New Zealand guide to temporary traffic management

All workers and road users go home safe every day

WAKA KOTAHI
NZ TRANSPORT AGENCY

3

The toolbox

Part 3 sets out what we do to design a TTM site. It provides information about engineering design principles, geometrics, safety, traffic assessments, equipment, and specialist projects. This includes references to relevant design guides and standards.

Who should read this?

- Practitioners planning and preparing for temporary traffic management activity.
- Temporary Traffic Management Planner (TTMP).
- Site Traffic Management Supervisor (STMS).
- Corridor manager.
- Traffic management managers.
- Project managers.
- Contract managers.

Contents

TTM toolbox – what TTM engineering includes

Introduction

Structure

The toolbox has two main components:

- Design for TTM – the design section covers all engineering principles used to ensure the geometry, safety and traffic engineering are appropriate.
- Equipment for TTM – the equipment section covers equipment currently available for use on TTM sites. This includes both material and use specifications.

References and why we have them

This section of the NZGTTM includes references to several external documents. This is because:

- Most importantly, TTM is permanent road design delivered temporarily, so for geometric design and traffic engineering there's no need to develop TTM specific material.
- Many of the concepts of road safety are applicable to temporary traffic management.
- By referencing permanent design material, it's easier for a TTM planner to find what they need for complex TTM sites, for example major capital works projects with temporary road alignments. Note – common design information is included in the NZGTTM to assist with simple TTM sites.
- Design guidance is kept up to date with links to source documents for all reference information.

Professional advice

If at any time you are unsure how to proceed with the engineering of a TTM site, talk to a professional engineer. Note professional engineers often specialise in geometric design, safety or traffic engineering.

All major, and many smaller engineering consultancies have these skills. The key is knowing when professional expertise is required and when it's not. This skill set would be valuable to any major project such as construction of a new road or work on an arterial or state highway in a city. If in doubt, ask.

Design

Human behaviour guiding TTM design principles

Changing the permanent transport system using TTM measures influences human behaviour. Workers on the transport system are at risk of harm when exposed to many different hazards. The focus of the NZGTTM is on the risk from the interface between the activity and traffic. Whenever the permanent transport system is changed through a TTM site being installed, road users need to change their actions.

The users of the transport system are also at risk of harm when exposed to the hazards from a site – change in surface, geometry, roadside hazards such as trenches, plant, and partially completed guardrails, products such as bitumen, pedestrians exiting a concert, racing cyclists and more. These introduced and unexpected hazards pose a risk to road users.

The goal of any TTM measure is to aid road users to detect and navigate a TTM site in a manner that is both safe for them and safe for the worker. Road workers and road users are humans and humans all behave differently to what they see in front of them on a road. For comparison, water molecules in a pipe all behave the same for a given pressure and temperature. Humans, the workers and users of the transport system, all behave differently:

- Levels of comprehension or detection and reaction
  - "I didn't understand what the sign meant."
  - "I didn't know I wasn't allowed in the exclusion zone."
  - "What's an exclusion zone?"
- Risk tolerance
  - "I'm very nervous, I don't know how to drive on gravel."
  - "It's only a little snow, I have a 4wd, she'll be right."
  - "I can chuck some mix in the pothole in the gaps in traffic, stand back."
- Understanding of their rights of access to the transport system
  - "You can't stop me."
  - "Those are my car parks."
  - "I demand to drive down this closed street."
  - "I have an over dimension permit, get your TTM site out of my way."
  - "I have an approved TMP, you cannot come through here."
- Motivators/personal stress
  - "My business will fold if I can't deliver this product/get to this job today."
  - "My child is waiting for me at the school gate and very stressed."
  - "No worries I'll go another way."
  - "I've got to get this job done within the next 5 mins or we don't meet our contract KPI."

Providing for all the needs of those using the transport system is challenging, but Health and Safety at Work Act 2015 (HSWA 2015) requires that safety is prioritised above other risks.

From the seven guiding principles of Road to Zero, the following are key to TTM:

- We promote good choices but plan for mistakes.
- We design for human vulnerability.
- We make safety a critical decision-making priority.

Road design and safety are based on the concept of PIEV time, this is:

1. Perception – the time required for the sensations received by the eyes or ears and transmitted to the brain through the nervous system and spinal cord.
2. Intellection – the time required for understanding the situation. It's also the time required for comparing the different thoughts, regrouping, and registering new sensations.
3. Emotion – the time passed during emotional responses to the situation such as fear, anger, or even superstition. Therefore, the emotion time of a driver is likely to vary depending upon the problems involved.
4. Volition – the time taken for the final action.

PIEV time can also be described as the time between stimulus and response or just response time. This is the time from detecting something is different until the time the appropriate response is initiated.

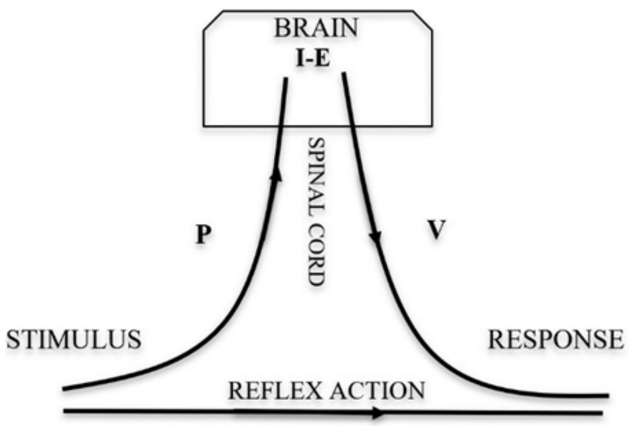

Figure 1 - PIEV time
Image credit: Civilease.com

Governing design principles

Given the PIEV time of humans, all design decisions need to communicate changes in transport system operating conditions to drivers, cyclists, pedestrians, and public transport users so they know what is expected of them and can safety use the changed transport system.

In designing a TTM site layout this means that we must provide clear:

- **Advanced warning** – make sure the public know there is a change to the road operating conditions ahead. This is typically the fact there is a TTM site ahead and the type of TTM site.
- **Guidance** – make sure the public know how to navigate the TTM site from advanced warning to return to normal.
- **Protection** – ensure protection from site hazards for the public or protection from traffic for workers.
- **Return to normal** – make sure the public know they have passed the TTM site and permanent road operating conditions and rules apply.

These are the most important principles for design of a site. If anything within the design section of the NZGTTM contradicts these principles, the governing design principles take precedence.

It is important to note that every change in road environment requires the drivers attention and has a prior PIEV time. For example, changes include a speed change, a lane shift/change, a loose surface, a stop/go operation, a follow me, or a works end sign.

A useful practical example is advanced warning sign spacing. Advanced warning must always be provided to allow time for drivers to take in the change in conditions and react appropriately in a time. If something changes such as queue lengths increase, the advanced warning signs must be relocated so they remain effective. This may happen when traffic flows increase beyond the capacity of a manual traffic control system. An advance warning sign that is midway along a stationary queue is no longer an advance warning sign.

Geometric design

Geometric design guides help us make sure the shape of a road is appropriate for the way it's being used. It's based on PIEV time as well as physics such as braking forces (kinetic energy and friction), and cornering forces (radial acceleration and friction). Dimensions used are usually time (seconds) and distance (meters).

Horizontal and vertical geometry

The traditional approach to permanent design is to consider both horizontal and vertical geometry and combine them into one complete three-dimensional design.

Horizontal geometric design is designing the straights, curves, cross-section widths and crossfall of roads. It deals with time and distance in 2 dimensions, along the road and across the road (coordinates).

Vertical geometric design is designing the gradients and crest and sag curves of roads. It deals with time and distance in one dimension, height or depth (levels).

It's very important horizontal and vertical geometry are considered when assessing required clearances, lane widths, taper rates and taper distances for a TTM layout. It's also very important they are reassessed when the layout has been installed on site. However, the majority of TTM layouts won't involve a change to the existing shape of the road surface, so where the lanes are temporarily moved (contra-flow, tapers, temporary curves) apply appropriate speed limits to make sure travel along the horizontal and vertical geometry of the existing road is safe.

Where this isn't appropriate, temporary changes to the road surface may be necessary. These changes must be removed when the temporary layout is no longer required.

Seek professional engineering advice if you're unfamiliar with these issues.

Design for users

Design decisions must consider all transport system users and make provision for them if they use the road network affected by the works or activity. Common transport system users can include:

- blind and low vision users
- mobility impaired
- pedestrians
- cyclists
- public transport
- light vehicles
- heavy vehicles
- over-dimension and over-mass vehicles.

Providing for these transport users, or any others identified, can be done through creating separated facilities, combined facilities, exclusion or redirection. Regardless of the approach, all user types identified must be considered and a decision made. It's unacceptable to ignore any user group.

Detailed design references

Below is a list of references to assist with design of TTM for TTM sites.

- Traffic Control Devices Manual part 1 2010 – nzta.govt.nz/resources/traffic-control-devices-manual/index.html
- Austroads Guide to Road Design part 3 2021 – austroads.com.au/safety-and-design/road-design/guide-to-road-design
- Waka Kotahi NZ Transport Agency Pedestrian Network Guidance (2021) – nzta.govt.nz/walking-cycling-and-public-transport/walking/walking-standards-and-guidelines/pedestrian-network-guidance
- Public transport design guidance – nzta.govt.nz/walking-cycling-and-public-transport/public-transport/public-transport-design-guidance
- Temporary bus stops - nzta.govt.nz/assets/resources/code-temp-traffic-management/docs/Section-I-13-bus-stops-copttm-4th-ed-may2016.pdf
- Cycling network design guidance – nzta.govt.nz/walking-cycling-and-public-transport/cycling/cycling-standards-and-guidance/cycling-network-guidance/designing-a-cycle-facility/#design-guidance
- Road safety barrier systems – nzta.govt.nz/assets/resources/road-safety-barrier-systems/docs/m23-road-safety-barrier-systems-appendix-c.pdf

Go to austroads.com.au/publications/road-design/agrd-set for the full ***Austroads Guide to Road Design***.

Specific references for various design elements are provided below.

Advanced warning

- Providing the appropriate information to all network users before they reach a change in the road operating conditions. This is to allow them to make an informed decision in a timely, safe manner.
- Visibility of devices due to both corners (horizontal geometry) and crests and dips (vertical geometry) – *Traffic Control Devices Manual* part 1, section 7.3 Location.

Guidance

Providing enough time for the public to identify the route including relocation to the correct lanes.

- Visibility of devices due to both corners (horizontal geometry) and crests & dips (vertical geometry) – *Traffic Control Devices Manual* part 1, section 7.3 Location.
- Advanced warning time (distance) should be longer than any traffic queue – see page 72 for more information on working out queue lengths.
- All horizontal and vertical design – *Austroads Guide to Road Design* part 3 (2020) and Waka Kotahi NZ Transport Agency Supplement TM-2501. This covers lateral shifts, curves, crossfall, and warp rates. Note temporary roads must have their geometry checked.

Lane dimensions to ensure all users have sufficient space.

- Traffic lane widths (horizontal geometry) – *Austroads Guide to Road Design* part 3 (2020), section 4.2.4
- Bus lane widths (horizontal geometry) – *Austroads Guide to Road Design* part 3 (2020), section 4.10.2
- Bus stops – Waka Kotahi public transport design guidance
- Cycle lane widths (horizontal geometry) – Waka Kotahi Cycling network design guidance
- Cyclists at intersections – Waka Kotahi Cycling network design guidance
- Footpath widths (horizontal geometry) – Waka Kotahi Pedestrian network guidance, Design
- Pedestrians at intersections – Waka Kotahi Pedestrian network guidance, Design

Safe and appropriate speed limits to ensure safety and compliance

Speed limit selection is subject to human body tolerances, vehicle technology and both horizontal and vertical geometry. There are two methods to determine an appropriate speed for a TTM site. It's recommended they're applied in the following order:

- **Human activity based** – the primary speed decision process. The human body can only withstand so much force before injuries become fatal. So, how humans are physically affected by motorised vehicles guides the selection of an appropriate speed limit. This is the best way choose a speed limit. The following table shows target speeds for different activities. These speeds have been taken from research by Wramborg, P. (2005) and later reviews.

Activity – sites with	Target safe system speed
possible crashes between motorised vehicles and: • workers on foot • pedestrians • cyclists • any other person affected and not protected by a vehicle.	30 km/h
possible side-on crashes between vehicles	50 km/h
possible head on crashes between vehicles	70 km/h

- **Environment based** – the secondary speed decision process. The speed should be appropriate for the road environment. In this situation the geometry (vertical and horizonal curves), roadside infrastructure, surfacing, weather etc are considered.

Environment – sites with	Target safe system speed
• significant loose material on surface (fresh chip seal or steel plates) • step in surface (pavement milled) • tight radius curves with no or adverse superelevation	30 km/h
• limited loose material on surface (pavement rebuilt but unsurfaced, recently swept chip seal, secured steel plates) • moderate radius curves with no or adverse superelevation	50 km/h
• small potholes – vehicle tyre does not drop into them, pavement cracking, pavement deformation • moderate radius curves with superelevation	70 km/h

Protection

Ensuring that those who do not observe the controls do not crash into queued traffic, people, or plant on the site:

- Safe stopping distances (subject to both horizontal and vertical geometry) – *Austroads Guide to Road Design* part 3 (2020), section 5.3
- Roadside safety space (for risk mitigation, recovery or stopping safely when lose control) – *Austroads Guide to Road Design* part 6 (2020), section 3.5
- Shy lines (the closet to an object that a driver feels comfortable driving) – *Austroads Guide to Road Design* part 6 (2020), table 5.4
- Crash protection systems – Waka Kotahi Specification M23 appendix C.

Return to normal

Providing enough time for the public to know they have left the TTM site and permanent road operating conditions resume:

- Visibility of devices due to both bends (horizontal geometry) and crests and dips (vertical geometry) – Traffic Control Devices Manual part 1, section 7.3 Location.

Common horizontal and vertical geometry information

As many of the sites TTM is prepared for are simple TTM sites, the following table is a summary of common geometric design information from the references above. The engineering detail for each of these dimensions can be found in the basis of dimensions guidance note. Values in Table 1 have been rounded.

The dimensions are given in both time and distance. It's expected that distance will used for planning, however both time and distance will be used for TTM site set-out. For example, when setting out a TTM site, the sign visibility distance of 3 seconds can be used to determine the location of an advanced warning sign. The STMS can do this by measuring the time from when they can first see a vehicle until it passes the point where the sign is proposed to be installed. This ties in with the operating speed rather than the permanent speed limit, creating a fit for purpose solution.

Note the separation from shadow vehicle to working vehicle distances. The separation needs to account for two risks:

- The roll forward risk – this is where a shadow vehicle rolls forward after being struck by an approaching road user and strikes a worker or the working vehicle.
- Lane re-entry risk – this is where a road user re-enters the lane between the shadow vehicle and the workers or the working vehicle.

If the shadow vehicle is too close to the workers or working vehicle, the roll forward risk could happen. If the shadow vehicle is too far away from the workers or working vehicle, the lane re-entry risk could happen. Unfortunately, the roll ahead distance is often longer than the lane re-entry distance. Waka Kotahi has commissioned expert advice on this matter and will update this section of the NZGTTM as soon as possible.

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

Table 1: Common geometric dimensions

* values additions since V1 of the table was released to the industry

** values subject to amendment based on further research being done

Safety assessment

The land transport system is made up of two main parts – intersections and links. This information will help with risk assessments, decisions around identifying the appropriate fundamental TTM controls and the detailed design of the TMP for the TTM site.

Waka Kotahi has more information on safety and identifying and assessing risk for rural roads and intersections:

- High Risk Rural Roads Guide - nzta.govt.nz/resources/high-risk-rural-roads-guide
- High Risk Intersections Guide - nzta.govt.nz/resources/high-risk-intersections-guide

Intersections

The fewer conflict points and the lower the speed, the lower the risk. In order of least safe to most safe, intersection forms are:

1. Uncontrolled intersections – no stop or give way sign .
2. Give way controlled intersection.
3. Stop controlled intersection.
4. Traffic signals.
5. Roundabout.
6. Grade separated interchange.

Additional information

a. Higher speed at an intersection = higher risk from higher probability and higher consequence.

b. More approaches (legs) = higher risk (greater probability and consequence). Crossroads (4-way) intersections are more dangerous than T intersections (3-way). This is because there are more conflict points, that is, points where paths of vehicles overlap. Figure 2 shows the conflict points of a four-way intersection.

c. Some crash types are higher consequence. Glancing crashes are generally safer than T-bone crashes. Roundabout crashes are usually glancing crashes rather than T-bone because of the curved travel path. Interchanges, while high speed, are low angle glancing crashes.

d. Y intersections have a higher probability of crashes than T intersections. This is because drivers must look over their shoulder and have trouble judging the speed of an approaching vehicle.

e. Property entranceways and site accesses are also intersections and must be considered when doing risk assessments.

Cycling and pedestrian movement through intersections follows the same principles regarding speed and conflict points. However, as cyclists and pedestrians travel at a different speeds to motorised vehicles this means the order of least safe to safest intersection types is different:

1. Interchange in high-speed environments.
2. Roundabouts in high-speed environments.
3. Roundabouts in low-speed environments.
4. Interchange in low-speed environments.
5. Uncontrolled intersections – no stop or give way sign.
6. Give way controlled intersection.
7. Stop controlled intersection.
8. Traffic signals.

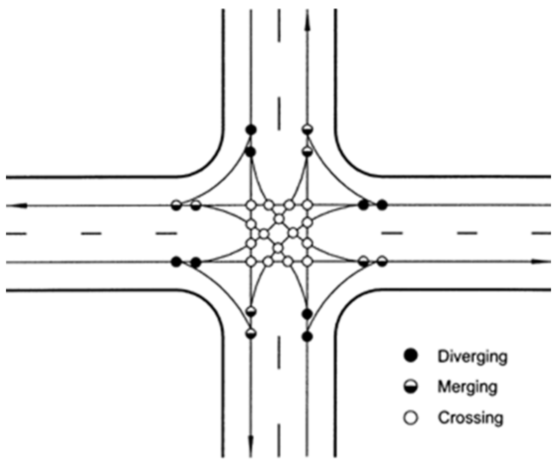

Figure 2 Four way intersection conflict points
Source: Federal Highway Administration Research and Technology

Links

A link, also known as mid-block links, is a section of road or path between intersections. The safety of a link is dependent on the cross section, speed, traffic volume, and any features that introduce vulnerable user crossings, such as pedestrian crossings and schools.

- Cross section
  - Where the cross section has many hazards such as poles, drainage ditches and headwalls, risk increases through higher probability of an out-of-control vehicle coming to an abrupt stop.
  - Where the sealed pavement is narrow, risk increases. This is because there is less space and time for drivers to correct steering errors, for example, an unsealed shoulder or no shoulder. A wide sealed shoulder is safer than an unsealed one, and an unsealed shoulder is safer than no shoulder.
  - Where there is no protection, such as guard rails, from roadside hazards or oncoming vehicle, the risk of a severe crash increases.
  - Where there is something on the surface that reduces skid resistance the risk of a loss of control crash increases. Examples include, gravel road, sealing chip, ice, snow, rain, flooding, mud from slips and soil tracked onto the road.
  - Where permanent delineation is poor or there is none, the risk of a run-off-road crash increases, especially in low light conditions. Examples include, no line marking, no raised reflective pavement markers, or no edge marker posts.
- Speed
  - Speed increases both probability and consequence of a crash. A higher speed means less time for drivers to correct errors and increases severity when something does go wrong.
- Volume of traffic
  - At high speeds, high volumes of traffic increase the probability of a crash. However, when congestion occurs, for example high volumes at low speeds, the volume no longer matters as low speed greatly reduces crash severity.

The information above will help with risk assessments, decisions around identifying the appropriate fundamental TTM controls and the detailed design of the TMP for the TTM site.

Traffic impact assessment

The priority of the TTM layout must always be the safety of road workers and the wider public network users. However, there may be occasions when alternative solutions provide an acceptable level of safety, while minimising disruption or delays to the network users.

Delay information will help with both risk assessment and design. Longer delays can increase the risk of drivers making poor choices due to frustration. Delays, specifically queue lengths, inform detailed design of the TMP for the TTM site.

For traffic impact assessment guidance the *CTOC Transport Efficiency and Impact Guide* is a suitable option found on the CCC Transport page. ccc.govt.nz/assets/Documents/Transport/CTOC/1804-CTOC-Transport-Efficiency-and-Impact-Guide.pdf

Note this was written during the rebuild of Christchurch and at a time when journey efficiency was as important as safety. This is no longer correct – safety has priority.

The following points are a summary of the key concepts:

- Delays are calculated for intersections and links separately and summed to determine the impact on a journey. There are several formulas to aid in both scenarios.
- Flow and speed are related through traffic density. As flow increases, speed slowly decreases, until capacity is reached – maximum density. At maximum density this is also maximum flow, any increase in flow will result in slowing of speed. This is called flow breakdown.
- Capacity of any lane is 1800 vehicles per hour (vph) because of the two second rule. The shortest distance between any two vehicles at maximum density is two seconds. As an hour is 3600 seconds, at two seconds between vehicles this results in 1800 vehicles per hour.

$$\frac{3600 \frac{\text{sec}}{\text{hr}}}{2 \frac{\text{sec}}{\text{veh}}} = 1800 \frac{\text{veh}}{\text{hr}}$$

- The 1800vph per lane is the basis, however it must be modified for various scenarios:
  - 30kph temporary speed limit has a capacity of 1500 vehicles per hour. If the front bumpers of two cars are two seconds apart at 30kph, the following car would crash into the car in front.
  - A merge at any speed has a capacity of 1300vph. This has been observed at many merges. It is because of the varying choices of drivers when merging – not all drivers merge like a zip.
  - Intersections lower capacity by reducing the time within an hour that movement can be made. For example, a traffic signal provides 65% of each cycle to the main road and 35% to the side road, so the capacity on each road is a percentage of the 1800 vehicles per hour. Main road capacity is.

    $$1800 \frac{\text{veh}}{\text{hr}} \times 0.65\% = 1170 \frac{\text{veh}}{\text{hr}}$$

    This is a great way to do a basic analysis of an intersection, but when there are right hand turn phases, uncontrolled movements, and random arrival of opposing traffic, it quickly becomes more complicated.
  - Stop/go or portable traffic signals are the same as traffic signals, only part of the hour is available to any one movement, so capacity is less than 1800vph. Stop/go is more complicated as the time it takes for the last car to enter and exit the TTM site must also be counted. At 30kph or 8.34 meters per second, it can take 18 seconds for a car to travel through a 150m TTM site.

- Queuing happens when traffic is stopped or when demand is higher than the capacity.
  - For stopped traffic such as stop/go, traffic signals, the queue length is determined by assessing the flow rate and the time of the stop. For example, if the flow rate is 1000vph and traffic is stopped for 40 seconds this leads to a queue length of:

$$40\text{sec} \times \frac{1000 \dfrac{\text{sec}}{\text{hr}}}{3600 \dfrac{\text{sec}}{\text{veh}}} \times 8 \frac{\text{m}}{\text{veh}} = 88.9\text{m}$$

  - When the traffic volume approaching a location is higher than the capacity, queueing will happen. For example, if there are 1500vph approaching a merge with 1300vph capacity, 200 vehicles will queue per hour.
  - Queues grow over time. Using the merging example, if a demand is 1500vph for two hours, there will be 200 vehicles queued at the end of the first hour and 400 vehicles queued at the end of the second hour.
  - Each vehicle takes up around 8m of space on average – some vehicles are shorter and others such as trucks are much longer. So, 400 queued vehicles will create a queue of around 3,200m (3.2km).

Equipment

General

All temporary traffic management equipment must be manufactured to comply with the relevant specifications and test protocol. Details of accepted equipment are in the Waka Kotahi M23: Specification and guidelines for road safety hardware and devices on our website at nzta.govt.nz/resources/road-safety-barrier-systems

Lightweight TTM equipment not requiring specific crash testing is listed in the M23 appendix F. This contains details relating to:

- delineation devices including cones, tubular delineators, barrels etc
- channelising devices including cone bars and traffic separators
- access prevention (fences)
- temporary traffic control systems
- beacons, arrow boards and light arrow systems
- advanced warning variable message systems (AWVMS)
- hazard covers
- temporary sign standards and supports
- traffic calming and arrest systems.

Further products will be added as they are submitted and assessed through the acceptance process outlined in the M23.

The M23 appendix F also contains relevant specification information relating to some TTM equipment that may be developed into standalone specification documents over time.

Heavy TTM equipment requires crashworthiness testing to an agreed international crash test protocol to ensure safe performance when correctly deployed. Currently Waka Kotahi uses the *AASHTO Manual for Assessing Safety Hardware (MASH)* protocol. Accepted equipment meeting the requirements of this protocol is listed in the M23 appendix C which covers:

- Temporary road safety barrier systems.
- End treatments to be used with the above barrier systems.
- Truck- and trailer-mounted attenuators.

Any equipment not covered by the specification or on the approved list must be submitted to the Waka Kotahi Programme and Standards Lead Safety Advisor for review and acceptance on a project or site-specific basis.
Email m23.queries@nzta.govt.nz

High visibility clothing

High visibility clothing is important at TTM sites, though as the hierarchy of controls shows, it's the least effective risk mitigation control.

Details of specifications for high visibility clothing for TTM purposes can be found in Waka Kotahi Specification E06 *Specification for the design and manufacture of high visibility safety garments for temporary traffic control purposes*.

Specialist projects

Where a project requires use of specialist equipment not listed in this toolbox, its use must be supported through a detailed risk assessment. Examples of this are as follows:

- Hostile vehicle mitigation
  Where there is a clear and present danger of someone using a vehicle to cause intentional harm, hardened devices such as concrete blocks or heavy plant may be used to stop the hostile vehicle. These devices will cause harm, so the lowest total risk assessment must be robust enough to support the use of this equipment.
- Race end gantry
  For the end of a race, a race end gantry may be used to signal to participants the end of a race and a shift in focus from racing to application of road rules.
- Banners/bunting
  To guide large crowds across roads to a large event.
- Portable lighting
  If the function of an intersection or crossing is changing either in purpose or volume of people using it, additional lighting may be necessary.

Te Kāwanatanga o Aotearoa
New Zealand Government