially larger than a standard cross-road or side-road-ahead sign. The static sign design has been publicly criticised as being “too large and an eyesore” (pers. comm. City of Onkaparinga Council). There are also practical advantages for using a smaller sign, such as limiting the potential for visual obstruction caused by the sign or reducing the costs associated with the need for twin poles for large static signs. Additionally, the reduced roadside clearance and height constraints required to install the smaller VMS design allows for greater flexibility during installation of this system compared to a large static sign.
- Avoiding misperception of risks on nearby intersections – The high alert created by the sign that employs flashing lights may create a negative halo effect towards nearby intersections by inducing motorists to misperceive a lower risk at these other intersections due to the lack of additional treatment. It should be noted that the validity of this theory has not been tested.

4.3.2. Minor road run-through prevention

Two minor road run-through prevention signs have been used in previous trials – a modified R1-1 Stop sign (Figure 4.8, left) and a modified R1-2 Give Way sign (Figure 4.8, right). Both signs consist of a standard control sign modified to include imbedded red flashing LED lights. The flashing lights are located around the boarder of the sign. The flashing lights should be easily visible to drivers on approach to the intersection from a distance at least as great as the farthest point of activation. It is desirable that the flashing lights be visible only within a restricted viewing angle, to reduce the risk that drivers along the major road will see the flashing lights.

Figure 4.8
R1-1 Stop sign (left) and R1-2 Give Way sign (right), both with imbedded red flashing LED lights.

4.4. Example design

The first RJAWS Lite treatment for the City of Onkaparinga was installed at the intersection of Chalk Hill Rd/Olivers Rd/Field St. Design drawings for this site are provided in Appendix B. These design drawings are intended to serve as an example but are not reflective of the exact layout or information required.

5. Operational performance

The desired and intended operational performance of the treatment should be outlined before the system is implemented. This may include discussion of the types of crashes to be affected and the reduction in speeds and run-through events that are desired. It may also include technical performance of the equipment, such as solar and battery capabilities. Operational performance that does not meet expectations may be indicative of a design deficiency, failure, or wrongful assumptions of the operating environment. Due to the current novelty of this treatment, it is expected that estimating and meeting the operational performance objectives will be more difficult compared to more common infrastructure treatments.

5.1. Safety performance of major road speed advisory

Safety is affected by a reduction in speed. In previous trials, a speed advisory of 30 km/h below the speed limit has been used. This was adopted from the speed limit reduction used in South Australian installations of RJAWS and RIAWS. The argument for a speed advisory 30 km/h below the speed limit is that it is enough to instigate a meaningful reduction in speed, without going so far as to frustrate motorists who may otherwise decide to ignore the advisory altogether. Too high a speed reduction may also introduce safety issues, namely the increased risk of rear-end collisions where a following vehicle does not adhere to the advisory speed.

Based on previous trials, it is speculated that the reduction in average speed when the major road speed advisory flashing lights/VMSs are activated is at most approximately 20 km/h (using a speed advisory of 30 km/h below the speed limit). This speculation is based on speed reductions seen during previous trials (Mongiardini et al. 2021). It is therefore postulated that the target speed used when designing the treatment should be greater than the speed advisory that is to be displayed. For previous trials, the target speed used to design the major road speed advisory system has been 10 km/h above the advisory speed (see Section 4.2). For example, for a speed advisory of 50 km/h, a target speed of 60 km/h has been used. Consideration should be given to the expected reduction in speed when setting the target speed that is used to design the treatment.

It is not intendent that a speed advisory of 30 km/h below the speed limit be universally adopted. Instead, it is for the designers and road managers to decide what is acceptable. To avoid driver confusion, it is desirable that the speed reduction is not arbitrary and does not differ substantially over intersections that may appear similar in nature.

The speed reduction seen at different intersections may be different, and some intersections may present underwhelming results compared to what is expected. From previous trials, some environmental factors have been linked to lesser speed reductions. While not comprehensive, the below list provides some indication of environmental factors that may limit the speed reduction potential of the treatment.

- Geometric design: Two trial intersections had constrictive curvature that reduce the speed of vehicles on the major road approach and may have limited the speed reduction attributed to the major road speed advisory when it was activated.
- Speed limit change: one trial intersection had a change in speed limit (from 50 km/h to 100 km/h) near the treated intersection, which may have resulted in lowering vehicle speeds as

they traversed the intersection, leading to a lesser speed reduction from the major road speed advisory when it was activated.
- Grade: one trial intersection had a downward gradient on the major road approaches, which may have contributed to a lesser speed reduction, possibly due to the accelerative effect of the downward gradient.
- High traffic volumes: one trial intersection had especially large traffic volumes that may have contributed to a lesser speed reduction when the major road speed advisory was activated, possibly due to driver hesitation to reduce speed with other traffic following.
- Weather conditions: testing in adverse weather conditions may elicit a speed reduction less than that expected in fair weather conditions. This was not specifically seen at the previous trial intersections but is reasonable to expect.

5.2. Safety performance of minor road run-through prevention

Safety is affected by warning drivers of potential run-through events, in-turn potentially reducing the likelihood that run-through crashes will occur. In previous trials, the effectiveness of the minor road run-through prevention system has been evaluated using vehicle approach speed as a surrogate measure. This method has produced inconclusive results, owing to the indirect method of evaluation. It is assumed that most vehicles surveyed as triggering the minor road run-through prevention flashing lights would not have been at risk of a run-through, diluting the results enough to prevent discrimination of the few events that may have constituted a heightened risk. Accordingly, the performance outcomes of the minor road run-through prevention cannot be accurately estimated. This should be an objective of further trials, using more direct means of measuring the effect, as outlined in Section 9.2. If an effect is generated, the minor road run-through prevention should reduce the incident of run-through events, which in-turn should reduce the rate of crashes caused by run-through events.

5.3. Performance of technical equipment

The performance requirements of the technical equipment is dependent on the hardware requirements (see Section 4.1), such as the need to maintain electrical power, and the design and operational requirement (see Section 4.2), such as the need to detect vehicles over a certain distance. Please refer to these sections for the performance requirements of the technical equipment.

6. Testing for commissioning

Testing the operational performance of RJAWS Lite is required before it can be fully commissioned. The objective of testing is to validate the intended functionality of the treatment and check for sub-standard operational quality. The information contained within this section is general in nature – specific testing plans should be agreed upon on a project-by-project basis. An example framework for commissioning is shown in Figure 6.1.

Testing should also be used to determine if fine-tuning of the operational specifications is required, such as changes to detection distances and speed thresholds. Testing can include both on-site and remote testing. All testing and validation of the operational performance, and any fine tuning adjustments, should be made before the commencement of any evaluation surveys. If this is not possible (e.g. by later identification of a required adjustment), then adjustment should, if safe to do so, be made after conclusion of the evaluation surveys so as not to bias the result of the evaluation.

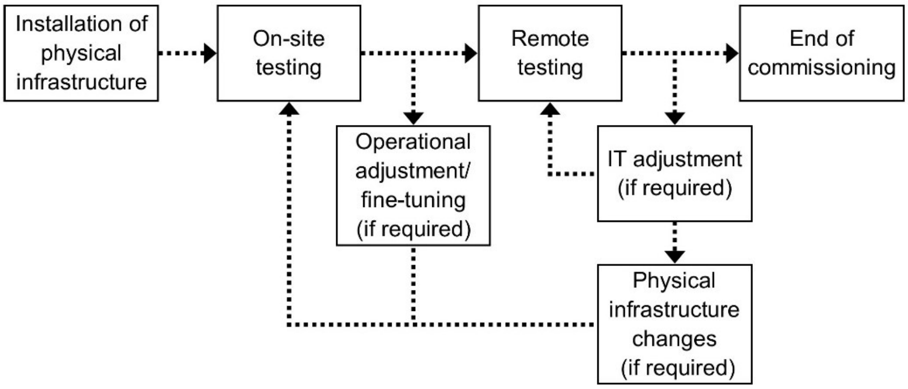

Figure 6.1
Example framework for the commissioning of RJAWS Lite

6.1. On-site testing

This section is about testing undertaken after installation of the treatment. While factory acceptance testing prior to installation should also be undertaken, the details of such testing are beyond the scope of this design guide and are dependent on the type of technology that is employed.

On-site testing includes subjective monitoring of traffic and testing of detection equipment using contractor vehicles. All on-site testing, particularly that involving testing using contractor vehicles, is inherently risky. Risk assessments should be undertaken and, when the residual risk is considered too high, other forms of testing should be considered.

Monitoring of public traffic should be undertaken on-site to visually confirm the activation of flashing lights/VMSs in accordance with the design specification (e.g. within specified detection distances and speed thresholds). It should be noted that systematic delays with communications equipment, though small, may be detected. For example, flashing lights/VMSs may activate after the intended point of activation due to delays in processing and communicating the detection signal. These delays should be noted and if deemed excessive, factored into the adjustment of the treatment's operation.

Testing vehicles can be used to validate the detection of vehicles. This is undertaken by repeatedly driving a vehicle past a detector and validating the detection signal. Note that this is likely required for:

- Two-phase activation of the major road speed advisory flashing lights/VMSs (i.e. where activation is made by detection of both a minor road and major road vehicle). Two vehicles are required to be driven in synchronised timing to achieve activation. Note that individual activation of the two-phases can be tested, but full activation under operational conditions (i.e. true two-phase activation) should be achieved as well to validate functionality of the entire system.
- Speed threshold activation of the minor road run-through prevention flashing lights. As activation occurs above a specified speed, the vehicle will need to achieve this speed. As the threshold speed used during operation may represent an unacceptable risk for testing, the threshold speed may be lowered for this testing phase.

Note that radar detectors previously used for RJAWS Lite can be sensitive to vehicle type. A variety of vehicles should be used to validate detection (e.g. motorcycles, light and heavy vehicles). This may be achieved either through use of contractor vehicles or public traffic.

A minimum list of on-site testing requirements is provided below. Note that the final design of the system may require forms of testing that are not listed here.

- All vehicle detection equipment (detection location and range of speeds detected).
- All vehicle detection equipment with speed thresholds (activation above speed threshold, non-activation below speed threshold).
- Flashing lights/VMSs (activation when expected)

6.2. Remote testing

Remote testing can be used to achieve a scale of testing not possible on-site. Remote testing requires remote communication with RJAWS Lite or periodic downloads of stored data if live communications are not provided. This form of testing can be undertaken in the weeks following installation of the treatment, before any evaluation surveys are undertaken. Where the treatment is run in silent mode (see Section 9), data should be capable of replicating all normal operational functions, including when activation of the flashing lights/VMSs would occur, should they be operational. Remote testing may include the following:

- Monitoring of solar charge and battery levels to determine sufficient electrical capacity. Note that retesting may need to be undertaken during winter if installation does not occur during this time of the year. If testing is performed while the treatment is run in silent mode, retesting should be undertaken once full operation of the treatment commences to take into account the electrical load of the flashing lights/VMSs.
- Monitoring of detection numbers. If detection numbers are seen to substantially change or detections cut out for a period of time, this may be indicative of a system failure.
- Monitoring of threshold speeds. This testing should also be used to fine tune the threshold speeds to achieve the desired rate of activations of the minor road run-through prevention.
- Once RJAWS Lite goes live (i.e. with displayed signage and working flashing lights/VMSs), monitoring should continue to preliminarily assess the effect of the treatment. Note this is not

in-place of a proper evaluation, but may give insight into whether the effectiveness of the system meets expectations. Where expectations are not met, further remote or on-site testing may be required to identify the cause and if deemed necessary, identify possible rectification measures.

7. Maintenance

Maintenance requirements will be dependent on the type of technology used to operate RJAWS Lite. Beyond normal maintenance requirements for road infrastructure, the following is likely to be required:

- Servicing of electronic equipment
- Realignment of detection equipment
- Replacement of batteries
- Replacement of lights
- Possible cleaning of solar arrays (i.e. in the event that dirt reduces solar output)
- Updating of firmware

A maintenance schedule should be determined and associated costs considered when designing the treatment.

Periodic checking of operations should also be undertaken to ensure RJAWS Lite is operating as expected. This can likely be undertaken remotely when remote communication with the treatment is provided.

Safe access to the equipment should be considered during the design phase. Safe access off the road should be provided for maintenance crews. Additional requirements such as the use of traffic management or infrastructure such as roadside barriers may need to be considered if safe roadside access cannot be otherwise provided. The decision of whether temporary (e.g. traffic management) or permanent (e.g. roadside barriers) solutions should be employed is dependent on economic justification. The ability to work safely at heights should also be considered, such as for maintenance of the electronic equipment and replacement of batteries.

8. Decommissioning

It is anticipated that some installations of RJAWS Lite will be used as temporary treatments before more permanent solutions can be found. It is therefore desirable that, in these situations, RJAWS Lite is designed and installed with the ease of decommissioning in mind. The following considerations should be made when designing and installing a temporary installation of RJAWS Lite.

- Infrastructure that requires minimal work to install and deinstall should be used. For example, sleeved poles can be removed quickly, with minimal infrastructure remaining at the intersection, and can be reinstalled at a future intersection with minimal additional outlay.
- Minimal use of permanent or in-ground infrastructure should be made. The use of bolt-on componentry that can be easily installed and removed should be prioritised.
- The use of equipment should be transferable. Equipment that is specifically set up for an intersection and cannot be reset for a future intersection should be avoided. For example, by using fixed-place brackets for detection equipment and solar panels that does not allow for future adjustment.
- The major road speed advisory signs should include interchangeable features, such as being able to change the type of intersection warning sign that is used. For example, replacing a Side Road Intersection sign with a Cross Road sign.
- The entire treatment should be dismantlable and relocatable using standard-sized flatbed truck(s).
- The installation should be possible using minimal construction equipment. For previous trials, installation was achieved using a crane-equipped flatbed track, a vacuum excavation truck, a platform ladder and small power tools.

It is desirable that any temporary sites be rectified to their pre-RJAWS Lite condition after the removal of the treatment, with minimal additional infrastructure remaining on site. For previous trials, the only infrastructure remaining after decommissioning of the treatment were the sleeves used to house the poles upon which the technical equipment was installed.

9. Evaluation requirements

Evaluation is an important part of developing and verifying the effectiveness of a novel road safety treatment. It is also important when implementing a treatment in a different context than that previously used, including in a jurisdiction where the treatment has previously not been widely used. Evaluation may also be used to justify the expenditure of funding on a treatment and validate its use over other treatment options.

The recommendations made in this section are based on experience from the evaluation of RJAWS (Mongiardini et al. 2021) and RJAWS Lite (Mongiardini & Stokes 2023). Two aspects are considered in the evaluation of safety benefits: travel speed and crashes.

While the evaluation of crash data does not affect the operation of RJAWS Lite, a robust evaluation of speed data requires a period of time where the system is installed but not visually functioning (referred to as “silent mode” of operation). This may result in practical implications such as bureaucratic hesitation at delaying the activation of a safety treatment and public inquiry as to why the treatment is not activated. A guide to the timeframe required for robust evaluation of speed data is shown in (Figure 9.1).

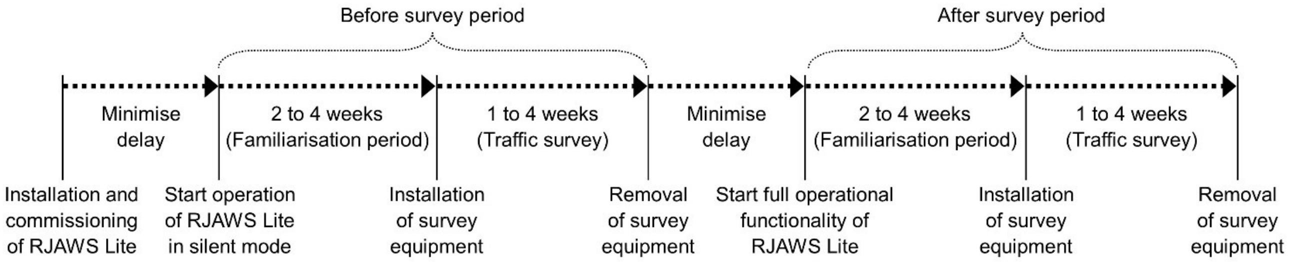

Figure 9.1
Guide to the timeframe required to undertake a robust speed evaluation for RJAWS Lite

9.1. Major road speed advisory

There are two forms of evaluation that can be used to verify the effectiveness of the major road speed advisory. In the short term, such as immediately after the installation of a treatment, the evaluation of traffic speed can be undertaken as a surrogate measure of safety improvements. Over the longer term, the evaluation of crash or injury data can be used, though depending on the rate of crashes or injuries at the treated location, this could be feasible only several years after its installation.

9.1.1. Evaluation of speed data

As the primary safety benefit of the major road speed advisory is a reduction in speed through the treated intersection, evaluating speed can be used as a surrogate measure for an improvement in safety. A controlled before-after evaluation approach has been previously used and is considered best-practice for evaluating RJAWS Lite. For this approach, speeds are evaluated and compared before and after the installation of RJAWS Lite. A similar intersection without installation of RJAWS Lite is used as a control to account for outside effects (i.e. those not related to the RJAWS Lite treatment, such as changes in weather and traffic composition). The following points should be considered when designing the evaluation method.

- The major road speed advisory only acts to reduce speed when there is potential for a crash between major and minor road vehicles. It is important that the evaluation of speed considers this operational detail. Data from the RJAWS Lite equipment can be used to equate the times when the flashing lights/VMSs are on. If this data is not available, then traffic counters (e.g. pneumatic tubes) can be used as a surrogate measure when place near the intersection on the minor road – this method may be preferred for practical reasons but will likely reduce the scientific rigor of the evaluation.
- The segregation of speed data discussed in the point above should be undertaken in both the before and after survey periods. To allow for the discrimination of flashing light/VMS on and off statuses in the before period (i.e. when the flashing lights/VMSs would be on or off, if the treatment were installed), installation of the RJAWS Lite equipment has previously been undertaken prior to commencing the before traffic surveys, with the treatment running in a silent mode during the before survey (i.e. with the RJAWS Lite-specific signage covered or removed and the flashing lights/VMSs not working).
- Because of the need to evaluate speeds separately when the flashing lights/VMSs are on or off, it is important that all devices used during the survey have precise, synchronized timing. Differences in timing, even as small as several seconds, could substantially alter the results of the evaluation.
- Speeds along the major road should be surveyed as close as practical to the point of conflict between major and minor road traffic. In previous evaluations, pneumatic tubes have been installed approximately 20 metres from the centre of the intersection. It is important that speeds be surveyed at the exact same location for both the before and after periods.
- The same speed data should be surveyed at the control intersection as at the treatment intersection. For the most rigorous evaluation, this means installing similar vehicle detection equipment at the control intersection as is used at the treatment intersection. Failing this, traffic counters can be used at the control intersection to detect when the flashing lights/VMSs would be on or off, if the treatment were installed. If this method is used, then traffic counters should also be installed at the treatment intersection to ensure similar data is being recorded.

Traffic surveys should be undertaken for a minimum of one week. Ideally, traffic surveys should be undertaken for longer in order to validate the uniformity of data from one week to the next. Any days with suspicious data that is beyond normal bounds, such as substantially increased/reduced speeds or traffic volumes, should be investigated and removed if they are deemed to be outliers. A habit of collecting more data than that required is good practice to ensure sufficient data is available in the event of a survey failure, such as the damage of pneumatic tubes or the happening of unforeseen events that substantially alter the data beyond normal bounds. It is important that surveys occur at the same time for both treatment and control sites. It is also beneficial to undertake the before and after surveys during similar conditions. This includes choosing times of the year with similar weather and avoiding periods such as school holidays and public holidays, when traffic is likely to be altered.

Traffic surveys that are planned after visible works have occurred on site should be delayed by a sufficient period to reduce the likelihood of a novelty effect (the familiarisation period). The novelty effect is when visible changes to the road or roadside, such as the installation of new signage, may alter the behaviour of drivers. This change in behaviour can be due to the novelty of the works and it is not desirable to include the effect of this behaviour in the evaluation. For previous evaluations, a familiarisation period of at least two weeks (desirably four weeks) has been undertaken. The two events that are likely to require such a period of time are after installation of the treatment (to be used in a silent mode), prior to commencement of the before surveys; and after installation/activation of the treatment prior to commencement of the after surveys. Using desirable timing, this may mean that the period from installation of the treatment to conclusion of the traffic surveys is several months. While it can be desirable to shorten this period, it can come at the cost of a less scientifically robust evaluation.

For previous evaluations, average traffic speed has been used to calculate the reduction in speed affected by the major road speed advisory. The effect has been calculated as the reduction in speed from before to after the installation of RJAWS Lite. Both the treatment-only effect and the controlled effect (i.e. subtracting the effect at the control intersection) have been presented.

9.1.2. Evaluation of crash data

To date, no crash data evaluation has been undertaken for RJAWS Lite. This is owing to the relative novelty of the treatment. Crash data evaluations should only be considered after enough time has passed to provide a robust study of the effect. This period may be several years for a location with an infrequent crash history. While it is desirable to evaluate the effect on serious injury crashes, lesser crashes may need to be considered if there are too few serious injury crashes at the treated intersection. It is also desirable to survey several treated intersections, as one intersection is unlikely to yield enough data to provide a meaningful evaluation.

Evaluation should focus on crash types that are likely to be affected by the treatment. These are likely to be intersection-related crash types. Definition for coding accident (DCA) codes are suitable for identifying appropriate crash types. The following crash types are considered most likely to be affected:

- 110-119: predicted reduction in crash numbers/crash severity. DCA 110 to 112 most likely to reduce in number due to presumably high speed of major road vehicles.
- 121: unlikely to be affected in current design guise, though may be reduced if system includes activation by right-turning major road vehicles
- 130: predicted increase in crash numbers if any change is detected, due to rear-end crashes with slowing lead vehicles
- 170-176, 180-184: potential reduction due to reduction in speed, though change relatively less likely.

It is preferable to evaluate the change in the number of crashes, rather than injuries, as the sample size is likely to be small and therefore easily skewed by the number of injuries from each crash. Evaluating the change in the number of injuries adds bias towards collisions with more participants and as such skews the results towards an evaluation of the factors that affect the number of participants in the crash, of which RJAWS Lite is unlikely to be a factor.

A controlled before-after evaluation approach is preferred for the evaluation of crash data. Control intersections can either be individually matched (i.e. each control intersection is matched to a particular treatment intersection) or unmatched. If the control intersections are matched, there will need to be an equal amount of control intersections as there are treatment intersections. If the treatment of intersections that are to be included in the evaluation occurs at substantially different time periods, then the control intersections will need to be matched in order to allow comparable time periods to be used. Unmatched control intersections should only be used if the treatment intersections are treated at the same time (e.g. all within the same calendar year) and if they are all comparable (i.e. if each control intersection can be matched with respect to its environment with each of the treatment intersections).

9.2. Minor road run-through prevention

Evaluation of the minor road run-through prevention is likely to be difficult in the short-term, owing to the relative rarity of events that are related to a run-through crash. Evaluation of speed or video data may provide reasonable short-term results. A long-term study of crash data is likely to be required to provide more robust results.

9.2.1. Evaluation of speed and video data

The objective of the minor road run-through prevention is to reduce the likelihood of run-through crashes. These crashes occur when a driver runs through the intersection at speed from the minor road. The driver may or may not have been aware of the intersection or their need to give way to other traffic before traversing the intersection – the act could be intentional or unintentional. It is more likely that the minor road run-through prevention will affect the outcomes of unintentional run-throughs, owing to there being presumably no intent to purposely run-through the control – if the driver was aware of their need to give way, they would presumably do so.

The focus of evaluation should be to determine if a reduced prevalence of run-through events is occurring. The most direct evaluation would include video surveys of the intersection to count the number of run-through events that occur over time and then compare the number of events before and after installation of RJAWS Lite. Failing this, speed can be used as a surrogate measure of run-through events. Speed near the intersection on the minor road approach can be measured and vehicles approaching above a certain threshold can be considered as at risk of running through the intersection. As this is similar to the method used to activate the minor road run-through prevention flashing lights, it is possible that activations of the flashing lights may also be used as a measure. However, the threshold speed for activating the flashing lights is likely to be conservative, with many more activations than there are actual run-throughs, meaning that this method is likely not preferable. Whichever method is utilised, considerations should be made for the follow:

- The length of traffic surveys should be sufficient for a statistically robust study. The rarity of the event being surveyed will determine the length required. A speed survey may only require one to four weeks of data (see Section 9.1.1 for further information). A longer survey time may be required if the speed threshold used to detect possible run-through events is particularly stringent. Due to the rarity of actual run-through events, video surveys may require a considerably longer period, allowing enough time to detect enough run-through events.
- As with evaluations of crash data, the rarity of run-through events means that collection of data from multiple treatment and control sites should be considered.
- If a single speed survey location is used on approach to the intersection along the minor road, then it should be placed as close as practicable to the intersection to give the greatest likelihood of discriminating between possible run-through and non-run-through events.
- Control intersections should be chosen that closely match the environmental conditions at the treatment intersections. The same data collection method should be employed at the control intersection as is used at the treatment intersection, and before and after surveys should be undertaken at the same time.

- As per Section 9.1.1, traffic surveys that are planned after visible works have occurred on site should be delayed by a sufficient period to reduce the likelihood of a novelty effect.

9.2.2. Evaluation of crash data

Evaluation of crash data should be undertaken using the same considerations as those outlined in Section 9.1.2. Evaluation should focus on crash types that are likely to be affected by the treatment. These are likely to be intersection-related crash types. Definition for coding accident (DCA) codes are best suited for identifying appropriate crash types. The following crash types are considered most likely to be affected:

- 110-119: predicted reduction in crash numbers. DCA 110, 113 and 116 most likely to reduce in number due to presumably high speed of minor road vehicle.
- 170-176, 180-184: potential reduction due to a loss of control that may be associated with run-throughs (e.g. due to spoon drains or major road cross fall), though change relatively less likely. Note these codes are likely to be denoted in cases where a single-vehicle run-through event occurs at a three-way intersection.

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Appendix A Calculating L_{min} and L_{max}

The following sections outline the procedure for calculating L_{min} and L_{max}. The worked example outlined below are for the installation of a major road speed advisory sign along the major road approach of an intersection with the following properties:

- Speed limit = 80 km/h
- Design speed (speed limit + 10 km/h) = 90 km/h
- Advisory speed = 50 km/h
- Target speed (advisory speed + 10 km/h) = 60 km/h
- Control point speed (assumed maximum speed through the minor road control) = 20 km/h
- Coefficient of deceleration (d) for major road approach = 0.2
- Coefficient of deceleration (d) for minor road approach = 0.26
- Longitudinal grade (a) = 0%
- Range of minor road radar (L_{AT}) = 160m

Calculation of L_{min} and L_{max} should be aimed towards a more conservative outcome (i.e., an outcome that encompasses a greater proportion of possible situations within the design parameters). For appendices A.1 to A.5, use of the design speed and target speed confer a more conservative result. For Appendix A.6, use of the speed limit confers a more conservative result.

A.1 Calculating L_{min}

L_{min} is the minimum distance that the major road speed advisory sign should be placed from the intersection. L_{min} is dependent on the rate of deceleration of the major road vehicle. The braking component equation adopted by Austroads (2021, 2023) and used for sight distance calculations is used here. The equation for calculating the braking distance is

$$L = \frac{V^2}{254(d + 0.01a)}$$

where L is the braking distance; V is the vehicle's initial speed (km/h); d is the coefficient of deceleration; and a is the longitudinal grade (%) (+ for upgrade, - for downgrade). As L is being calculated for between two points at which the vehicle is at a speed above zero (V_1 = design speed; V_2 = target speed), the braking component of V_2 must be deducted from the braking component of V_1, such that

$$L_{min} = \frac{V_1^2 - V_2^2}{254(d + 0.01a)}$$

For this example, the following values are assumed: V_1 = 90 km/h; V_2 = 60 km/h; d = 0.2; and a = 0%.

$$L_{min} = \frac{90^2 - 60^2}{254(0.2 + 0.01 \times 0)} = 88.6m$$

A.2 Calculating $L_{AT\text{-}A}$ and $L_{AT\text{-}B}$

L_{AT} will generally be determined by the range of the minor road radar. L_{AT} comprises two components: an approach phase ($L_{AT\text{-}A}$) and a braking phase ($L_{AT\text{-}B}$). $L_{AT\text{-}B}$ is the critical phase and can be calculated using the same equation as used for L_{min} (see Appendix A.1), such that

$$L_{AT\text{-}B} = \frac{V_1^2 - V_2^2}{254 \times (d + 0.01a)}$$

where L is the braking distance; V_1 is the design speed (km/h); V_2 is the control point speed; d is the coefficient of deceleration; and a is the longitudinal grade (%).

For this example, the following values are assumed: V_1 = 90 km/h; V_2 = 20 km/h; d = 0.26; and a = 0%.

$$L_{AT\text{-}B} = \frac{90^2 - 20^2}{254 \times (0.26 + 0.01 \times 0)} = 116.6m$$

And hence, assuming a radar range (L_{AT}) of 160 m

$$L_{AT\text{-}A} = L_{AT} - L_{AT\text{-}B} = 160.0 - 116.6 = 43.4m$$

A.3 Calculating *AT*

AT is the sum of *AT-A* and *AT-B*, the respective time periods required to traverse $L_{AT\text{-}A}$ and $L_{AT\text{-}B}$. *AT-A* can be calculated using the following equation, with the assumption that the vehicle's speed while traversing $L_{AT\text{-}A}$ is constant

$$AT\text{-}A = \frac{3.6 \times L_{AT\text{-}A}}{V}$$

where *AT-A* is the time period required to traverse $L_{AT\text{-}A}$; $L_{AT\text{-}A}$ is the distance travelled before the initial point of braking; and V is the design speed (the speed of the vehicle over the distance $L_{AT\text{-}A}$), which is assumed to be constant.

For this example, the following values are assumed: $L_{AT\text{-}A}$ = 43.4m (from Appendix A.2); and V = 90 km/h.

$$AT\text{-}A = \frac{3.6 \times 43.4}{90} = 1.74s$$

The following equation can be used to calculate *AT-T*, with the assumption that the vehicle's rate of deceleration remains constant between the initial point of braking and the intersection

$$AT\text{-}B = \frac{7.2 \times L_{AT\text{-}B}}{(V_1 + V_2)}$$

where *AT-B* is the time taken to travel from the initial point of braking to the intersection (s); $L_{AT\text{-}B}$ is the distance traversed between the initial point of braking and the intersection (the braking distance) (m); V_1 is the design speed (km/h); and V_2 is the control point speed (km/h).

For this example, the following values are assumed: $L_{AT\text{-}B}$ = 116.6m; V_1 = 90 km/h; and V_2 = 20 km/h.

$$AT\text{-}B = \frac{7.2 \times 116.6}{(90 + 20)} = 7.63s$$

AT is equal to the sum of *AT-A* and *AT-B*. For this example, *AT* = 7.63 + 1.74 = 9.37 s.

A.4 Calculating L_{DT}

L_{DT} is calculated assuming the vehicle's speed remains constant. The following equation can be used to calculate L_{DT}

$$L_{DT} = \frac{DT \times V}{3.6}$$

where L_{DT} is the distance travelled during the time *DT*; *DT* = observation time + reaction time (s); and *V* is the speed of the vehicle (km/h).

For this example, the following values are assumed: *DT* = 2 s + 2 s = 4 s; and *V* = 90 km/h.

$$L_{DT} = \frac{4 \times 90}{3.6} = 100m$$

For this example and as used for previous trials, an observation time of 2 s is used. Austroads (Austroads 2023) suggests using an observation time of 3 s. Assuming a reaction time of 2 s is used (Austroads 2021), this would lead to a decision time (*DT*) of five seconds. However, such a decision time can result in the major road speed advisory sign being placed infeasibly close to the intersection for many situations. A minimum decision time of five seconds may also be too far for the vehicle detection technology, if a battery-saving system is used.

A.5 Calculating *RT*

RT can be calculated using the following equation

$$RT = AT - DT$$

where *RT* is the time taken for the major road vehicle to arrive at the intersection after passing the major road speed advisory sign (s); *AT* is the time taken for the minor road vehicle to arrive at the intersection after detection by the minor road radar (s) (see Appendix A.3); and *DT* is the decision time (s) (see Appendix A.4). For this example, *RT* is calculated to be 9.37 – 4.0 = 5.37 s

A.6 Calculating L_{max}

The following equation can be used to calculate L_{max}, with the assumption that the vehicle's rate of deceleration remains constant between the initial point of deceleration and the intersection

$$L_{max} = \frac{RT \times (V_1 + V_2)}{7.2}$$

where *RT* is the time taken for the major road vehicle to arrive at the intersection after passing the major road speed advisory sign (s); V_1 is the speed limit (km/h); and V_2 is the target speed as the vehicle traverses the intersection (km/h).

For this example, the following values are assumed: *RT* = 5.37s; V_1 = 80 km/h; and V_2 = 60 km/h.

$$L_{max} = \frac{5.37 \times (80 + 60)}{7.2} = 104.4m$$

Once L_{max} is calculated, it is advisable to calculated the coefficient of deceleration to ensure it is within tolerable limits. This can be done using the following equation

$$d = \frac{V_1^2 - V_2^2}{254 \times L_{max}} - 0.01a$$

where d is the coefficient of deceleration; V_1 is the speed limit (km/h); V_2 is the target speed as the vehicle traverses the intersection (km/h); L_{max} is the distance between the major road speed advisory sign (m); and a is the longitudinal grade (%).

For this example, the following values are assumed: V_1 = 80 km/h; V_2 = 60 km/h; L_{max} = 88.8m; and a = 0%.

$$d = \frac{80^2 - 60^2}{254 \times 104.4} - 0.01 \times 0 = 0.11$$

A.7 Selecting a value for *L*

Once L_{min} (see Appendix A.1) and L_{max} (see Appendix A.6) have been calculated, the distance of the major road speed advisory sign from the intersection (L) can be selected. For the example given here, L can be selected between a value of 88.6m (L_{min}) and 104.4m (L_{max}).

If the value of L_{min} exceeds that of L_{max}, it is likely that the range of the minor road radar (L_{AT}) is too short to allow for coordination of the minor and major road vehicles. In this case, there are two probable solutions: (1) to increase the range of the minor road radar; or (2) decrease the length of L_{min} by increasing the coefficient of deceleration (d) used to calculate its value. The latter solution may not be preferential as it will reduce the distance in which vehicles have to slow down, which may increase the risk of rear-end collisions with following vehicles.

Appendix B Example design drawings

Example design drawings are shown on the following pages. These design drawings are intended to serve as an example but are not reflective of the exact layout or information required.

RJAWS Lite installation — Olivers Rd/Field St and Chalk Hill Rd, McLaren Vale

All locations and distances are approximate. Locations and distances shall be determined on site before commencement of any works.

All dates are approximate. Dates shall be confirmed before commencement of any works.

All drawings shall be read in conjunction with the notes provided on this and subsequent pages.

Item	Description	Action	Responsibility
1	Major Road Activated System “wig wag” flashing light activation	When the Minor Road Radar (Items 9 and 10, page 2) detects a vehicle on the minor road at the detection location (Items 16 and 17, pages 4 and 5, respectively), the “wig wag” flashing lights (Items 4 and 7, page 2) are activated (illuminated) for a period of 30 seconds. ~~When the southbound Major Road Radar (Item 4, page 2) detects a vehicle on the major road at the detection location (Item 14, page 3) travelling at a speed equal to or less than 60 km/h, the northbound “wig wag” flashing lights (Item 7, page 2) are activated (illuminated) for a period of 15 seconds.~~ ~~When the northbound Major Road Radar (Item 7, page 2) detects a vehicle on the major road at the detection location (Item 15, page 3) travelling at a speed equal to or less than 60 km/h, the southbound “wig wag” flashing lights (Item 4, page 2) are activated (illuminated) for a period of 15 seconds.~~ When the “wig wag” flashing lights are already active and another detection event activates the flashing lights, the flashing lights will remain active for a further 30 seconds from the time of the subsequent activation.	Sage
2	Minor Road Activated System R1-1 flashing light activation	When the minor road radar (Items 9 and 10, page 2) detects a vehicle on the minor road at the detection location (Items 16, 16a-f, page 4 and 17, 17a-f, page 5) at a speed above the relevant trigger speed, the R1-1 flashing lights (Items 9 and 10, page 2) are activated (illuminated) for a period of 5 seconds. When the R1-1 flashing lights are already active and another detection event activates the flashing lights, the flashing lights will remain active for a further 5 seconds from the time of the subsequent activation.	Sage
3	Data logging	Speed data from all radar units and activation timing data for all flashing lights shall be logged for later use.	Sage

Olivers and Chalk Hill Rd (Rev D)		Not to scale
21/12/2022	C. Stokes	Page 1 of 6

Item	Description	Action	Responsibility
4	Major Road Activated System (see Item 15, page 6)	All signage/flashing lights to be covered with opaque protective covering until before traffic surveys are completed.	Sage
5	Directional/tourist sign	Existing at site. To be relocated as per direction from Onkaparinga.	Onkaparinga
6	Tourist sign	Existing at site. To be relocated as per direction from Onkaparinga.	Onkaparinga
7	Major Road Activated System (see Item 15, page 6)	All signage/flashing lights to be covered with opaque protective covering until before traffic surveys are completed. Note restricted height allowance under power lines. Note proximity of Stobie pole—all infrastructure to be placed beyond minimum clearance distance.	Sage
8	Directional/tourist sign	Existing at site. To be relocated as per direction from Onkaparinga.	Onkaparinga
9	Minor Road Activated System (see Item 16, page 6)	To be installed with R1-1 (stop) sign and replaced with flashing stop sign once before traffic surveys are completed. Note duplicate static stop sign to remain as is.	Sage
10	Minor Road Activated System (see Item 16, page 6)	To be installed with R1-1 (stop) sign and replaced with flashing stop sign once before traffic surveys are completed. Note duplicate static stop sign to remain as is. Note pole may need to be placed further from kerb than current pole location—exact location to be agreed upon on site before works commence.	Sage
11	W2-1 (cross road ahead) sign	Existing at site. To be removed when Major Road Activated System sign (Item 7, page 2) is uncovered.	Onkaparinga
12	Duplicate W2-1 (cross road ahead) sign	Existing at site. To be relocated parallel to Major Road Activated System (Item 7, page 2).	Onkaparinga
13	Tourist sign with caravan symbol	Existing at site. To be relocated approx. 1m to left.	Onkaparinga

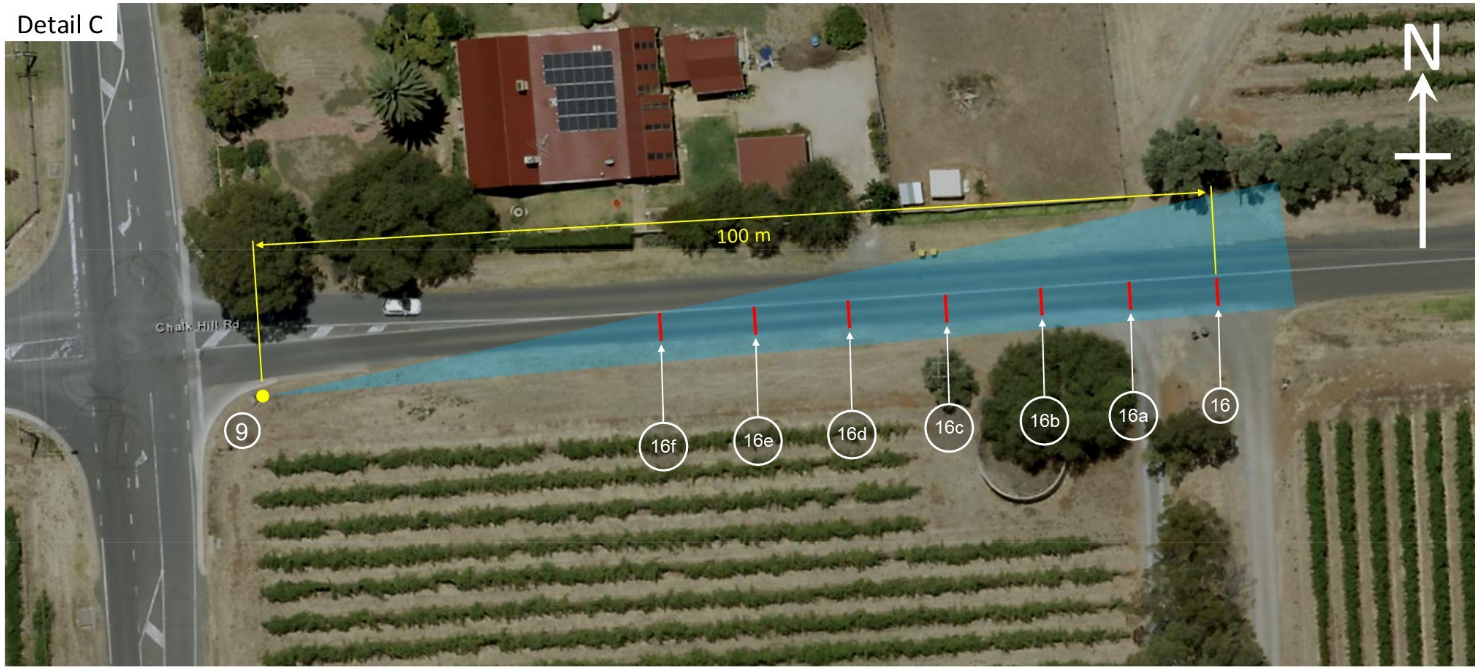
Olivers and Chalk Hill Rd (Rev D)		Not to scale
21/12/2022	C. Stokes	Page 2 of 6

Detail A

Detail B

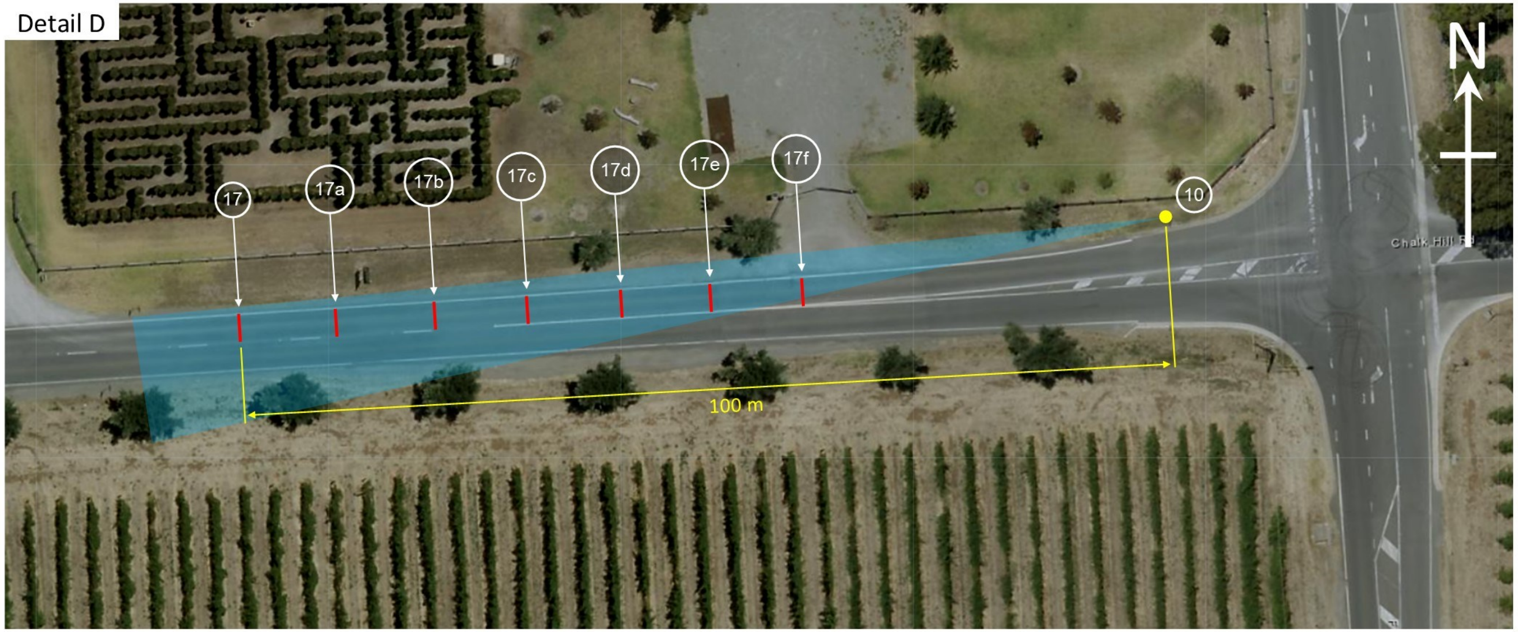
Item	Description	Action	Responsibility
14	Radar trigger location for Major Road Activated System	Radar to be aimed such that Major Road Activated System flashing lights are activated if vehicle detected travelling at or below 60 km/h at 38m upstream of intersection centreline.	Sage
15	Radar trigger location for Major Road Activated System	Radar to be aimed such that Major Road Activated System lights are activated if vehicle detected travelling at or below 60 km/h at 38m upstream of intersection centreline.	Sage

Olivers and Chalk Hill Rd (Rev D)		Not to scale
09/09/2022	C. Stokes	Page 3 of 6



Item	Description	Action	Responsibility
16	Radar target location for Major/Minor Road Activated System	Major Road Activated System flashing lights (Items 4 and 7, page 2) are triggered when vehicle is 100m upstream of radar unit. Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 100m upstream of radar unit, travelling at or above 76 km/h.	Sage
16a	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 90m upstream of radar unit, travelling at or above 73 km/h.	Sage
16b	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 80m upstream of radar unit, travelling at or above 70 km/h.	Sage
16c	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 70m upstream of radar unit, travelling at or above 66 km/h.	Sage
16d	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 60m upstream of radar unit, travelling at or above 63 km/h.	Sage
16e	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 50m upstream of radar unit, travelling at or above 59 km/h.	Sage
16f	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 9, page 3) are triggered when vehicle is 40m upstream of radar unit, travelling at or above 54 km/h.	Sage

Olivers and Chalk Hill Rd (Rev C)		Not to scale
09/09/2022	C. Stokes	Page 4 of 6



Item	Description	Action	Responsibility
17	Radar target location for Major/Minor Road Activated System	Major Road Activated System flashing lights (Items 4 and 7, page 2) are triggered when vehicle is 100m upstream of radar unit. Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 100m upstream of radar unit, travelling at or above 80 km/h.	Sage
17a	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 90m upstream of radar unit, travelling at or above 80 km/h.	Sage
17b	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 80m upstream of radar unit, travelling at or above 80 km/h.	Sage
17c	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 70m upstream of radar unit, travelling at or above 80 km/h.	Sage
17d	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 60m upstream of radar unit, travelling at or above 77 km/h.	Sage
17e	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 50m upstream of radar unit, travelling at or above 72 km/h.	Sage
17f	Radar target location for Minor Road Activated System	Minor Road Activated System flashing lights (Item 10, page 3) are triggered when vehicle is 40m upstream of radar unit, travelling at or above 67 km/h.	Sage

Olivers and Chalk Hill Rd (Rev C)		Not to scale
09/09/2022	C. Stokes	Page 5 of 6

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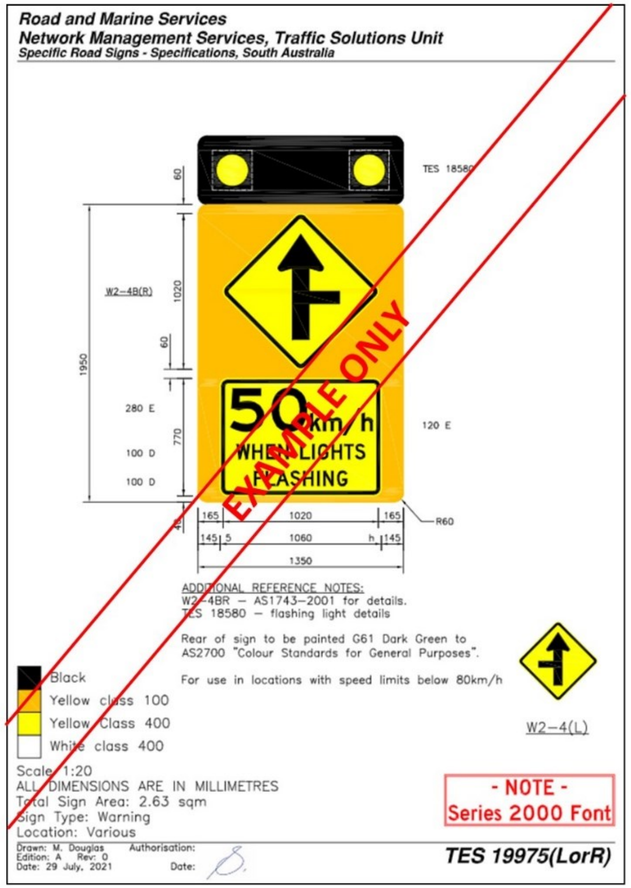

ADDITIONAL REFERENCE NOTES:
W2–4BR – AS1743–2001 for details.
TES 18580 – flashing light details

Rear of sign to be painted G61 Dark Green to AS2700 "Colour Standards for General Purposes".

For use in locations with speed limits below 80km/h

Scale 1:20
ALL DIMENSIONS ARE IN MILLIMETRES
Total Sign Area: 2.63 sqm
Sign Type: Warning
Location: Various

Drawn: M. Douglas
Edition: A Rev: 0
Date: 29 July, 2021
Authorisation:
Date:

Item	Description	Action
18	Example of Major Road Activated System with TES19975(R) sign mounted to pole.	Note signage will require W2-1 warning sign in place of W2-4(R) sign shown here. Note: Approx. 500mm distance between pole centres required for clearance of wig-wag light flashing units.
19	Example of Minor Road Activated Sign with R1-1 (stop) sign mounted to pole.	For noting.
20	Design drawing for TES19975 sign.	For noting.

Olivers and Chalk Hill Rd (Rev E)		Not to scale
09/09/2022	C. Stokes	Page 6 of 6

NOTE: Below image was not included in the original design drawings. For example only to show VMS option.

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Item	Description	Action
17	Example of Major Road Activated System with VMS option.	
18	Example of Minor Road Activated Sign with R1-1 (stop) sign mounted to pole.	For noting.

Olivers and Chalk Hill Rd (Rev D)		Not to scale
17/07/2024	C. Stokes	Page 6 of 6