OFFICIAL

Traffic Signal Standard

TS001

Signal Timings

Government of South Australia
Department for Infrastructure and Transport

Signal Timings - TS001

AMENDMENT RECORD

Version	*Page(s)*	*Date*	*Amendment Description*	*Init*
1.0	All	31/08/2021		EC
1.1	All	07/12/2021	Clarification of pedestrian crossing definitions and calculations. Clarification of speed limit definitions. Specified rounding for calculations.	EC
1.2	13	26/07/2022	Edit Section 6.2 to align with microwave sensor policy.	PCH
1.3	8	28/04/2023	Edit minimum green time requirement for stretch phase.	PCH

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1. Introduction

All road agencies across Australia are working towards greater consistency between States and Territories in road network management. To achieve this, the Austroads Guide to Traffic Management and Australian Standards relating to traffic management have been adopted to support consistency and harmonisation across jurisdictions and hence serve as the primary technical references.

This document specifies the methodology and provides additional guidance for determining phase interval periods including yellow times, red times and minimum green times for traffic signals on South Australian roads as illustrated by Figure 1 which shows the various periods within a phase interval.

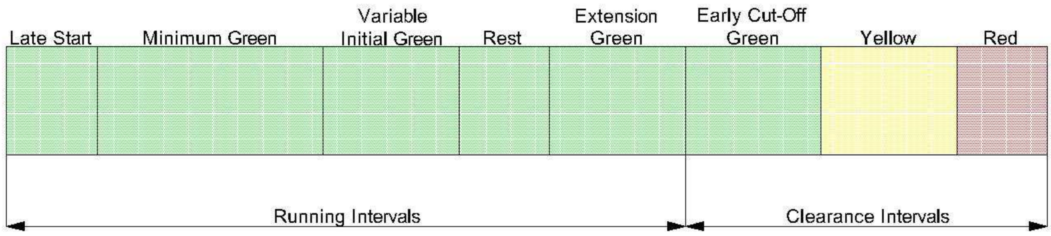

Figure 1: Phase interval diagram.

In addition to vehicle signal intervals, guidance is provided for determining pedestrian crossing times. This guide shall be read in conjunction with the *Austroads Guide to Traffic Management (AGTM) Part 9: Transport Control Systems – Strategies and Operations* and the *National Heavy Vehicle Regulator's (NHVR) performance-Based Standards (PBS) Scheme – Network Classification Guidelines*. The values derived from this process shall be used in conjunction with the *yellow-red spreadsheet* for the purpose of signal operation and programming.

2. Definitions

Vehicle Acceleration	a_v	The acceleration rate of a vehicle.
Clearance 1 Time	t_{c1}	The length of time when the pedestrian signal flashes the red 'do not walk' signal.
Clearance 2 Time	t_{c2}	The length of time when the pedestrian signal displays a steady red 'do not walk' signal (after flashing the red 'do not walk' signal).
Critical Clearance Distance	L_{cd}	The longest clearance distance of all movements within the active phase.
Posted Speed Limit	v_d	The sign posted speed limit for the road.
Minimum Intergreen Time	I_{min}	The shortest intergreen time (sum of red and yellow times) of the phases in which a pedestrian movement is active.

Minimum Green Time	t_{mg}	The minimum green time required for a vehicle to clear the intersection conflict points from a resting position at the stop line.
Late Start Time	t_{LS}	The length of time applied to a controlled movement for a late start of the green interval.
Length of Vehicle	L_v	The maximum length of the design vehicle class.
Minimum Green Time Clearance Distance	L_{mg}	The clearance distance used for calculating the minimum green time of a phase.
Pedestrian All Red Time	t_{wr}	Although, similar to t_{c2} in displaying a steady red 'do not walk signal', the pedestrian 'all red' time ensures any filtering vehicles clear the intersection and do not conflict with pedestrian movements before the onset of the next phase.
Pedestrian Crossing Distance	L_c	The total pedestrian crossing distance required in one movement measured from the kerb edge to kerb edge along the centre of the marked pedestrian crossing zone.
Pedestrian Walk Time	t_w	The length of time when the pedestrian signal displays a green 'walk' signal.
Pedestrian Walking Speed	v_w	The walking speed of pedestrians.
Minimum Green Clearance Time	t_{cd}	Time required to clear the minimum green time clearance distance.
Total Pedestrian Clearance Time	t_{pc}	The total time required for a pedestrian travel across a pedestrian crossing.

3. Yellow Time

The primary technical reference for this section is AGTM Part 9 Appendix G.4.6. The purpose of the yellow interval is to provide sufficient warning of the termination of the phase which is best considered through the concept of 'dilemma zone'.

3.1 'Dilemma Zone'

The 'dilemma zone' is defined as being the range of distances from the stop line where at the onset of the yellow interval, drivers may face the predicament of being too close to the stop line to stop safely but also too far from the intersection to safely clear the conflict area. The 'dilemma zone' concept is illustrated in Figure 2 where vehicles within the green zone have passed the 'dilemma zone' and thus would be able to pass through the intersection within the yellow interval, vehicles within the red zone have not arrived at the 'dilemma zone' and would be able to decelerate to a stop before the onset of the red signal and the purple 'dilemma zone' where at the start of the yellow interval, drivers may not be able to stop at the stop line before the red signal nor clear the conflict points of the intersection within the red interval.

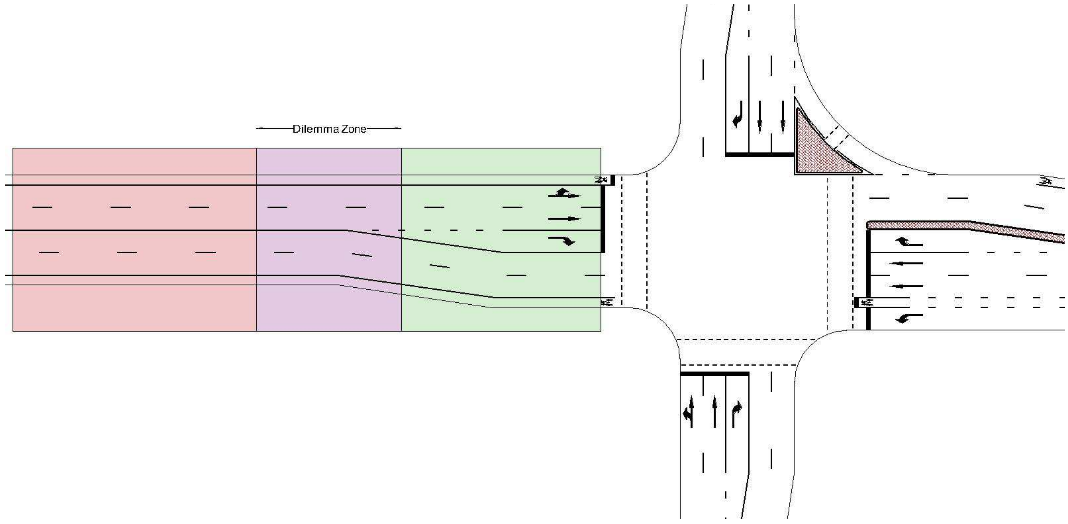

Figure 2: 'Dilemma zone' concept.

The size of the 'dilemma zone' and its location relative to the stop line is affected by several factors including vehicle travel speeds, vehicle specifications (e.g. braking capability and vehicle length) and driver reaction times. The impact of each factor on the 'dilemma zone' is different. For instance, higher speed environments have 'dilemma zones' further from the stop line than for lower speeds while longer driver reaction times increases the size of the 'dilemma zone'.

The design objective for the yellow interval length is to ensure that drivers travelling at the speed limit are not caught in the 'dilemma zone' and that at the onset of the yellow signal, all drivers can make a safe decision as to proceeding through the intersection on the yellow signal or stopping at the stop line.

3.2 Calculation of Yellow Time

The duration of the yellow interval shall be determined using Table 1. The yellow time values are based on the values of AGTM Part 9 Table G2 but are adjusted for use in South Australia. The table also includes yellow times for higher posted speed limits.

Table 1: Yellow time values

Posted Speed Limit	Yellow Time
40 km/h	3.0s
50 km/h	4.0s
60 km/h	4.0s
70 km/h	4.5s
80 km/h	5.0s
90 km/h	5.5s
100 km/h	6.0s
110 km/h	6.5s

4. Red Time

The purpose of the red interval is to provide safe clearance for vehicles that cross the stop line at the end of the yellow interval and thus is based on the critical clearance distance and the vehicle speed. The primary technical reference for this section is AGTM Part 9 Appendix G.4.6.

4.1 Clearance Distance

The clearance distance is defined as the distance between the stop line for a particular movement and the last conflict point of that movement with any conflicting movements, including vehicles, cyclists and pedestrians, of any subsequent phase within the cycle. The example signalised intersection and corresponding diamond phasing operation in Figures 3 and 4 will be used to demonstrate the process of determining clearance distances for various movements.

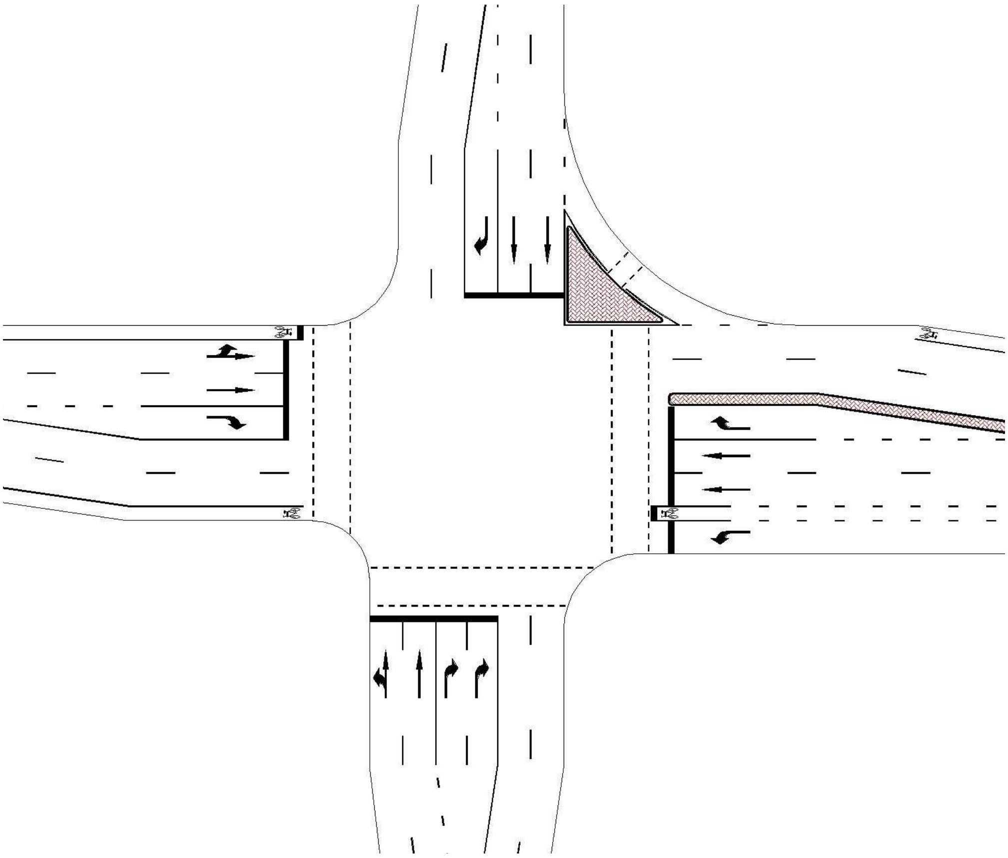

Figure 3: Example signalised intersection layout.

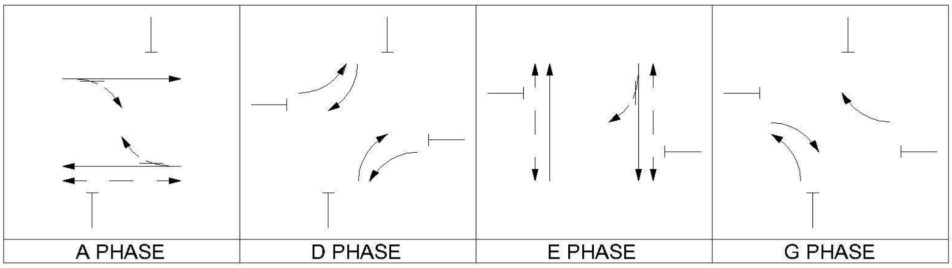

Figure 4: Phasing sequence diagram.

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The green lines in Figures 5 and 6 illustrate the idealised travel path of movements within the ‘active’ phase and the blue lines illustrate the idealised travel paths of movements in the subsequent phase. The dashed lines indicate filter turn movements and the purple dots represent the last conflict points for active movements.

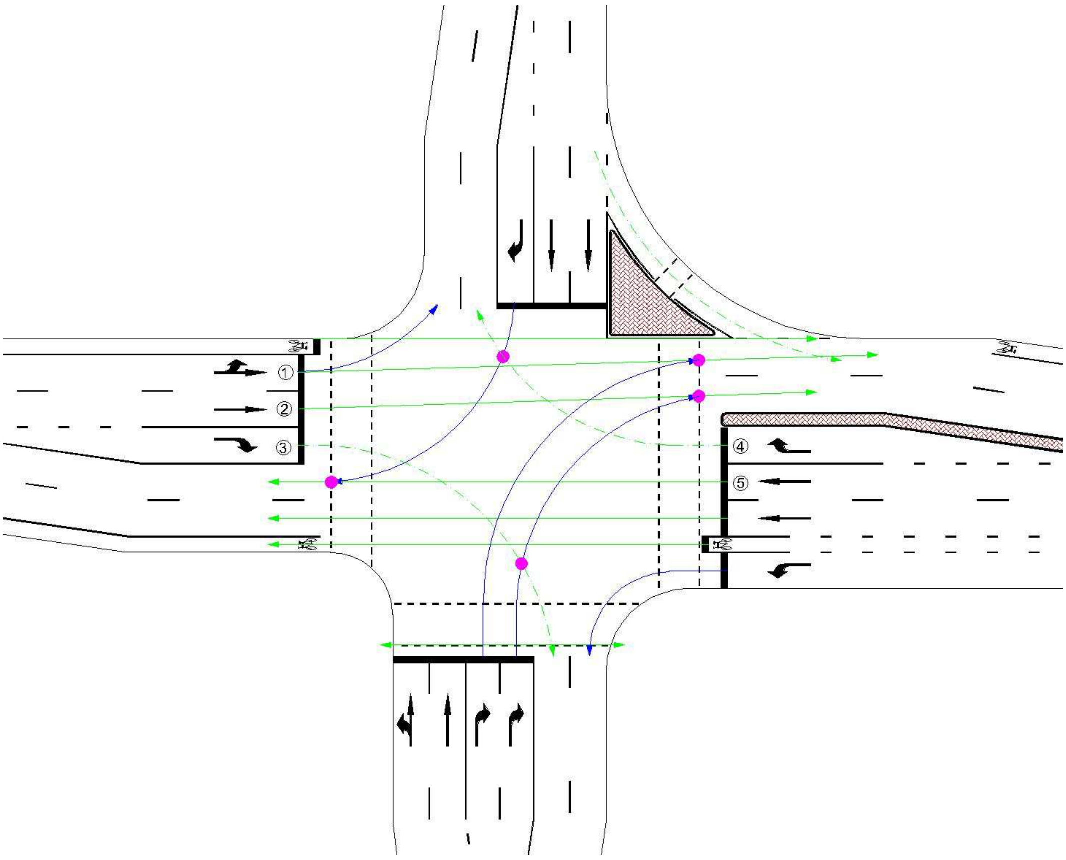

Figure 5: Example intersection with active A phase and subsequent D phase.

The clearance distance is measured from the last point of potential conflict to the stop line for that active movement. The longest clearance distance of all movements for the active phase represents the Critical Clearance Distance which should be used in determining the red time for that phase. Table 2 summarises the clearance distances for each A phase movement in Figure 5.

Table 2: Example intersection A phase movement clearance distances.

Movement	Clearance Distance
1	41m
2	41m
3	28m
4	24m
5	40m

In this example, the longest clearance distance measured is 41m and this is the critical clearance distance to be used in determining the red time for A phase.

For D phase, the last point of conflict for the right turn movements 2 and 4 in Figure 6 are with the pedestrian crossing points which activate in the subsequent E phase. Given that the critical clearance distance is based on the longest clearance distance, the conservative approach is to use the far edge of the pedestrian crossing zone. Section 4.1.2 outlines the methodology for addressing potential conflicts with left turn slip lanes.

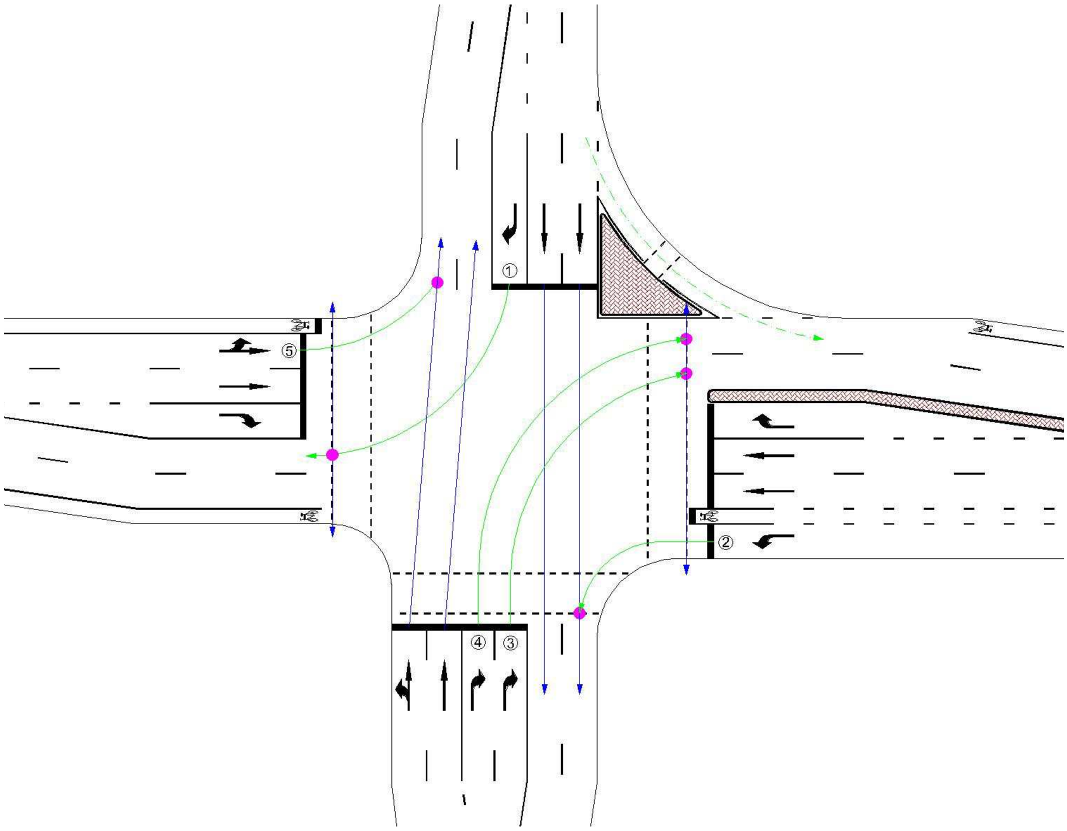

Figure 6: Example intersection with active D phase and subsequent E phase.

4.1.1 Variable Phasing

Phase sequences may not necessarily be fixed in the same sequence for each cycle as has been shown in the example in section 4.1. Due to possible programmed phase skipping and irregular or low demand movements resulting in phases not running, the critical clearance distance may vary depending on which phase is the subsequent phase. As such the process shown in section 4.1 should be undertaken considering each active phase and each potential subsequent phase given that red time is fixed for each phase. The longest critical clearance distance should then be used to determine the appropriate red time.

4.1.2 Left Turn Slip Lanes

The example in section 4.1 outlined the general methodology for determining clearance distances used for calculating the red-time excluded the left turn slip lane. This is due to the fact that uncontrolled left turn slip lanes are not considered to be part of the signal operation and thus are not considered in the critical clearance distance calculation process.

Controlled left turn slip lanes, either introduced through the use of a 'turn left with care' signal or designated green signal, are also not considered as part of the critical clearance distance calculation process. The former being considered similarly as an uncontrolled left turn slip lane and the latter as follows. Where left turn slip lanes are controlled and introduced by a designated green signal, a late start, t_{LS}, is used to introduce the green left turn signal. At most sites, 2 seconds is selected for the late start time but this may be varied should a longer time be required to ensure the opposing vehicle clears the conflict point with the left turn slip lane. Figure 7 illustrates the application of the late start in allowing right turn vehicles to clear the conflict point with the controlled left turn slip lane.

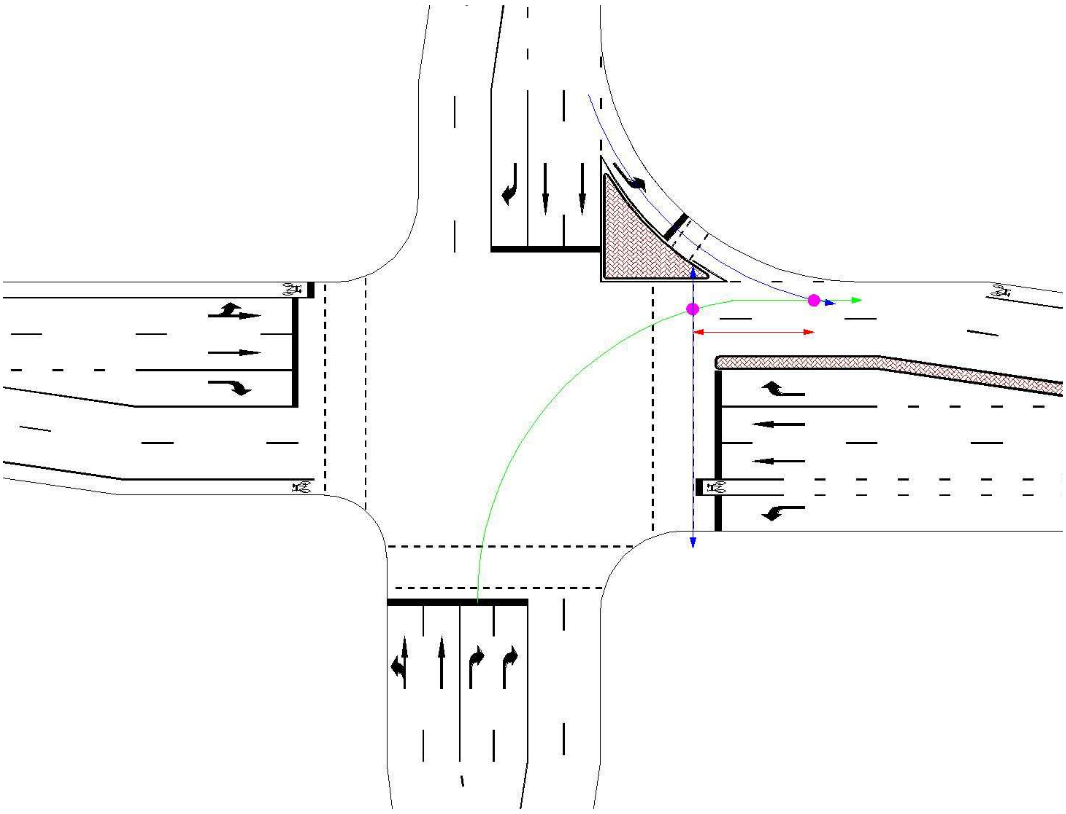

Figure 7: Example controlled left turn slip lane late start calculation.

4.2 Calculation of Red Times

The duration of the red interval shall be determined using Tables 3-4 and are dependent on the critical clearance distance and vehicle speed. Similar to the calculation for the yellow time, the vehicle speed to be used in calculating the red time should be the posted speed limit, v_d, and the same speed is used for all movements from that approach. For example, where a local road (with a posted speed of 50 km/h) intersects an arterial (with a posted speed of 60 km/h), the v_d for all movements from the local road would be 50 km/h and v_d for all movements from the arterial would be 60 km/h. The red time values are derived from AGTM Part 9 Appendix G.4.6 Equation A3 but are adjusted for use in South Australia and thus, in some cases, are longer.

Table 3: Red time values for posted speed limits less than 80 km/h.

Critical Clearance Distance	Red Time
< 14m	1.0s
14 – <21m	1.5s
21 – <28m	2.0s
28 – <35m	2.5s
35 – <42m	3.0s
42 – <49m	3.5s
49 – <56m	4.0s
56 – <63m	4.5s
63 – <70m	5.0s
70 – <77m	5.5s
77 – <84m	6.0s
84 – <94m	6.5s

Signals are **not recommended** in areas where the posted speed limit is greater than 80km/h due to the longer stopping distance requirements of vehicles, especially heavy vehicles, and the longer sight line requirement for drivers to observe the presence of traffic control devices.

Table 4: Red time values for posted speed limits of 80 km/h to 100 km/h.

Critical Clearance Distance	Red Time
< 21m	1.0s
21 – <32m	1.5s
32 – <42m	2.0s
42 – <53m	2.5s
53 – <63m	3.0s
63 – <74m	3.5s
74 – <84m	4.0s
84 – <94m	4.5s

Where the clearance distance is longer than 84m a split intersection should be considered as there are operational issues related to total intergreen times of 10 seconds or greater.

5. Minimum Green Time

The purpose of the minimum green time is to ensure that the green signal is displayed for a safe minimum length of time due to the fact that green intervals which are unexpectedly short may result in erratic behaviour and rear-end collisions. The primary technical reference for this section is *AGTM Part 9 Appendix G.4.2* and section 2.5 of the *NHVR's PBS Scheme – Network Classification Guidelines*.

In South Australia, minimum green times are implemented in three different ways. Firstly, a basic minimum green time of 5 seconds is used for general purpose intersections which is based on the Austroads recommendations but adjusted for use in South Australia. The basic minimum green time for the stretch phase is 10 seconds. The other two methods for implementing minimum green times use a calculated minimum green time for locations where heavy vehicle movement considerations are required. For roads designated as National Highway the minimum green time is always set to be the time determined following the process outlined in 5.1 and 5.2. For roads that are not national highways but are classified freight routes or have relatively high freight volumes, for example a heavy vehicle proportion of 5% or greater, the minimum green time is set to the basic minimum green time but, using detector logic (which is based on the length of time the detector is occupied by a vehicle), can be extended to the minimum green time determined following the process in 5.1 and 5.2.

5.1 Vehicle Performance Level

The minimum green time is predominantly affected by the clearance distance (or intersection geometry), acceleration capability of the design vehicle and the length of the design vehicle. To simplify the calculation process, rather than calculating from first principles and determining specific vehicle performance, the design vehicle capability is determined based on its classification within the NHVR's performance-based standards vehicle performance levels. This classification system is based solely on the vehicle length as per the NHVR guidelines from which Table 5 is extracted (L_v representing the vehicle length in metres). In general, level 1 vehicle performance should be used for articulated bus and semi-trailer design vehicles whilst level 2B should be used for national highways and major freight routes which are rated for B-double access.

Table 5: Vehicle performance level classifications.

Vehicle Performance Level	Access Class 'A'	Access Class 'B'
Level 1	$L_v \leq 20m$	
Level 2	$L_v \leq 26m$	$26m < L_v \leq 30m$
Level 3	$L_v \leq 36m$	$36.5m < L_v \leq 42m$
Level 4	$L_v \leq 53.5m$	$53.5 < L_v \leq 60m$

5.2 Calculation of Minimum Green Time

The calculation of minimum green time is based on the time required by the design vehicle, waiting at the stop line, to cross the stop line at the onset of the green interval and clear the intersection conflict points by the end of the intergreen period of the phase. Due to the fact that heavy vehicles are longer than light vehicles, it is necessary to ensure that the entire vehicle is able to clear the last conflict point for the movement. As such, the clearance distance in this calculation is the sum of the critical clearance distance, L_{cd}, and the length of the vehicle, L_v, as shown in Equation 1

$$L_{mg} = L_v + L_{cd} \qquad (1)$$

It should be noted that Lv should be assumed to be the maximum length of vehicles within the selected design vehicle class rather than for a specific design vehicle. For example, should the specific design vehicle be an 18.5m articulated bus, which would classify as a Level 1 performance vehicle, 20m, being the maximum for this vehicle performance class, should be used in the calculation as Lv. An example is illustrated in Figure 8 where a 20m semi-trailer (level 1 performance) is selected as the design vehicle.

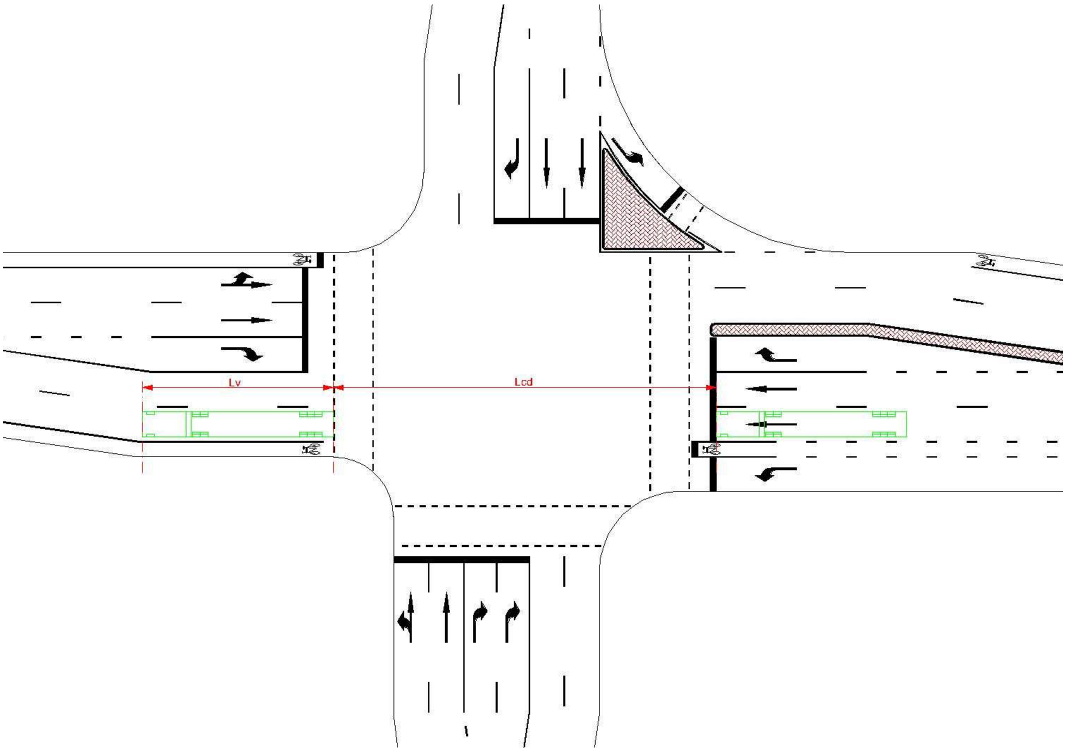

Figure 8: Clearance distance for minimum green time calculation.

The minimum green time is a function of both the distance L_{mg} and the acceleration capability of the vehicle as defined by the rearrangement of the relationship between displacement with time, velocity and acceleration as shown in Equation 2.

$$s = ut + \tfrac{1}{2} a_v t^2 \qquad (2)$$

Since the initial velocity in this calculation is 0, given that the vehicle is assumed to be resting at the stop line, the relationship between time, t_{cd} (to clear the distance L_{mg}), and displacement ($s = L_{mg}$) is simplified as shown in Equation 3.

$$t_{cd} = \sqrt{(2L_{mg} / a_v)} \qquad (3)$$

The acceleration of the design vehicle should be assumed to be equal to that of the minimum required of the vehicle class under the NHVR Performance Based Standards Scheme. Table 6 shows the vehicle classes and the minimum acceleration capability values.

Table 6: Vehicle class minimum acceleration capabilities.

Performance Based Standards Road Class	Time to Travel 100m from Free Rest (secs)	Acceleration (m/s^2)
1	20	0.500
2	23	0.378
3	26	0.296
4	29	0.238

Once the time to clear the distance L_{mg}, t_{cd}, is determined, the minimum green time t_{mg} is simply determined by the difference between the t_{cd} and the intergreen for the phase as shown in Equation 4.

$$t_{mg} = t_{cd} - I \qquad (4)$$

It should be noted that for this calculation, the minimum green time value should be rounded to the nearest second.

6. Pedestrian Clearance

The purpose of the pedestrian clearance time is to provide sufficient time for pedestrians to cross the road. The pedestrian crossing time is made up of five elements; the initial interval delay, the pedestrian 'walk time', the 'clearance 1' time, the 'clearance 2' time and the 'all red' clearance time as illustrated in Figure 9.

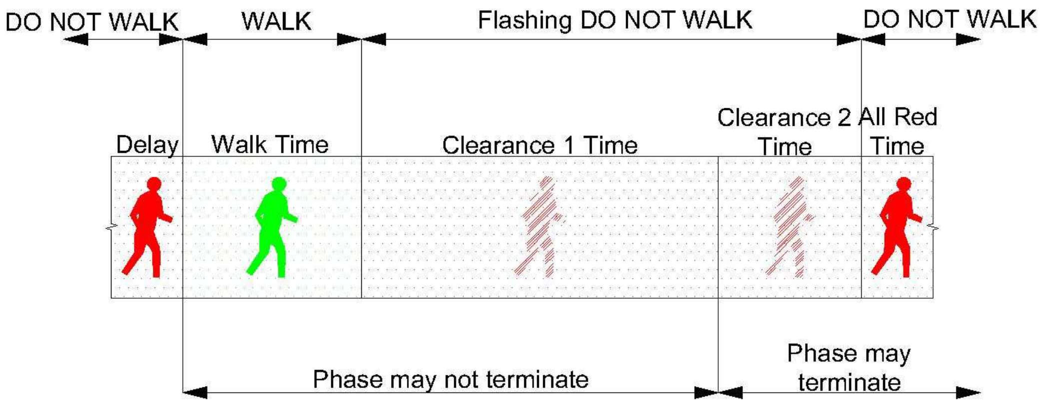

Figure 9: Pedestrian crossing phase interval.

The main use of the pedestrian delay period is to delay the registration of pedestrian demand and is not significant for the purpose of traffic modelling. The pedestrian 'walk time' is characterised by the pedestrian signal displaying the green 'walk' signal and should be designed to provide sufficient time for the pedestrians to begin the crossing movement. In South Australia, the 'walk time' has a basic minimum setting of 5 seconds and this figure should be used for general pedestrian crossing signal operations. Consideration may be made to increase the 'walk time' for situations such as a pedestrian activated school crossing, where there is a known high usage of the pedestrian crossing by elderly or people with disabilities or where there is a high volume of pedestrians queuing to cross. The 'clearance 1' time is characterised by the pedestrian signal flashing the red 'do not walk' signal during the green interval of the vehicle phase whilst 'clearance 2' time is characterised by the flashing red 'do not walk' signal during the intergreen intervals of the vehicle phase. It should be noted that the 'clearance 1' time and the 'clearance 2' time have the same pedestrian signal display that there is no visible transition between the two times. The purpose of the pedestrian clearance time is to allow for pedestrians who have left the footpath at the commencement of the pedestrian clearance interval to safely complete their crossing movement. The 'all red' clearance time functions to allow for any filtering vehicles, which may conflict with the pedestrian movement, to clear the intersection before the onset of the next phase. The primary technical reference for this section is *AGTM Part 9 Appendix G.5.2 and G.5.3.*

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6.1 Calculation of the Pedestrian Clearance Times

The pedestrian clearance times are dependent on three key factors; the crossing distance, the intergreen time for the active phase and the pedestrian walking speed. The crossing distance is the distance between kerbs measured through the centre of the marked pedestrian crossing as illustrated by the red lines in Figure 10.

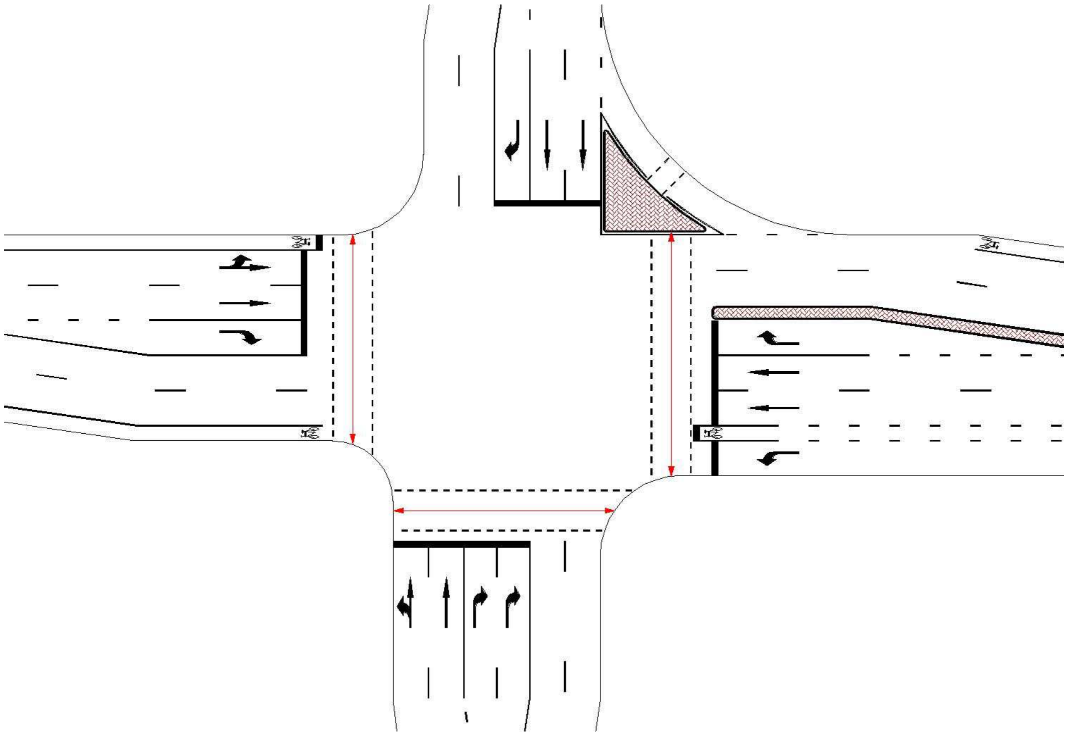

Figure 10: Pedestrian crossing distance measurement.

The total pedestrian clearance time t_{pc} (in seconds) is then simply calculated using Equation 5 where crossing distance L_c is measured in metres. *Austroads* literature indicates that the 15th percentile walking speed is approximately 1.2m/s and this speed is nominally used for pedestrian clearance calculations in South Australia.

$$t_{pc} = L_c / v_w \qquad (5)$$

As previously mentioned, the total pedestrian clearance time is an aggregate of two components; the 'clearance 1 time' and the 'clearance 2 time' as shown in Equation 6.

$$t_{pc} = t_{c1} + t_{c2} \qquad (6)$$

The 'clearance 2 time' is determined using Equation 7 where 'I' is the shortest intergreen of all the phases in which the pedestrian movement can activate and 't_{wr}' represents the 'all red' clearance time which is typically 2 seconds. Furthermore, for all sites within the City of Adelaide, the 'clearance 2' time is fixed to 4 seconds.

$$t_{c2} = I_{min} - t_{wr} \qquad (7)$$

The ‘clearance 1 time’ is simply the remaining component of the total clearance time as highlighted in Equation 8.

$$t_{c1} = t_{pc} - t_{c2} \tag{8}$$

It should be noted that for this calculation, pedestrian clearance times should be rounded up to the nearest second.

6.2 Extended Pedestrian Clearance Time

At sites where a need has been identified, pedestrian clearance may be programmed to be longer than that which is determined through the pedestrian clearance calculation in 6.1. These longer clearance times can be implemented in SCATS through a fixed setting in the program, where it operates at all times, through a fixed setting by time of day, or a variable setting using microwave sensors. Where microwave sensors are installed, the maximum clearance time is determined by applying a pedestrian walking speed of 1.0m/s using the same process as in 6.1.