New Zealand guide to temporary traffic management:

Basis of dimensions

WAKA KOTAHI
NZ TRANSPORT AGENCY

TTM set-out table: basis behind dimensions selected

The purpose is to describe how the various TTM site set-out dimensions have been worked out. In general, the lineal dimensions in the common geometric dimensions table in the NZGTTM toolbox are based on the operating speed, however, temporal dimensions, that is, dimensions related to time, have also been provided. This is to allow an observer on site to work out the lineal dimension based on the time taken for an observed fastest (or 85th percentile) vehicle in the traffic stream to travel the distance associated with the lineal dimension.

Amendments to dimensions in the NZGTTM table

The parameters shown in this document and in the NZGTTM table are intended to be a starting place for working out the appropriate set-out dimensions for TTM activities. Practitioners are expected to do risk assessment for every activity and every site, which may mean the dimensions in the table are increased or decreased.

In using this document, any changes to dimensions based on a risk assessment have a technical foundation on which those amendment decisions can be made.

Presentation of parameters in document and in table

Parameters for the various dimensions are presented linearly and temporally. Some the values in this document are different from the values in the NZGTTM. This is because the table of set-out values intended for standard use includes rounding of the dimensions rather than the precise values in this document.

Permanent speed limit or operating speed (km/h) where measured

The permanent speed limit is a simple parameter to identify for any TTM site from the National Speed Limit Register (NSLR) at nzta.govt.nz/national-speed-limit-register

However, from a risk perspective, the operating speed is more relevant than the speed limit. To accurately determine the operating speed it is necessary to survey the speed of a sufficient number of vehicles from which to determine the 85th percentile operating speed, which is the appropriate parameter to use for design purposes, whether for a permanent design solution or a temporary design solution. However, given the often dynamic nature of temporary traffic management, and the sometimes short timeframes, it can be appropriate for the operating speed to be determined over relatively short periods of time.

For the purposes of the NZGTTM table, TTM designers have the option of applying the permanent speed limit or the operating speed. However, the permanent speed limit is likely to be most applicable for those portions of the TTM installation encountered by road users on approach to the site. For static sites, once there has been a reduction in road user operating speed, the design parameters associated with the permanent speed limit are not necessarily applicable. A key factor in this regard is that if TTM design is based on an operating speed less than the permanent speed limit, the TTM designer needs to ensure that the operating speed on which the design is based will be achieved.

For on site application, the temporal dimensions described in the table can be used to adjust site set-out distances based on the operating speed of traffic through the site. For example, a taper length could be reduced if the operating speed of traffic is reduced such that the temporal dimensions described in the table can be met.

Reaction (PIEV)

The temporal dimension often described as "reaction time" is comprised of a number of components, which as a whole can be described as PIEV time. The components of PIEV time are as follows:

P = Perception
I = Identification
E = Emotion
V = Volition

By way of example, a road user may identify an object on the road ahead (perception), they visually determine that the object is a dog standing on the road (identification), the road user likes dogs, and they do not want to hurt the dog (emotion), the road user decides that they must take action to protect the dog (volition). While the PIEV time is typically short, it is only once the road user has gone through this process that they begin to act. Having decided that they want to protect the dog, the road user will then act such as braking, steering, use of horn, et cetera, to reduce the potential for the dog being hurt by the road user's vehicle.

From a TTM perspective, the same PIEV time process is followed by road users, however, the road user is identifying TTM equipment and deciding on the action to take based on the information presented through that TTM equipment.

In order to simplify the descriptor used, the term "reaction time" is used in this document rather than the term "PIEV time".

For the parameters described in this document, the assumption has been made that as the permanent speed limit and/or operating speed increases so too does road user reaction time. The foundation behind the assumption is that lower speed limits tend to be associated with more congested and complex road network operating conditions. The complexity tends to increase road user attention and reduce reaction time. The reaction time values adopted for the calculations described in this document are as follows:

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Assumed reaction time (seconds)	1.5	1.5	1.5	2	2	2	2.5	2.5	2.5

Road users on approach to a TTM site should become aware that the normal operating conditions of the road have changed as they travel past the advance warning signage for the site. From a risk assessment perspective, the TTM designer may determine that some of the dimensions described in this document (and the associated NZGTTM table) could be reduced on the assumption that reaction times reduce once road users have travelled past the advanced warning signage for a traffic management site. However, this document and the associated NZGTTM table generally incorporate the more conservative assumption that reaction times do not reduce once road users have travelled past the advance warning signage for a traffic management site.

Walking

From a risk management perspective, some of the dimensions described in the table require consideration of the speed at which someone can walk from a location at which they would otherwise be exposed to risk associated with an errant vehicle. While the presentation of such a risk is likely to result in someone moving faster than the normal walking speed, from a conservative risk management perspective, it is more appropriate to consider conservative walking speeds.

Various sources are available that identify typical walking speeds; the following sources and speeds have been considered:

- 1.4 m/s – source: business-standard.com/article/current-affairs/fit-proper-what-is-the-ideal-walking-speed-for-you-115100900029_1.html
- 1.31 to 1.39 m/s – source healthline.com/health/exercise-fitness/average-walking-speed
- 1.31 m/s – source ncbi.nlm.nih.gov/pmc/articles/PMC7806575
- 1.27 m/s for women in their 70s and 1.46 m/s for men in their 40s.
- 1.2 m/s Austroads guide to road design part 4a
- 1.42 m/s average, with 1.23 m/s minimum and 1.56 m/s 85th percentile based on empirical testing of unhurried walking in New Zealand.

For the purposes of this document, the most conservative (Austroads) walking speed of 1.20 m/s (4.32 km/h) has been adopted for calculation purposes.

Safe intersection sight distance (SISD)

Safe intersection sight distance (SISD) is a sight distance parameter that provides sufficient distance for the driver of a vehicle on a major road to observe a vehicle on a minor road approach moving into a collision situation and to decelerate to a stop before reaching the collision point. While for TTM situations the collision point is often not associated with an intersection, the principles of SISD apply because the height of the objects associated with TTM are not significantly dissimilar to the height of objects associated with vehicle movements at intersections. Therefore, from a TTM perspective, there are situations where road users should be provided with the equivalent of SISD from the point at which they are first aware of a situation until the point at which they may need to come to a stop.

Sign visibility distance

Sign visibility distance has been calculated based on 1.5 times reaction time. Essentially, this allows a 50% margin for a road user to be able to observe a sign and decide the actions they will take in response to that sign. The sign visibility distances determined by this approach are described in the table below.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Sign visibility distance (m)	18.8	25.0	31.3	50.0	58.3	66.7	93.8	104.2	114.6
Sign visibility distance (seconds)	2.3	2.3	2.3	3.0	3.0	3.0	3.8	3.8	3.8

Sign visibility applies whether the sign is a static sign on a stand on the side of the road or a sign attached to a vehicle. Therefore, for a mobile operation, a tail pilot vehicle (which should be positioned clear of the live lane) is essentially a sign that has a vehicle as the sign support.

The sign visibility times described in the table above are based on the assumption that the message a sign presents to road users will be simple and unambiguous, such as the suite of temporary warning signs described in the Traffic Control Devices Rule. However, as sign message complexity increases, the time a road user requires to view and comprehend a sign also increases. While the minimum criteria described in the table are suitable for "standard" temporary traffic management signs, they are unlikely to be suitable for signs that contain greater amounts of information, such as may occur with a variable message sign (VMS). Therefore, TTM practitioners should consider the content of signs being used on a site and determine the sign visibility time required to allow road users to view and comprehend the sign content.

Sign spacing

Sign spacing is the distance along the road between adjoining signs viewed by an approaching road user. Therefore, road users should have at least the minimum reaction time to be able to respond to the message presented by each sign.

However, although the sign spacing needs to be at least equivalent to reaction time, adding a 25% margin allows for a relatively simple correlation between sign spacing and warning distance (refer below). It also includes an additional margin for road users to comprehend the message presented by each sign and respond accordingly. Therefore, for the purposes of the NZGTTM table, sign spacing is calculated as 1.25 times reaction time.

With reference to sign complexity, as described in the section above, it may be necessary to increase sign spacing to any signs that are likely to require longer than typical for road users to read and comprehend the message presented.

Warning distance

Warning distance is the total distance between the first advance warning sign and the start of a taper or beginning of the closure or working space. That is, it is the total distance within which a road user can respond to the information presented by the TTM equipment. Taking into account the reaction time associated with the sign visibility distance, the warning distance is the length of road within which a road user is required to take action. For example, in the case of a manual traffic control operation, where a "STOP" legend is displayed, it is the distance within which the road user must bring their vehicle to a stop.

SISD is the distance required for a road user at a TTM site to bring their vehicle to a stop in response to a situation requiring the response (such as a manual traffic controller). From a TTM perspective, road users are warned of the potential need to stop from the point at which they observe the first sign, therefore, warning distance should be SISD minus sign visibility distance.

Taking into account the various parameters associated with TTM set up, warning distance based on the parameters described in this document varies between 1.7 and 2.3 times the sign spacing distance. Therefore, as a rule of thumb, warning distance can be taken to be at least twice the sign spacing distance.

Longitudinal exclusion zone: static sites

The longitudinal exclusion zone is the area set aside on the upstream side of the site within which to accommodate mistakes made by errant road users. In determining the length of the longitudinal exclusion zone, consideration has been given to the walking speed of road workers as well as the distance required for a road user to stop a vehicle. As operating speeds increase, the time required for stopping is greater than the time required for walking out of the way, therefore, the more conservative approach has been adopted.

Austroads Guide to Road Design Part 3 (AGRD3 2021) describes the stopping sight distance for cars on sealed roads, however, for some sites the longitudinal exclusion zone will not have a sealed surface. Therefore, the length of the longitudinal exclusion zone needs to allow for the distance road users breaching the zone require to be able to bring their vehicle to a controlled stop.

Stopping sight distance has been adopted for the longitudinal exclusion zone (as opposed to safe intersection sight distance, which is described elsewhere in this document) because the object height for stopping sight distance (0.2 m) is less than the object height for safe intersection sight distance (1.1 m).

Sealed surfaces

The values adopted for the length of the longitudinal exclusion zone for sealed surfaces in good condition are based on reaction times that are generally less than those described previously. For most cases, a reaction time of 1.5 seconds has been adopted because drivers should be aware (due to the presence of signs and other TTM devices) that the driving environment has changed, therefore, reaction times should have reduced. The reaction time for 100 and 110 km/h has been reduced to 2.0 seconds (from 2.5 seconds) for this reason. However, as noted in the Reaction (PIEV) section of this document, the reaction time reduction has not been universally applied to the parameters for the NZGTTM table.

The desirable maximum deceleration rate (d = 0.36) from AGRD3 (Table 5.5) has been adopted. While it could be argued that the maximum deceleration rate (d = 0.46) should be adopted, that coefficient may not be appropriate for all sealed road situations in New Zealand and, by applying the lower rate, a measure of conservatism is introduced that makes an allowance for the greater stopping distances required for heavy vehicles. Notwithstanding that, it may be appropriate for the longitudinal exclusion zone to be extended where the traffic stream comprises a high proportion of heavy vehicles.

Unsealed or low friction surfaces

Road surfaces at TTM sites will not all be sealed surfaces in good condition. A range of surface conditions can exist, which include (but are not limited to) the following:

- Unsealed road surfaces, whether as a result of the site being on an unsealed road or a sealed road under construction that does not have a sealed surface.
- Detritus on a sealed surface including oil, loose gravel, and soil.
- Metal plates covering excavations.
- Ice and snow.

While this document provides guidance regarding lengths for the longitudinal exclusion zone, the TTM practitioner should consider the friction of the road surface and extend the longitudinal exclusion zone if required. However, because of the significant variation in skid resistance (and associated stopping distance) on roads with unsealed or low friction surfaces, it is not practicable to identify a single deceleration rate or surface friction value that is applicable to all unsealed or low friction surfaces.

The ARRB Unsealed Roads Best Practice Guide (October 2020) indicates that the coefficient of deceleration for cars on unsealed roads ranges between 0.24 and 0.27. Similarly to sealed roads, stopping distances for heavy vehicles on unsealed roads are greater than stopping distances for cars. The longitudinal exclusion zone lengths for unsealed surfaces described in the NZGTTM Table are based on d = 0.25 and reaction times as described in the sealed surfaces section above.

Lateral exclusion zone: static sites

The appropriate width for the lateral exclusion zone is very dependent on the angle at which a road user deviates from the live lane intended for their use. Applying the reaction times described previously, and a gentle lateral shift rate of 0.6 m/s, the identified lateral exclusion widths have been determined. Essentially, these relate directly to the reaction time. However, if a road user has a greater lateral shift rate than the assumed value of 0.6 m/s, the errant vehicle will cross the lateral exclusion zone more quickly. The other factor that needs to be kept in mind is the feature or features beyond the lateral exclusion zone from which road users are being separated. For example, if the feature beyond the exclusion zone is a section of road being resealed, an errant vehicle will pass on to a road surface at a similar level to the surface from which they have exited. However, the potential exists for that vehicle to collide with construction vehicles or road workers on foot.

Therefore, from a risk management perspective, the greater the risk beyond the lateral exclusion zone, the greater the width appropriate for the lateral exclusion zone. It needs to be kept in mind that a road user will not necessarily bring their errant vehicle to a stop once it has reached the edge of the working space.

Where excavations are involved, a conservative angle of repose approach should be adopted. In this regard, the lateral exclusion zone width could be increased by a ratio of two for every unit of depth of the excavation. For example, if an excavation is 500 mm deep, the lateral exclusion zone width could be increased by 1 m. However, consideration should also be given to providing more robust protection, such as a temporary barrier system, for road workers and road users where excavations are involved.

Taper

From a road user perspective, the key factor associated with taper length is the lateral shift rate. However, the lateral shift rate varies depending on the alignment of a road. For example, on a straight section of road a lateral shift rate of 1 m/s (which is a faster lateral shift rate than the 0.6 m/s lateral shift rate typically used in New Zealand for the diverge taper for a right turn bay) can be readily determined. The reasons for adopting the 1 m/s lateral shift rate are as follows:

- 0.6 m/s is desirable for merge tapers and is therefore conservative when compared with the 1 m/s diverge taper lateral shift rate described by Austroads in AGRD 3 Section 9.9.2.
- The less sharp the lateral shift rate, the less the impact of that shift rate on road users, which in turn has the potential to discourage road users from reducing speed.
- The advance warning and delineation associated with a taper on a TTM site is significantly different to that associated with a right turn bay. Therefore, because of the presence of advance warning signs to warn road users of the site ahead, and delineation devices that provide vertical as well as horizontal elements for the taper, a rate of 1.0 m/s is reasonable.
- If the taper rate is reduced, there is a commensurate extension to the length of the taper, which will result in the length of the site being extended and have the potential to create consequential adverse effects.

The taper lengths described are based on a 1 m/s lateral shift rate. These lengths can be applied to curvilinear alignments without specific geometric design being completed, subject to the minimum radius criteria described in this document being exceeded.

Distance between

The intention of having a separation between successive tapers is to allow traffic flow to stabilise before an additional lateral shift associated with subsequent tapers is introduced. However, it needs to be kept in mind that an alternating flow operation on a two-lane two-way road comprises a taper followed by a distance between tapers alongside the working space, followed by a second taper that returns the traffic stream to its designated lane. On that basis alone, the distance between tapers should be not less than the length of the longitudinal exclusion zone. Therefore, the longitudinal exclusion zone dimension for sealed roads has been adopted as the minimum distance between tapers.

Temporary lane width

Temporary lane widths need to meet two criteria:

- Be sufficiently wide to accommodate all vehicle types likely to be using the road during the temporary works.
- Be sufficiently narrow to encourage operating speeds commensurate with those on which the TTM installation is based.

It is not practicable within this document to identify minimum lane widths for every situation because of the very wide variety of situations for which TTM is provided. TTM design needs to consider the composition of the traffic stream and the alignment of the route along which road users are required to travel past the site. For example, as curve radius reduces the lane width required to accommodate the tracking width required by trucks will increase. Refer to AGRD3.

There does not appear to be a robust technical basis behind the lane widths described in previous TTM documentation. For example, while a 2.75 m wide lane may be suitable for slow speeds (30 or 40 km/h) on relatively straight alignments in locations where there are very few trucks, the width is inadequate to accommodate large volumes of trucks and is more inadequate where the alignment is not straight. Considering that the maximum legal (not over-dimension) width for a heavy vehicle is 2.55 m (Vehicle Dimensions and Mass 2016 Rule: Schedule 2), a lane width of 2.75 m is simply impractical because it allows only 100 mm clearance on either side of a conventional heavy vehicle. However, the 2.55 m width does not include the permissible collapsible mirrors (extending no more than 240 mm beyond the side of a vehicle) described in Section 3.4(1)(b)(i) of the Vehicle Dimensions and Mass Rule. While collapsible mirrors are likely to extend above TTM signs and delineation, there is potential for them to protrude into an opposing lane. Therefore, in terms of temporary lane widths, TTM designers need to consider a wide variety of factors including, but not limited to, the following:

- Road users and vehicle types most likely to be travelling past the site. Include consideration of motor vehicles, bicycles, and pedestrians.
- Horizontal alignment of the section of road. As curve radius reduces, the lane width needs to increase to accommodate the swept path of vehicles.
- Vertical alignment of the section of road. For example, as gradient increases, the width cyclists need to be able to safely operate also increases.
- Delineation devices used to define the temporary lanes. As lane widths reduce the likelihood of devices being struck increases, which in turn increases the need for the TTM maintenance and the associated risk presented to road workers.
- Other measures in place to promote reduced operating speeds. These measures may include manual traffic control, TTM vehicles, thresholds, frequency of temporary speed limit signage, and so on.
- The NZGTTM table includes the original temporary lane width dimensions from previous TTM documentation, however, those dimensions should not be followed blindly, but rather used as a starting place for consideration of the appropriate temporary lane width for a site taking into account the wide range of factors associated with each site.

Delineation spacing on straights

The intention of delineation alongside the working space is to present to road users a clear understanding that they are not intended to pass through the line of devices that separate the live lane from the working space. Two key factors arise in relation to the spacing of delineation devices on straights:

- The manner in which the devices appear to the road user; that is, how many delineation devices do they drive past per second of travel.
- The separation of the devices and whether they present road users with the impression that the gaps are sufficiently narrow that they cannot readily manoeuvre their vehicle through the line of devices.

On the assumption that a road user will travel through a line of delineation devices at a constant angle (based on a relatively steep lateral shift rate of 3 m/s) rather than by performing a turning manoeuvre, a 1.5 m wide vehicle can pass through a line of delineation devices with separation as described in the table below.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Delineation spacing (m)	4.4	5.8	7.1	8.5	9.8	11.2	12.6	14.0	15.4

Therefore, to avoid having different delineation spacing for each operating speed, the NZGTTM table includes spacing based on three groupings that are aligned with the reaction times. That is:

- **30 – 50 km/h:** 5 m spacing
- **60 – 80 km/h:** 10 m spacing
- **90 – 110 km/h:** 15 m spacing

On sealed roads with dashed centre-line lane line markings, the delineation spacing can be readily determined on site. The most difficult spacing to readily determine is 15 m, however, the traffic management plan should not propose a greater spacing (such as 20 m) if the designer considers the team on site would have difficulty identifying 15 m spacings. But rather, spacings should be reduced (for example, to 10 m) in order to provide simplicity for the team on site.

An important aspect of the spacing of delineation devices (whether on straights, curves, or in tapers) is that as operating speeds decrease the potential for road users to manoeuvre between delineation devices increases for the same spacing of devices. Therefore, from a risk assessment perspective, as operating speeds decrease, the spacing of delineation devices should also decrease. For example, in a location where the speed limit is 100 km/h, if the operating speed of traffic through a TTM site is 70 km/h, the spacing of delineation devices on straights should be 10 m rather than 15 m.

Delineation devices in tapers and on curves

For tapers and for low radius curves, the delineation devices will first be presented to road users as a penetrable wall of devices across the path of the road user. Therefore, enough delineation devices should be used to present the impression of a "wall" across road users' path. For a given width of lateral shift and a given lateral shift rate, the number of delineation devices in a taper should be consistent regardless of the operating speed.

On the assumption that the base of a typical delineation device (most frequently a cone) is 400 mm wide, and a typical lane is 3.5 m wide, 10 delineation devices (1 + 3.5/0.4 = 9.75) are required to present the impression of a "wall". The table below describes the un-rounded calculated taper lengths and the resultant delineation device spacing for tapers.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Taper length (m)	29.2	38.9	48.6	58.3	68.1	77.8	87.5	97.2	106.9
Device spacing (m)	3.2	4.3	5.4	6.5	7.6	8.6	9.7	10.8	11.9

Similarly, to the approach for the spacing of delineation devices alongside the working space, the NZGTTM table includes spacing based on three groupings that are aligned with the reaction times. Ideally, those spacings would be 3 m, 6 m, and 9 m. However, the difficulty with that approach is that the spacings would require measurement of the position of individual delineation devices. While measurement would be required for any locations where there are not conventional dashed centre-line or lane line markings, it is desirable for there to be simple field-based methods for identifying the spacing for delineation devices. Therefore, while the approach would generally result in more delineation devices being installed than potentially necessary, the NZGTTM table proposes the following spacings for delineation devices in tapers and on low radius curves:

- **30 – 50 km/h:** 2.5 m spacing. That is, 5 equally spaced delineation devices between the start of one dashed marking to (and including) the start of the next dashed marking.
- **60 – 80 km/h:** 5 m spacing. That is, 3 equally spaced delineation devices between the start of one dashed marking to (and including) the start of the next dashed marking.
- **90 – 110 km/h:** 10 m spacing. That is, 1 delineation devices at the commencement of each dashed marking.

The first two dimensions are half the spacing of delineation devices on straights. The third dimension does not follow the same relationship because of the complexity associated with identifying 7.5 m spacings on site.

However, if flexible delineators (which are typically narrower than cones) are the delineation devices used for a TTM site, consideration should be given to decreasing the spacing of the devices in order to discourage road users from intentionally or unintentionally attempting to drive between the devices.

Threshold length

Thresholds can be used to provide horizontal and vertical constraints for road users on approach to a TTM site. The intention of a threshold is to increase road user awareness of a TTM site and to encourage them to reduce their operating speed and, in some cases, to prepare to stop. Previous TTM documentation proposed that thresholds should be comprised of delineation devices along the left-hand side and right-hand side of a road user's approach to a site; these thresholds typically comprised five delineation devices on either side. For the purposes of this document and the NZGTTM table, thresholds are described as comprising five delineation devices with the separation between delineation devices being equivalent to the spacing of those devices in a taper. However, TTM designers should undertake a risk assessment and, if required, amend (typically reduce) the spacing of delineation devices for a threshold and the number (typically increase) of devices that are used. The overall length of the threshold can also be increased to increase the length of road over which road users are constrained.

Radius of alignment

The alignment that road users follow through a TTM site is affected by the configuration of the delineation devices used on that site. For example, if a taper of delineation devices is developed on a left-hand curve (and accepting that driving a curve is not the same as driving a taper) that effectively has a lateral shift rate of 1 m/s, a coincidental taper to the right (such as occurs if two lanes are merged into one lane) will result in the road user effectively travelling straight. Similarly, if a taper to the right with a lateral shift rate of 1 m/s is developed on a right-hand curve, that effectively has a lateral shift rate of 1 m/s, this will result in road users effectively being subject to a lateral shift rate of 2 m/s.

Road users are sometimes also guided along temporary alignments that are defined by delineation devices; for example, traffic being moved from one side of a median barrier to the other side of a median barrier to allow an opposing carriageway to be used for the movement of traffic.

In many cases, the temporary alignment along which road users are guided will not result in curve radii that cannot be traversed readily by the traffic needing to travel past the site. However, in some cases, TTM will create or exacerbate an alignment that results in low radius curves. This section describes alignment thresholds below which specific geometric design should be adopted to ensure road users are guided safely past the site.

Determining radii parameters for existing curves

The smaller the curve radius and the faster the travel speed the greater the rate of lateral movement for a road user. Notwithstanding that lineal tapers and curves are different, for a lateral shift rate of 1 m/s, the 1 m lateral offset would be located 30.6 m beyond the start point of the lateral shift when travelling at 110 km/h. By comparison, the 1 m lateral offset would be 8.3 m beyond the start point of the lateral shift when travelling at 30 km/h. The curve radii over which the 1 m lateral offset is achieved are as described in the table below.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Radius (m)	35	60	100	140	190	250	315	390	470

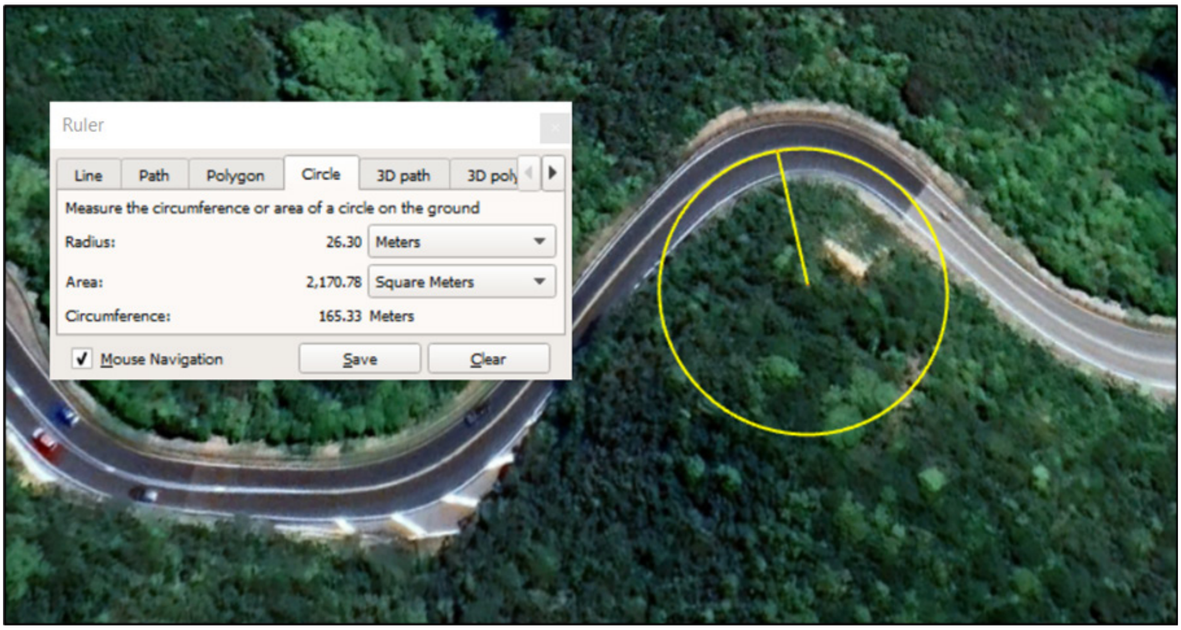
While the equation is not exact, the approximate radius values described above can be determined by the equation R = V2 / 26, where V is the operating speed in kilometres per hour. This results in an approximate 1 m lateral shift (attributable to the curve), which could then (for example) be combined with a 1 m/s lateral shift rate to the right for a taper, which results in close to a 2 m/s lateral shift rate for a right-hand curve. Desirably, tapers should not be established on curves, however, where this is unavoidable, tapers that effectively decrease the curve radius should not be established on any curves with a radius less than those described in the table above, unless specific geometric design is completed for the curve taper so that road users can safely travel along the tapered curve at the intended operating speed. This criterion applies for tapers to the right on the right-hand curves and tapers to the left on left-hand curves. In that regard, TTM designers need to consider the vertical and horizontal alignment of the section of road (including superelevation). The expectation is that, for a given operating speed, as curve radius decreases, taper length will increase so that the lateral shift and curve radius applied to road users will be suitable for the operating speed.

Applying radii parameters for existing curves

There are two primary difficulties with applying radius parameters:

- How does a TTM designer determine the radius of any particular curve for which they need to prepare a traffic management diagram?
- For generic TMPs in particular, how does an STMS on site determine the radius of the curve on which they need to establish a TTM site so they can determine whether the generic TMP can be applied to their particular curve?

The TTM designer will need to determine the radius of any curve affected by the works so they can determine whether they need to undertake specific geometric design. While the approach is not exact, tools such as Google Earth can be used to obtain a reasonable indication of the radius of a curve, as illustrated in the following image.



However, determining the radius of a curve on site is significantly more difficult unless digital resources such as Google Earth are available and the STMS on site is able to determine the curve radius. While a chord and offset method could be used on site to determine the radius of a curve, the method requires measurements to be made, which would expose workers to risk, and calculations to be completed using those measurements. Even if lookup tables were provided, to avoid the need for calculations being required, it would still be necessary to make physical measurements on site.

A line-of-sight approach could be considered as a de facto chord and offset method (with assumptions made regarding lane width), however, workers would still be exposed to risk and the method relies on the people on site undertaking their assessment at the location where the curve radius is least. While there may be simple field methods that can be used to determine curve radius, these had not been identified at the time this document was completed. Therefore, the simplest method for determining curve radius while on site may be for the STMS to contact their office and have the radius for any particular curve measured on screen in the office and the STMS on site advised of the result. Otherwise, it may not be practicable for minimum curve radii criteria to be applied to the application of generic TMPs, but only to site-specific TMPs.

Radii parameters for created curves

Any temporary alignment along which road users are guided needs to be geometrically suitable for the vehicles that will be following that alignment and the speed at which those vehicles travel. As noted in Section 14 of this document, as the size of vehicles in the traffic stream increases so too does the width of road required to accommodate those vehicles. In addition, as the operating speed of vehicles increases, so too does the width of road required to accommodate those vehicles.

Geometric design of roads (whether on a permanent or temporary alignment) involves the provision of suitable horizontal alignment, vertical alignment, and carriageway cross falls to suit those alignments. For example, on a low radius right-hand curve, the cross section of the carriageway will typically slope from left to right, whereas on a low radius left-hand curve, the cross section will typically slope from right to left. Any TTM alignments that require road users to follow a route where cross falls are contrary to good design practice or where the alignment itself is not designed in accordance with good practice, have the potential to result in the TTM not operating efficiently (at best) or for road users to be unable to safely follow the temporary alignment.

It is not practicable within this brief document to provide TTM alignment design advice for practitioners. However, Austroads Guide to Road Design Part 3: Geometric Design provides an overview of parameters for geometric design of roads including for TTM. Section 3.8 of AGRD3 (2021) notes "[…] horizontal curvature has the greatest effect on the operating speed." However, that horizontal alignment must be suitable for the temporary alignment. For the purposes of this document, TTM designers may incorporate horizontal alignment based on fully circular curves only, provided those curves are fully circular and the radii are not less than the values described in Section 18.1 of this document. While there is not a direct correlation, the radii in Section 18.1 are aligned with those described in Table 7.3 of AGRD3. Where the radius of any curve created for TTM purposes is less than those described in Section 18.1, full geometric design including transition spirals and detailed consideration of cross falls should be carried out.

Clear sight distance

The clear sight distance (CSD) criteria that previously applied to vehicle based mobile activities have been superseded by the approach described in this document. However, from the perspective of workers on foot, needing to move off the carriageway in order to allow other road users to travel along the road unimpeded, the clear sight distance criterion is still relevant.

Two approaches have been used for determining clear sight distance; these are described below.

Exiting vehicle

For an activity (most likely an inspection activity) where a worker needs to exit a vehicle that is parked adjacent to the edgeline, but clear of the live lane, the sight distance required should be adequate to allow the worker to safely exit the vehicle and move to a safe position in front of the vehicle or beyond the side of the vehicle. Based on empirical data, the time required to safely exit a vehicle is between 10.5 seconds and 12 seconds; the process followed for obtaining the data was:

- Check exterior rear-view mirror for gap in the traffic.
- Unfasten seatbelt, open door, exit vehicle, and close door.
- Walk to a position on the shoulder of the road 10 m in front of the vehicle and 1 m beyond the edgeline.

Exiting a vehicle is one of the tasks on which the time required for clear sight distance can be established. However, there are likely to be other tasks associated with movement to and from vehicles that result in the required CSD being greater than that described above. This document does not include CSD for the full range of tasks associated with moving to and from vehicles, however, practitioners should consider the following variables to determine the minimum amount of additional sight distance in excess of 12 seconds that is required to allow activities to be completed safely:

- The type of vehicle being used; it may take longer to enter or exit a truck than it takes to enter or exit a car.
- The people involved in the task; fit and agile road workers may require less time to complete some tasks than personnel that are less physically capable.
- The time required for a road worker to be securely seated in a vehicle. It typically requires less time to unfasten a seatbelt than it does to fasten a seatbelt. However, it is important that a person exiting a vehicle keeps their seatbelt fastened for as long as practicable; similarly, on entering a vehicle, the seatbelt should be fastened as soon as possible.

Moving from carriageway

In the worst case, someone standing on a road may need to walk across two lanes to get to a safe location on the side of the road. For the highest risk (high-speed) situations, the reaction time for the person on the road is unlikely to be as slow as for a road user approaching, therefore, a road worker reaction time of two (2.0) seconds has been adopted for this analysis. Consideration needs to be given to the wide range of tasks that may be carried out at the time the worker is on the live lane, therefore, consideration also needs to be given to the time required to pick up an item of equipment (for example, a measuring wheel) before walking off the road. Based on empirical trials and adopting a conservative result from those trials, it typically takes no more than about 3.5 seconds (test results ranged from 2.7 seconds to 3.3 seconds) to bend down, pick up an item, raise the item to a carrying position and take a first walking step. If a mistake is made picking up the item or more time is required because of the position of the item relative to the worker, more than 3.5 seconds may be required. However, the adopted value is greater than the maximum value determined from tests conducted by nine individuals.

On the assumption that the person moving off the road needs to be 1 m clear of the edgeline to be in a safe location, the walking distance could be up to 8 m (two 3.5 m lanes plus 1 m beyond the edgeline). The walking time required is 6.4 seconds.

Therefore, approximately (2 + 3.5 + 6.7 = 12.2) 12 seconds is required to walk off the carriageway. However, as noted above, this is based on conservative parameters, therefore, the actual time is likely to be less than 12 seconds. Coincidentally, the 12 seconds identified is the same as the time required for exiting a vehicle.

Selected clear sight distance criteria

Based on the empirical testing and calculated approach described above, clear sight distance needs to be 12 seconds. The three times speed limit approach included in previous TTM documentation represents an equivalent road user travel time of 10.8 seconds. The previous TTM documentation criterion was not conservative (when compared with the 12 seconds for walking off the road or exiting a vehicle), therefore, the criterion should not be retained for use under the NZGTTM.

While a simple rule of thumb approach (such as the dimensionally incorrect three times operating speed approach described in previous TTM documentation) has benefits, it is based on distances that are difficult to estimate in the field. Therefore, the lineal dimensions adopted for the NZGTTM table are based on 12 seconds travel time, with rounding to the nearest 5 m.

Separation from tail pilot to work vehicle (or shadow vehicle)

Because of the potential for the work vehicle (or shadow vehicle) to be out of sight of the tail pilot vehicle (tail pilot) TTM designers need to consider a worst-case scenario where a road user may have as little as sign visibility distance to the tail pilot and very short sight distance to the work vehicle. If the distance from the tail pilot to the work vehicle is too great, a road user will observe the tail pilot and may initially react, but then return to travelling as normal if they do not encounter the work vehicle soon enough. Therefore, the distance needs to be relatively short.

In the first edition of previous TTM documentation, the separation from the tail pilot to the work vehicle (or shadow vehicle) was 5 - 10 seconds travel time, however, that was subsequently increased to 5 - 20 seconds travel time as described in the fourth edition. At 100 km/h an approaching road user will travel 556 m in the 20 seconds between passing the tail pilot and reaching the work vehicle. Given the time and distance elapsed, it is likely that a road user will not anticipate the presence of the work vehicle based on the warning provided by the tail pilot.

One of the previous constraints associated with the tail pilot is that clear sight distance to the tail pilot vehicle was required. However, provided the tail pilot is positioned clear of the live lane, the tail pilot is effectively just a sign mounted on a vehicle. Therefore, there does not appear to be a significant argument for clear sight distance to the tail pilot, but rather sign visibility distance is the appropriate criteria. Noting that this fundamental change significantly increases the flexibility for the longitudinal positioning of the tail pilot, consideration then needs to be given to the separation between the tail pilot and the work vehicle (or shadow vehicle). In that regard, consideration should be given to the time required for a road user to take appropriate action to avoid collision with the work vehicle, which may require the road user to come to a stop. The associated difficulty is that there will not necessarily be sight distance for the road user from the position of the tail pilot to the position of the work vehicle, therefore, TTM practitioners cannot rely on a dimension such as SISD being available. Clearly, there is a risk associated with a work vehicle being positioned where there is very short sight distance from an approaching road user to the work vehicle. Noting that this document describes dimensions rather than TTM practice, TTM designers need to consider whether mobile operations are appropriate on sections of road where the alignment severely constrains forward sight distance.

Due to the dynamic nature of mobile operations and the variation in sight distance that can occur along a length of highway, TTM designers and practitioners should be aware of the associated constraints and apply a risk assessment and management approach to minimising the risks associated with those constraints. In that regard, the following factors should be considered:

- Sign visibility distance to the tail pilot should not be compromised; similarly, the tail pilot should always be positioned clear of the edgeline.
- Taking into account the importance of sign visibility distance and positioning of the tail pilot, the tail pilot should be moved up whenever practicable in order to minimise separation between the pilot vehicle and the shadow and / or work vehicle ahead.
- Noting that working and shadow vehicles associated with mobile operations typically do not have flexibility in relation to their longitudinal or lateral position on a road, sight distance to those vehicles should be maximised whenever practicable.
- Where a shadow vehicle is part of a mobile operation, consideration should be given to whether the overall risk to road workers and road users is least if the separation between the shadow vehicle and a work vehicle is reduced (refer also to Separation from shadow vehicle to work vehicle section of this document) in order to increase visibility to the shadow vehicle.

Taking into account the points above, the minimum distance between the tail pilot and the work vehicle should be at least "warning distance" and desirably no more than "safe intersection sight distance". These distances are still relatively significant; however, they are not dissimilar to the 5 to 10 seconds described previously in the first edition of previous TTM documentation.

This document describes warning distance and SISD based on reaction time, which results in three groupings depending on the operating speed. The table below describes those distances and the associated travel times for a road user travelling at operating speed.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Warning distance (m)	25.0	33.3	41.7	66.7	77.8	88.9	125.0	138.9	152.8
Warning distance (sec)	3	3	3	4	4	4	5	5	5
SISD (m)	N/A	67.0	90.0	123.0	151.0	181.0	226.0	262.0	300.0
SISD (sec)	N/A	6.0	6.5	7.4	7.8	8.1	9.0	9.4	9.8
SISD (sec) bracketed	6	6	6	8	8	8	10	10	10

Therefore, by way of summary, the proposed temporal separation between the tail pilot and the work vehicle (or shadow vehicle) is:

- **30 – 50 km/h:** 3 to 6 seconds
- **60 – 80 km/h:** 4 to 8 seconds
- **90 – 110 km/h:** 5 to 10 seconds

Mobile operations are complex dynamic activities, therefore, risks need to be reviewed and reassessed frequently while the operation is active, and regularly as an assessment of the operation itself, to ensure the overall risk to road workers and road users is minimised. For some activities that have previously been completed as mobile operations, this assessment process may indicate that an alternative TTM approach (such as a static operation) may be more appropriate than employing a mobile operation.

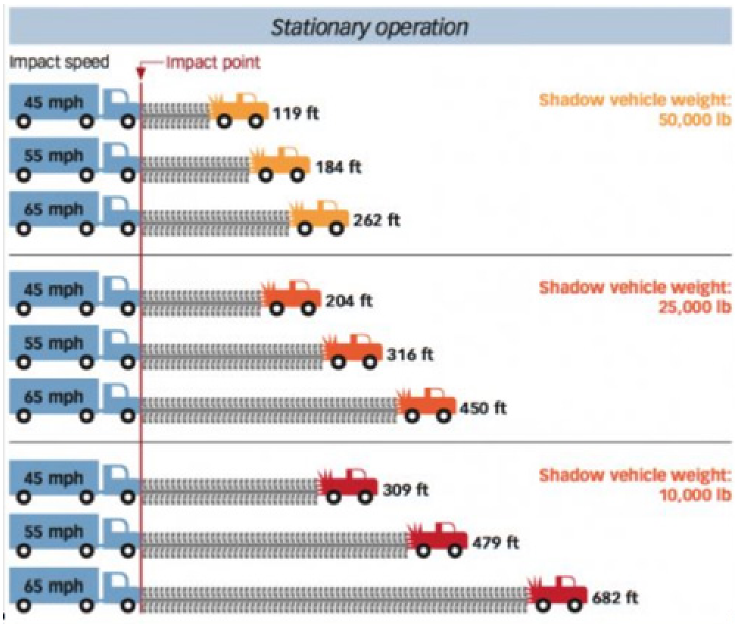
Separation from shadow vehicle to work vehicle

Note: This section is to be reviewed on receipt of additional information regarding TMA roll ahead distances.

The key features of the separation distance from the shadow vehicle to the work vehicle should sufficiently long be that if the shadow vehicle is struck by a following vehicle, any workers on foot in front of the shadow vehicle are at relatively low risk of being struck by the shadow vehicle. Alternatively, if workers are struck, the speed of impact is survivable. However, the gap between the work vehicle and the shadow vehicle needs to be minimised, to minimise the potential for a road user to move into the gap after passing the shadow vehicle. Therefore, there are competing risks.

The impact derived separation distance is very dependent on the mass of the vehicle being struck, the setting of its brakes, the mass of the vehicle striking, and the speed at which the striking vehicle is travelling. There is not a single simple answer and the 10 m described in previous TTM documentation is not a good starting place. Balance needs to be sought between having a roll ahead distance that may prevent an impacted vehicle from striking anyone standing in front of the vehicle, and a vehicle separation distance that “encourages” road users to move in between the shadow vehicle and the work vehicle.

Noting that the dimensions are imperial (from the United States) and the criteria considered vary, the sources below illustrate the very significant distances that a shadow vehicle with a TMA (TMA shadow vehicle) will be moved when impacted by a heavy vehicle. However, in considering the information provided, it is important to recognise that the speed limit for heavy vehicles is 90 km/h, therefore, while some heavy vehicles will travel faster than 90 km/h, it is not unreasonable to adopt 90 km/h as the maximum impact speed by a heavy vehicle.



Roll ahead distances impacted by 80,000lb semi truck – Texas Department of Transportation
static.tti.tamu.edu/conferences/tsc18/presentations/construction-2/weber.pdf

SHADOW VEHICLE MOVING OPERATION (B)					
Vehicle Weight (lb)	Prevailing Speed (mph)	Weight of Impacting Vehicle To Be Contained (a)			
		4,500 lb	10,000 lb	15,000 lb	24,000 lb
10,000	60-65	100 Ft.	175 Ft. (c)	225 Ft.	275 Ft.
	50-55	100 Ft.	150 Ft. (c)	175 Ft.	200 Ft.
	45 or less	75 Ft.	100 Ft. (c)	125 Ft.	150 Ft.
15,000	60-65	75 Ft.	150 Ft.	175 Ft.	225 Ft.
	50-55	75 Ft.	125 Ft.	150 Ft.	175 Ft.
	45 or less	50 Ft.	100 Ft.	100 Ft.	100 Ft.
24,000	60-65	75 Ft.	100 Ft.	150 Ft.	175 Ft.
	50-55	50 Ft.	75 Ft.	100 Ft.	150 Ft.
	45 or less	50 Ft.	75 Ft.	75 Ft.	100 Ft.

New York State Department of Transportation
dot.ny.gov/divisions/operating/oom/transportation-systems/safety-program-technical-operations/work-zone-control/repository/Shadow_Vehicle_Roll_Ahead_Distance_Table.pdf

For the NY DOT example provided above, the reference notes that "Distances are appropriate for the shadow vehicle speeds up to 15 mph [... 24.1 km/h]". The table below provides dimensioned examples of the magnitude of the movement described in the reference sources provided above.

Source	Mass of vehicle with TMA (t)	Speed of vehicle with TMA (km/h)	Mass of impacting vehicle (t)	Speed of impacting vehicle (km/h)	Distance TMA vehicle moved (m)
Texas DOT	4.5	0	36.3	72.4	94
Texas DOT	11.3	0	36.3	88.5	96.3
Texas DOT	22.7	0	36.3	88.5	56
NY DOT	4.5	24.1	10.9	72.4	46
NY DOT	10.9	24.1	10.9	88.5	46

The previous TTM documentation approach of a 10 m roll ahead distance was based on a light vehicle travelling at a speed of less than 100 km/h impacting a TMA shadow vehicle. However, the 10 m roll ahead distance was typically adopted for all situations and failed to recognise that the distance by which an impacted shadow vehicle moves is very dependent on a range of variables. Therefore, the TTM designer should adopt an approach where they consider the variables associated with the situation including:

- The composition of the traffic stream.
- The parameters of the shadow vehicle; including whether the shadow vehicle has a TMA.
- The operating speed of the traffic stream.
- The operating speed of the mobile activity.

From those variables, the designer should be able to determine:

- Whether there should be workers on foot between the between the shadow vehicle and the work vehicle.
- The separation (both minimum and maximum) between the shadow vehicle and the work vehicle.
- The maximum distance a worker on foot should be from the work vehicle.

Taking into account the distance required between a shadow vehicle and a work vehicle to accommodate the movement of the shadow vehicle when impacted by a vehicle in the traffic stream, consideration also needs to be given to the potential for a vehicle in the traffic stream to move past the shadow vehicle and then into the gap between the shadow vehicle and the work vehicle. The issue is the potential for a vehicle in the traffic stream to get between the shadow vehicle and the work vehicle. However, it needs to be balanced against roll ahead distance. At a high lateral shift rate of 3 m/s, a vehicle can fully cross the width of a 3.5 m lane within 1.2 seconds. AGRD4A Section 5.2.1 describes the 3 m/s lateral shift rate for the entry taper into a left turn slip lane, however, the guide also notes (Figure 5.1(b)) that it is unusual for a vehicle entering the slip lane to adopt a 3 m/s lateral shift rate. Therefore, if a lateral shift rate of 2 m/s is adopted, the separation between a shadow vehicle and a work vehicle would be as described in the table below:

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Vehicle separation (m)	14.6	19.4	24.3	29.2	34.0	38.9	43.8	48.6	53.5

Noting that there remains a significant element of risk, which will vary depending on the composition of the traffic stream and the speed at which heavy vehicles in particular are travelling, it is not unreasonable for the separation between a TMA shadow vehicle and a work vehicle to be based on a lateral shift rate of 2 m/s, provided the overall mass of the TMA shadow vehicle is 11 tonnes or more and the TMA shadow vehicle is stationary with brakes engaged. Any personnel on foot between the work vehicle and the TMA shadow vehicle should be no more than 10 m away from the work vehicle and at least 10 m in front of the TMA shadow vehicle where the separation between vehicles would otherwise be less than 20 m.

Separation from work vehicle to lead pilot

Similarly to the separation between the tail pilot and the work vehicle (or shadow vehicle), the separation between the work vehicle and the lead pilot vehicle (lead pilot) was 5 - 10 seconds travel time in the first edition of previous TTM documentation, however, that was subsequently increased to 5 - 20 seconds travel time as described in the fourth edition.

Separation for the lead pilot does not need to be the same as separation for the tail pilot. The issue is whether a road user travelling in the opposing direction will (1) see the lead pilot and (2) realise that the lead pilot is providing warning of a mobile activity in the opposing lane. The lead pilot also needs to be positioned so that road users approaching the rear of the lead pilot vehicle can clearly see the vehicle, therefore, visibility to the rear of the vehicle should be at least sign visibility distance. On sections of road where it is reasonable to expect road users to perform overtaking manoeuvres, it is also reasonable to expect there will be adequate visibility for the overtaking manoeuvre. Because the work vehicle is required to operate to the left of the centre-line, where forward sight distance is limited it is reasonable to expect opposing traffic to be operating within its lane, therefore, there should not be conflict between opposing traffic and the work vehicle operating in the live lane. Notwithstanding that, opposing road users need time to consider the presence of the work vehicle and to take action accordingly. Taking into account that it is all but impossible to manage forward sight distance along all sections of road on which the mobile operation is being carried out, the distance between the lead pilot and the work vehicle should be at least stopping sight distance, which is the same as the distance adopted for the longitudinal exclusion zone.

However, consideration also needs to be given to simplicity and consistency of approach. While there is an argument for the separation between the work vehicle and the lead pilot to be less than the separation between the tail pilot and the work vehicle, the consistency argument is considered stronger. Therefore, the same separation parameters are proposed.

Operating speed (V) km/h	30	40	50	60	70	80	90	100	110
Min (m)	25	33.3	41.7	66.7	77.8	88.9	125	138.9	152.8
Min (sec)	3	3	3	4	4	4	5	5	5
Max (m)	N/A	67	90	123	151	181	226	262	300
Max (sec)	6	6	6	8	8	8	10	10	10

NZGTTM table

The table below is the NZGTTM table to which reference is made in this document.

Permanent speed limit or operating speed (km/h) where measured									
Parameter	**≤30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Traffic signs									
Sign visibility distance (m)	20	25	30	50	60	70	95	105	115
Sign visibility distance (sec)	2	2	2	3	3	3	4	4	4
Warning distance (m)	30	40	50	80	100	120	160	180	200
Warning distance (sec)	4	4	4	5	5	5	6	6	6
Sign spacing (m)	15	20	25	40	50	60	80	90	100
Sign spacing (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Exclusion zones									
Longitudinal exclusion (m): Sealed	25	35	50	65	85	105	125	165	195
Longitudinal exclusion (sec): Sealed	3	3	4	4	4	5	5	6	6
Longitudinal exclusion (m): Unsealed	30	40	60	80	105	135	165	215	255
Longitudinal exclusion (sec): Unsealed	3	4	4	5	6	6	7	8	8
Lateral exclusion (m)	1	1	1	1.5	1.5	1.5	2	2	2
Lateral exclusion (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tapers									
Taper length (m)	30	40	50	60	70	80	90	100	110
Taper length (sec)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Distance between tapers (m)	25	35	50	65	85	105	125	165	195
Distance between tapers (sec)	3	3	4	4	4	5	5	6	6
Lanes									
Temporary lane width (m)	2.75	2.75	3	3	3.25	3.25	3.5	3.5	3.5
Temporary lane width (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Delineation spacing straights (m)	5	5	5	10	10	10	15	15	15
Delineation spacing straights (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Delineation spacing curves and tapers (m)	2.5	2.5	2.5	5	5	5	10	10	10
Delineation spacing curves and tapers (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Threshold length (m)*	10	10	10	20	20	20	40	40	40
Delineation spacing in threshold (m)*	2.5	2.5	2.5	5	5	5	10	10	10
Curve									
Min curve radius for generic design (m)	35	60	100	140	190	250	315	390	470
Min curve radius for generic design (sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vehicle operations									
Clear sight distance (m)	100	135	165	200	235	265	300	335	365
Clear sight distance (sec)	12	12	12	12	12	12	12	12	12
Separation (min) from tail pilot to work vehicle (m)	25	35	45	65	75	85	120	130	150
Separation (min) from tail pilot to work vehicle (sec)	3	3	3	4	4	4	5	5	5
Separation (max) from tail pilot to work vehicle (m)	50	70	90	130	150	190	240	260	300
Separation (max) from tail pilot to work vehicle (sec)	6	6	6	8	8	8	10	10	10
Separation from shadow vehicle to work vehicle (m)**	15	20	25	30	35	40	45	50	55
Separation from shadow vehicle to work vehicle (sec)**	2	2	2	2	2	2	2	2	2
Separation (min) from work vehicle to lead pilot (m)	25	35	45	65	75	85	120	130	150
Separation (min) from work vehicle to lead pilot (sec)	3	3	3	4	4	4	5	5	5
Separation (max) from work vehicle to lead pilot (m)	50	70	90	130	150	190	240	260	300
Separation (max) from work vehicle to lead pilot (sec)	6	6	6	8	8	8	10	10	10

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