A strategic alliance safety project

Design of road worksites for traffic accommodation

DRAFT REPORT for Industry Review

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1 Introduction

Extensive investment in new transport infrastructure is continuing and there is also an increasing program of activities directed to the enhancement and preservation of existing transport infrastructure.

This investment is required to try and match the growth in travel on roads in Australia which continues unabated as shown in Figure 1-1.

**Figure 1-1. Vehicle km travelled - Australia**

Many segments of the Australian road network constructed are approaching or have exceeded their design lives, either in terms of the pavement life or in terms of meeting current traffic demands. As a result, construction activity on existing facilities is increasing at a time when the facilities are of increasing importance to economic efficiency and social activity.

The challenge with continuous management of the road network is assuring their adequate performance in the near term and far into the future. The roadworks required to improve infrastructure are a source of potential disruption that often impede mobility and are widely perceived as locations of elevated crash risk. Management and design strategies can substantially reduce the negative consequences caused by roadworks.

This publication is intended to guide roadwork design decisions associated with road construction and maintenance activities.

Historically, plans for roadworks have emphasised temporary traffic control devices intended to facilitate travel through roadworks by the use of devices that inform, advise, and regulate motorists. Guidance for the development of Traffic Management Plans (TMPs) and Traffic Guidance Schemes (TGSs) is outlined in Australian Standard AS1742.3: Manual of Uniform Traffic Control Devices (MUTCD) Part 3: Traffic Control for Works on Roads (Standards Australia 2009). In Queensland, the Transport and Main Roads produced MUTCD Part 3: Works on Roads (TMR 2013) replicates most of this document but includes additional Queensland specific details, practices and guidance.
While the importance of Traffic Control grows as traffic exposure and public expectations increase, there are additional aspects of construction roadworks for which guidance is needed that are not covered by the MUTCD or other publications. In general, this guidance is related to the geometric characteristics and physical infrastructure of roadways within roadworks. Consequently, this publication is intended for use in conjunction with the MUTCD, not as a substitute.

This report on guidance for designing the geometric features of roadworks, is intended ultimately for use in national application. It supplements the MUTCD and other nationally disseminated publications addressing aspects of roadway and roadside design at roadworks. The Austroads (2012) research report “Implementing National Best Practice for Traffic Control at Worksites – Risk Management, Audit and Field Operations” provides guidance to assist designers consider the risks in the design of roadworks sites.

This report provides an approach for the selection of an appropriate roadworks strategies. Guidance and design references for the design of geometric features, including horizontal and vertical alignment, cross-sectional features, and barrier placement is included. Guidance for a variety of ancillary features (e.g., drainage systems, lighting, and surface type) is also provided.
2 Contracting Strategies and Considerations

Traditionally, road construction is undertaken during specified daylight hours by contractors procured through one of a range of contract models. In heavily trafficked areas and cities, the approach being used more frequently is to require that construction and maintenance activities with major impact to be performed during off-peak traffic periods (including at night).

Typically in the majority of contracts, the road authority prepares the contract documents, and typically include either a road authority prepared roadworks traffic management plan or a set of traffic management requirements that must be complied with. In some cases, the contractor may propose an alternative roadworks design, which can be adopted if approved. In Queensland, the current practice has been for the road authority to have the final approval for traffic management plans and traffic guidance schemes.

In the typical contract process, the costs for traffic management at the roadworks has been defined as a “below the line” cost item. That is that while the contractor submits a price for the traffic management, that price is not included in the assessment and selection of the preferred contractor. This practice was likely introduced to ensure that the “cost-cutting” was not employed in the traffic management aspect of the contract bid. While this outcome led to a higher level of quality at roadworks traffic management, it is also arguable that it has reduced the innovation within the industry in the development of traffic management techniques that provide broader advantages to the road agency.

With the shift in responsibilities now proposed in the draft versions of the TMR Standard for the Provision for Traffic (MRTS02) (TMR 2013 unpublished), there is now an intended increase in onus on the lead contractor, and the Traffic Management Companies employed, to consider and develop alternative traffic management plans which provide an improved level or service for traffic or improved constructability while maintaining or improving the safety at the roadworks.

There are a range of alternative contracting strategies which can be employed to reduce the impacts of construction on traffic. These strategies include alternative procurement techniques and contract provisions and are discussed below.

2.1 Alternative Contracting Techniques

Avoiding and reducing the traffic impacts of roadworks is an impetus for alternative contracting techniques and for specifying that work be undertaken at night. Other reasons for using alternative contracting techniques are to improve quality, and reduce project delivery time. The alternative contracting processes with the closest relationship to roadworks design, as described in Mahony et al (2007), are as follows;

- A+B bidding,
- Design-build contracting,
- Incentive-disincentive provisions, and
- Lane rental.

These contracting techniques can be regarded as a means to reduce roadwork impacts on traffic flow.
These strategies can be combined together in a single contract. For example, lane rental could be combined with A+B bidding or incentive-disincentive provisions. The strategies should be consistent with each other and with road authority goals. For example, a lane rental fee structure designed to discourage peak-hour traffic interference may not have its intended effect if the contract also includes an early completion incentive that is large enough to economically justify occupying lanes during peak-hour periods.

The role and responsibilities of contractors varies substantially with contracting type. This variation is intended and provides for a range of outcomes which can be determined by the road authority. Each of these contracting strategies and some of the associated opportunities and implications are described below.

2.1.1 A+B Bidding

This technique, used in the US, establishes the total cost to both the road authority and the community. This contracting technique, is also known as cost-plus-time bidding, and the total cost for each “bid” is computed using Equation 2-1.

\[
\text{Bid} = A + Bx
\]  

(2-1)

Where

\(A\) = the dollar amount to perform all work identified in the contract, as submitted by the bidder;

\(B\) = the total number of calendar days required to complete the project, as estimated by the bidder;

\(x\) = Road user cost per day as determined by the road authority.

This technique may be applied either to the entire contract value or to just the traffic management element of the contract. The total value of each bid is computed by considering the community costs of the traffic management scheme proposed by each contractor and the contractor bid.

A tool under development at Queensland Transport and Main Roads utilises results from a micro-simulation model within a spreadsheet format to undertake this form of analysis. The analysis allows alternative traffic management arrangements to be compared to determine the road user costs associated with each treatment and the variations in intensity of road user costs throughout the duration of the works. For each traffic management arrangement alternative construction and traffic management costs are input to establish the arrangement which leads to the lowest total cost.

Under the A+B arrangement, there can be a penalty for each day in excess of B used by the contractor to actually complete the work, or where impacts on traffic are being imposed. There would also be a reciprocal incentive provision when the actual number of days to complete construction is less than the number of days bid (B).

This arrangement leads to a strong business incentive to minimise the number of days needed to complete the specified work. Therefore, the contract documents must clearly indicate contractor duties and limitations with regard to traffic control and roadwork design. This strategy is generally applied to projects with a high potential for mobility and/or safety impacts, generally on high-volume roads that do not have reasonable detour routes.
2.1.2  Design & Construct

This contracting method is used most commonly for larger projects where the road authority procures a single contract providing for both design and construction. Benefits attributed to design & construct contracting include time savings, contractor innovation, and administration efficiencies.

 Preferably, a design and construct project should have a strong creative design component. Relatively simple projects, such as roadway resurfacing or minor roadway widening, do not provide significant design components and are not the ideal type of projects for this contract type.

Under design and construct contracts, to provide the greatest opportunity to realise benefits, roadwork and temporary traffic management design is generally the responsibility of the contractor. In some cases, the road authority may provide a schematic or conceptual plan, and in other cases, the development of the entire TMP may be assigned to the design and construct contractor. The road authority generally specifies its high-level requirements and acceptable criteria and processes. Examples of high-level requirements may include: minimum number of lanes by day and time (e.g., holidays and peak periods), access requirements and allowances, noise restrictions, and public information programs.

2.1.3  Incentive-Disincentive Provisions

Incentive-disincentive contract provisions provide for specified financial consequences to contractors based on actual completion of identified work (considered critical by the road authority) relative to scheduled completion. The schedule (calendar days or completion date) for critical work items is established by the road authority and identified in the bid documents. A daily incentive-disincentive amount is also established in the procurement documents. Additional contractor payment (i.e., incentive payment) is made for each day that the identified critical work is completed ahead of schedule, and contractor payment is reduced for each day that the contractor overruns the scheduled completion.

Incentive-disincentive provisions are intended primarily to minimise roadwork impacts on critical projects. The determination of incentive-disincentive daily amounts includes consideration of traffic safety, road user delay, and maintenance of traffic costs.

As it relates to roadwork design and traffic control, the use of an incentive-disincentive provision is somewhat similar to A+B (cost-plus-time) bidding. The contract documents must clearly indicate contractor duties and limitations with regard to traffic control and roadwork design.

2.1.4  Lane Rental

Lane rental involves assessing a pre-established fee to occupy a lane or shoulder as part of the contract. Rental rates are established by the road authority in the procurement documents and are typically stated in dollars per travel lane or shoulder per time period (e.g., day, hour, or fraction of hour), with peak periods carrying higher rates. The anticipated times or durations of occupation are not stated in the agency procurement or bid. The contract is awarded to the low bidder on the basis of pay items.

During execution of the contract, rental fees are computed by the road authority based on the rental rates and actual times that the contractor occupies travel lanes and shoulders. The rental fees reduce the net amount paid to the contractor and provide a financial incentive to minimise the duration of contractor occupations and hasten return of the facility to service.
The lane rental approach allows some flexibility in the distribution of roadwork design assignments between road authority and contractor. The conventional approach of providing a roadwork design with the contract documents is workable and common. When a traffic management plan and/or construction phasing plan are provided, the competitive and innovative forces are focused on minimising the time that travel lanes are occupied while completing the identified work. Alternatively, a road authority may identify the high-level requirements and lane rental fee schedule. This more open approach allows the contractor greater flexibility and more areas of potential innovation.

2.2 Night Construction

Conducting construction operations and implementing the associated capacity-reducing measures during periods of reduced traffic demand is a method of bringing available capacity more closely into balance with demand. Night traffic volumes are generally lower and consequently, night work as a means of reducing impacts is becoming more common.

When commercial land uses abut facilities being constructed (or reconstructed), access by customers and suppliers may be impaired. Restoring access and capacity during non-work periods (i.e., business day and time) reduces impacts. This consideration is more important in commercial areas, where speeds tend to be lower.

There are many costs involved in road construction, including those related to safety, user delay, and possible economic disruption. Road Authority costs are those paid to employees, contracting constructors, and engineers. These costs tend to be higher for night construction because of additional devices, wage differential, and producer costs. Additionally, road authorities and personnel experienced in administering night construction often refer to elevated risk factors (e.g., higher speeds, impaired drivers, and reduced visibility).

Construction often creates noise levels that while they may be tolerable and conform to regulations during day hours, may not be at night. Also, nearly all construction operations (e.g., materials placement and compaction) are vision dependent. Although lighting systems can mitigate this somewhat, there remains a concern that some work is compromised by limited visibility.

Specifying night work is a contracting strategy that is increasingly attractive to many road authorities. However, a careful evaluation of potential ramifications should be conducted before selecting this alternative. Paving high-volume roads is a common project type for this strategy.

2.3 Evaluation of Contractor Proposed Roadwork Designs

Historically, in the majority of projects, the major intent of the traffic management plan has been specified by the road authority, either through actually providing a traffic management plan to be applied, or through specifying the minimum road space that must be retained available to traffic.

Combined with the practice of traffic management costs not being included in the assessed contract price, this has potentially led to traffic management provision not providing the best value for money outcomes. Instead in many cases the applied traffic management has become a “more is better” outcome. There is a current desire within Queensland Transport & Main Roads to encourage more innovation in contracting and in the provision of traffic management. This has now led to a desire to allow contractors to suggest alternative traffic management arrangements.
In situations under which contractors develop roadwork designs and submit them for approval or concurrence, there are potential opportunities for greater efficiency in the construction program and sequencing to be realised. The evaluation of these traffic management plans by the road authority should consider factors such as the inherent safety for works, impacts on traffic in terms of both safety and travel delays, community impacts and acceptability by the road authority.
3 Conceptual Design & Planning of Roadworks

There are a wide range of traffic management strategies that can be applied in undertaking roadworks. It is rare that a contractor will be able to choose from all strategies and often the preferred design will be determined by site specific conditions and contractual requirements.

3.1 Designing for Maintenance and Future Works

In many cases the planning options for undertaking roadworks are constrained by decisions made at the time a road is initially designed and constructed. The practices and policies implemented within the initial design statement have direct and indirect impacts on the options available for maintenance and upgrade works.

For example, the most cost-efficient initial design for a road may entail construction of only the minimum pavement and formation width. However, this measure to minimise the pavement and formation width at the time of construction of a road, inherently limits the options for the maintenance, resurfacing and upgrade of the road.

Some road maintenance activities (e.g., resurfacing and deck repair) pose a limited number of design alternatives and perhaps even fewer feasible roadwork alternatives. However the initial design can limit these alternatives even further and substantial impacts can occur in connection with routine projects. The impacts may extend far beyond the limits of the roadworks and may take the form of traffic congestion, interruption of business, commercial and industrial activity, cost overruns, decreased constructability, adverse safety impacts, disturbance of local travel patterns and community complaints.

Roadwork design decisions should therefore be a key element of the design brief in project development. Alternative roadwork strategies, along with their impacts, mitigation, and costs should be evaluated at the same time as, and in conjunction with, other design factors. The level of detail to which roadwork issues are evaluated should be proportional to the potential roadwork consequences.

3.2 Project-Level Roadwork Strategies

All roadwork projects require a strategy, or set of strategies, to accommodate the construction operations while ensuring safety of workers and the public while maintaining acceptable traffic operations. These strategies are outlined in traffic management plans (TMPs), which are prepared for specific projects.

When potential impacts are substantial, a comprehensive, integrated and proactive roadwork management plan and design effort is needed. Impacts may be mitigated through strategies such as traffic demand reduction measures, community involvement and information, provision of permanent facilities with wider cross sections to accommodate temporary traffic use during construction, innovative construction techniques, incident management, and advanced traveller information systems.

In all cases, a strategy is needed to carry traffic through, past or around the roadworks through a system of infrastructure and traffic controls. This section identifies common roadwork strategies and
factors that should be considered in the selection process. The following strategies are options for the accommodation of traffic at roadwork sites:

- Alternating one-way operation,
- Detour
- Diversion
- Full road closure
- Intermittent closure
- Lane closure
- Lane constriction
- Median crossover, and
- Use of shoulder.

These strategies are not necessarily separate, individual choices. In fact, several of them are only a partial solution and would need to be implemented in coordination with other strategy(s). Use of a full road closure requires one or more additional strategies (e.g., detour or diversion). Some are mitigation strategies, meaning that they can be used to offset the negative consequences (e.g., reduced capacity and access limitations) for one or more other strategies.

The basic characteristics of individual roadwork design strategies result in general advantages and disadvantages, as summarised in Table 3-1 and outlined in successive sections.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Summary</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternating one-way</td>
<td>Mitigates for full or intermittent closure of lanes. Used primarily with</td>
<td>Low agency cost and low non-transportation impacts; flexible, several</td>
<td>Requires stopping of traffic; reduces capacity.</td>
</tr>
<tr>
<td>one-way operation</td>
<td>two-lane roads.</td>
<td>variations available.</td>
<td></td>
</tr>
<tr>
<td>Detour</td>
<td>Reroutes traffic onto other existing facilities.</td>
<td>Flexible; cost varies depending on improvements to detour route; in some</td>
<td>Usually reduces capacity; service and infrastructure on existing roads may</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cases, only traffic control devices needed.</td>
<td>be degraded; may need agreement of another agency.</td>
</tr>
<tr>
<td>Diversion / Side track</td>
<td>Provides a temporary roadway adjacent to construction</td>
<td>Separates traffic from construction; reduced impact on traffic.</td>
<td>Cost may be substantial, especially if temporary grade separation for</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>drainage or watercourses are involved; right-of-way often required.</td>
</tr>
<tr>
<td>Full road closure</td>
<td>Closes the facility to traffic for a specified (limited) duration.</td>
<td>Generally also involves expedited construction; separates traffic from</td>
<td>Some form of mitigation is needed (detour, diversion, etc.); potentially</td>
</tr>
<tr>
<td></td>
<td></td>
<td>construction.</td>
<td>significant traffic impacts.</td>
</tr>
</tbody>
</table>
Table 3.1 Summary of roadwork strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Summary</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent closure</td>
<td>Stops traffic for a short period.</td>
<td>Flexible and low agency cost.</td>
<td>Useful only for activities that can be completed in short time; requires stopping traffic.</td>
</tr>
<tr>
<td>Lane closure</td>
<td>Closes one or more travel lanes.</td>
<td>Maintains service; fairly low agency cost if temporary barriers are omitted.</td>
<td>Reduces capacity; may involve traffic close to active work.</td>
</tr>
<tr>
<td>Lane constriction</td>
<td>Reduces travelled way width.</td>
<td>Maximises number of travel lanes.</td>
<td>Travelled way width is less than desirable; may involve traffic close to active work.</td>
</tr>
<tr>
<td>Median crossover</td>
<td>Maintains two-way traffic on one roadway of a normally divided highway.</td>
<td>Separates traffic from construction; right-of-way not required.</td>
<td>Reduced capacity; not consistent with approach roadway; relatively costly; interchanges need special attention.</td>
</tr>
<tr>
<td>Use of shoulder</td>
<td>Uses shoulder as a travel lane.</td>
<td>Fairly low cost, depending on shoulder preparation.</td>
<td>Displaces traditional refuge for disabled vehicles; debilitates shoulder pavement structure; cross slopes may be problematic</td>
</tr>
</tbody>
</table>

3.2.1 Alternating One-Way Operation

This roadwork strategy is typically used on two-way roadways wherein opposing directions of travel take turns using a single travel lane. Traffic Controllers, with or without pilot vehicles; STOP / GIVE WAY signs; or signals are normally used to coordinate the two directions of traffic. This strategy compensates for the removal of permanent travel lanes from service and is referred to in the MUTCD as single lane operation under reversible flow.

There are several variations of this strategy related to the type of control employed. In most circumstances on higher speed roads, the reversible flow will be controlled by traffic controllers or traffic signals (portable or temporary). In short length, low speed situations, the control may consist of a GIVE WAY and ONE LANE assembly or in certain restricted situation (refer MUTCD) may not require any control. Design of the approaches to a single lane section of road and traffic control devices are required to facilitate the transition from high speed approaches to stop conditions for the spectrum of operational conditions (e.g., day-night and weather).

The costs (to the road authority and the construction contractor) and non-transportation impacts of this strategy are generally low. This strategy however can have a significant impact on capacity. The MUTCD outlines the typical length of single lane traffic operation based on the traffic volumes as the length of the one-way segment increases, capacity is reduced. Alternative simulation models are now also available to establish the likely traffic delays and impacts. One of the most significant
issues associated with this strategy is the potential for long queues to form and the risk of crashes occurring at the rear of the traffic queue. This risk requires particular attention to ensure that adequate sight distance to the rear of the queue is maintained at all times or an alternative warning system is utilised.

In this strategy, construction operations typically take place in close proximity to live traffic which can impact on worker safety.

Application of this strategy is generally limited to low-volume, two-lane, two-way roads.

3.2.2 Detour

A detour is a roadwork mitigation strategy wherein traffic in one or both directions is rerouted onto an alternative road to avoid the roadworks. This strategy is typically introduced in association with a full road closure but may be provided as an alternative even when some lanes remain open to traffic. It may also be applicable only for specific vehicles which exceed temporary height or weight restrictions. Detours are typically via alternative permanent roads or may be on a combination of permanent and temporary roads.

When traffic is directed from a facility under construction to an alternative traffic route, construction operations can be undertaken with less restraint. This can improve construction efficiency (i.e., reduce cost and program) and quality. Road authority and construction contractor costs to implement detours may require traffic control devices only, or potentially temporary infrastructure in association with traffic control devices.

Detouring traffic imposes additional capacity and load demands on the alternative route and may result in congestion and infrastructure deterioration on the detour route. Detours should be carefully evaluated to ensure that they are capable of accommodating the volume and types (configuration, size, and weight) of detoured vehicles. Mitigation may include temporary changes to traffic control (e.g., signal timing and signs) and remedial pavement and bridge work. When detours are being considered, the access normally provided to properties along and near the detour route should also be considered. The added travel time and distance of the detour is a cost to motorists and should be evaluated.

There may be issues to be negotiated between state and local road authorities if the agency detouring traffic does not own the roadway onto which traffic is detoured. In some jurisdictions, interagency agreements are needed and may provide for improvements to the detour route in preparation for the detour or as redress for damage induced by the detour traffic.

3.2.3 Diversion / Sidetrack

A diversion or sidetrack is an alternative to a detour as a roadwork mitigation strategy wherein traffic in one or both directions is carried by a temporary roadway around a work area. This strategy compensates for the removal of permanent travel lanes from service.

This strategy provides substantial separation of construction from traffic, although generally not as much as detours. Sidetracks are often used for bridge projects, including bridge replacements, but are also used for other types of work. When used in conjunction with bridge projects, a temporary bridge or culvert may also be needed.
Unless a detour is also established to carry a portion of the traffic, the sidetrack will accommodate the entire approach volume, including large and oversized vehicles. The sidetrack will require the selection of a temporary roadworks design speed according to the geometric and pavement design of the sidetrack. The capacity of the sidetrack should generally be close to or equal to that of the approach roadway to avoid substantial delay, queue formation, or trip-length extension. The geometry of the sidetrack and associated traffic control devices should consider traffic characteristics on the approach roadway. Construction of temporary roads can be costly. Major variables affecting cost include the length and design features (e.g., barriers, earthwork, hydraulic structures, and surface/pavement). The design and cost of these elements vary based on traffic volume and duration of use.

Sidetracks involve construction of new, temporary roads. Therefore, many of the processes associated with road construction may apply to provision of a sidetrack. The need to remain within the road boundaries, impose impacts on protected resources (e.g., heritage sites), or acquire permits generally can affect project schedules and should be considered.

3.2.4 Full Road Closure

A full road closure is a roadwork mitigation strategy wherein traffic operations are removed or suspended in either one or two directions on a segment of roadway or ramp.

When roadway traffic is completely eliminated, construction efficiency and the resultant quality of permanent features (i.e., bridge and pavements) are maximised, while the time required for completion is minimised. Contract provisions may be included to reflect the degree of disruption that this strategy involves and penalties may apply for not completing the work within agreed timeframes. This type of approach is more common in the rail industry with weekend shutdowns of commuter rail lines to allow for construction and maintenance activities.

The cost of the full road closure itself is very low; however, this roadwork strategy does not provide for maintenance of traffic. Therefore, one or more supplemental strategies are needed, with detours being the most common. The supplemental strategies may have impacts, as outlined in the relevant section, and should be considered. When full road closures are used with high-volume facilities, alternative strategies (e.g., detours) usually cannot fully compensate for the capacity reduction. Traffic Management Plans are needed, including a comprehensive community information component.

3.2.5 Intermittent Closure

An intermittent closure is a roadwork mitigation strategy wherein all traffic in one or both directions is stopped for a relatively short period to allow for construction operations.

This roadworks strategy alone is generally not adequate for an entire construction project. It is more often employed during specific operations (e.g., setting bridge beams, conducting blast detonation, and moving equipment) for which project personnel can select the beginning point and reasonably predict the duration. In nonemergency cases, intermittent closure should be used only if the duration of closure and period of traffic impact will be short (less than 20 minutes).

3.2.6 Lane Closure

Lane closure is one of the more common roadwork mitigation strategy wherein one or more travel lanes and any adjacent shoulders are closed to traffic. This strategy is not limited to closing one lane
of a multilane road or motorway and may involve closure of all lanes in one direction. Lane closures are inherent to median crossovers.

Reducing existing capacity increases the probability of queue formation and delays. Depending on traffic volumes, the ability of drivers to individually select their speeds is reduced or lost. Traffic impacts (e.g., speeds, queue formation, and delay) should be assessed, and lane-closure length, roadway grades, traffic volumes, and percent trucks should be considered. Road Authorities typically have a set of rules or processes to follow to evaluate the traffic impacts. Simple traffic models can also assist to determine the periods in which this strategy can be accepted.

The road authority and construction company cost to implement this roadwork strategy varies depending on the supporting infrastructure employed. Many common traffic control devices (e.g., signs, vehicle mounted devices, variable message signs and arrow panels) can be transported readily. When lane closures are used for invasive construction operations (e.g., pavement reconstruction) temporary road safety barriers are often used which can substantially increase the cost of implementation. When barriers are omitted, this roadwork strategy can be installed and removed over short periods (i.e., hours). Because of its flexibility, this roadwork strategy can be used on high-volume facilities during periods when traffic impacts are deemed acceptable (e.g., weekends, mid-day, and night).

This roadwork type is often used in conjunction with lane construction involving operations adjacent to an active traffic lane. This creates the possibility of conflict among construction equipment operations, workers, and roadway traffic. In addition to safety concerns, the proximity may interfere with construction quality objectives.

3.2.7 Lane Constriction

Lane constriction is a roadwork mitigation strategy wherein the width of one or more travel lanes is reduced. The number of travel lanes may be retained (possibly through median or shoulder use) or reduced.

This strategy is often one of the simplest to implement and in many cases the existing number of lanes can be retained through reallocation of shoulder space with narrow lanes. Research has shown (TMR 2013a) that there is little change in risk associated with narrower lanes, particularly when they are used in situations where drivers are alert to the change and vehicle speeds comply with posted limits.

The use of this roadwork strategy is often associated with traffic in close proximity to construction operations. This also creates the possibility of conflict among construction equipment operations, workers, and roadway traffic. In addition to raising safety concerns, the proximity may interfere with construction quality and program.

This roadwork strategy is employed when maintaining traffic with less-than-desirable travel lane widths is preferable to other candidate alternatives. The decision to use this strategy is made in consideration of the magnitude of the constriction (i.e., actual traveled way width), the service conditions (e.g., duration, length, and traffic), and the cost associated with avoiding the constriction.

This roadwork strategy can directly impact the ability of the facility to accommodate large vehicles. In some cases, road authority coordination involving permits for oversized vehicles is needed.
3.2.8 Median Crossover

A median crossover is a roadwork strategy used on freeways / motorways to establish two way traffic on a normally divided facility. In this strategy:

- The number of lanes in both directions is reduced;
- At both ends, traffic in one direction is routed across the median to the opposite-direction roadway on a temporary roadway constructed for that purpose; and
- Two-way traffic is maintained on one roadway while the opposite direction roadway is closed.

Substantial separation of construction from traffic is provided by this roadwork strategy. Generally, this strategy allows construction of an entire carriageway (including structures) with little conflict between traffic and the construction site. The work is generally more expedient and results in higher construction quality and a more efficient program than would be produced with a lane-construction approach. This roadwork type is typically employed with full (i.e., pavements or bridges) or extensive reconstruction.

Median crossovers involve a reduction in the number of travel lanes and capacity. Depending on traffic density, the ability for drivers to individually select their speeds is lost or reduced. Traffic impacts (e.g., speeds, queue formation, and delay) should be assessed, and overall median crossover length, roadway grades, traffic volumes, and percent heavy vehicles should be considered. Road Authorities typically have a set of rules or processes to follow to evaluate the traffic impacts. Simple traffic models can also assist to determine under which conditions this strategy can be accepted.

The overall median crossover length is defined by the distance between the temporary crossover roadways. Locating termini (and thus establishing the overall median crossover length) requires system and site considerations. Decisions to close or maintain existing access points (i.e., interchanges and intersections for motorways) may influence the crossover locations. Additionally, substantial grade differences between one-way roadways or within median topography can influence the feasibility and cost of a temporary crossover roadway. Even under favorable conditions, temporary crossover roadways are a significant cost consideration.

3.2.9 Use of Shoulder

The use of the shoulder is a commonly used roadwork mitigation strategy involving the use of the outside or median shoulder as all or part of a temporary traffic lane. This strategy compensates for the removal of permanent travel lanes from service and uses existing roadway width to compensate for the capacity lost by closing a permanent travel lane and is viable on many roads.

Employing this strategy may require constructing or upgrading shoulder pavement structures to adequately support traffic loads. Many shoulders are narrower than the closed travel lane and additionally may not have the same pavement structure as the adjacent travel lanes. Depending on the traffic service requirements (e.g., duration, traffic volumes and types, and speed), considerable work and expense may be required to provide a suitable surface or pavement structure. Full-width shoulders with the same pavement structure as the adjoining travel lane can generally be used as a travel lane at low road authority cost. Some bridges have narrower shoulders than the approach roadways, which may determine or limit the feasibility of this strategy.
Invariably, when a shoulder is used to carry traffic, the roadside hazards on that side will be closer to traffic. The existence, proximity, and nature of roadside features should be considered in assessing this strategy.

3.3 Identifying & Evaluating Alternative Roadwork Strategies

The identification of candidate strategies begins after the project scope is defined and other preliminary information (e.g., typical sections, traffic volumes, right-of-way, and context) is available. A set of preliminary alternatives is firstly identified.

Once identified, the preliminary alternatives are evaluated firstly to determine if an alternative has a “fatal flaw”. The remaining alternatives are retained for a comparative analysis. At this level, each alternative is rated against a set of criteria.

The fatal flaw and comparative analysis typically use most of the same evaluation factors. The following sections of this report provide guidance on a range of elements that may be considered in the evaluation phase. Detailed project-level analysis will generally be required with a multidisciplinary team considering a wide range of constraints. Personnel with experience and knowledge in construction operations and contract administration, geometric and structure design, highway and worker safety, and traffic engineering provide a valuable perspective. Evaluation of roadwork strategies should consider the factors in the following sections.

3.3.1 Access

All roads are accessible, but not to the same degree. The functional classification system is based on the proportional distribution of access and mobility functions. Figures 3.1 depicts the relative functionality of various road facilities and Table 3-1 describes the role of each road type. Potential work zone impacts are directly related to the functionality of a road in its permanent state (i.e., prior to roadworks). Temporary denial or impedance of access to commercial, industrial, recreational, and residential property can be very disruptive. Additionally, freeway interchanges are sometimes closed or substantially altered during construction. In designing the roadworks, the access function should be inventoried and well understood.

![Figure 3.1 Road Type and Function](source: Austroads (2009))
| Road Class / Motorways | Freeways/motorways are a particular form of arterial road in a hierarchical sense, but have distinctive operating characteristics.  
|------------------------|----------------------------------------------------------------------------------|
|                        | Provide for major regional and inter-regional traffic movement in a safe and operationally efficient manner.  
|                        | The prime traffic movement function dominates entirely and full access control ensures there are no competing access issues.  

| Arterial Roads | Provide for major regional and inter-regional traffic movement in a safe and operationally efficient manner.  
|----------------|----------------------------------------------------------------------------------|
|                | Commercial or industrial access requirements, or local public transport priorities may need to be given significant weight in developing suitable traffic management strategies.  

| Distributor / Collector Roads | Streets which do not easily fall into either the arterial or the local road category.  
|-------------------------------|----------------------------------------------------------------------------------|
|                               | Distribute traffic and bus services within the main residential, commercial and industrial built-up areas and link traffic on local roads to the arterial road network.  
|                               | May be streets which have been designed as local streets, but which have additional traffic functions, usually serving major traffic generators or providing for some non-local traffic movements.  
|                               | Problems often arise with intermediate streets, as their design usually promotes the traffic movement function, while the residents and sometimes the local council, consider the street to be a local street with emphasis on the need for low traffic speed and restricted width.  
|                               | Alternatively, in newer growth areas they may sometimes be under-designed in response to a desired emphasis on local road functions, resulting in operational and safety problems for the higher traffic volume that must use them.  

| Local Roads and Streets | May serve several functions to a greater or lesser degree. Some of the functions are at least partially incompatible. Typical functions include:  
|------------------------|----------------------------------------------------------------------------------|
|                        | providing vehicular access to abutting property  
|                        | providing vehicular access to other properties within a local area  
|                        | providing access for emergency and service vehicles  
|                        | providing a network for the movement of pedestrians and cyclists  
|                        | providing a means to enable social interaction within a neighbourhood, e.g. serving as a play area or community open space  
|                        | contributing visually to the ‘living’ environment  

The extent of each of these functions will vary within a local street network. For example, a street which provides access to several other streets, will have a more prominent vehicle movement role than a small cul-de-sac.  

| Table 3.1 | Roles of Urban Roads Source GTM4  

Source: Austroads (2009)
Access to roads is provided through the following mechanisms:

- Abutting land use (i.e., driveways and private roads),
- At-grade intersections,
- Interchange ramps, and
- Temporary occupancy (i.e., roadworks).

Each of these mechanisms is a roadwork design variable, meaning that the design process can affect the status quo. However, designers rarely exercise unconstrained flexibility on any aspect. Although excluding all other access to roadworks may result in the greatest construction efficiency, the option is rarely available. Normally, existing access mechanisms are sustained as part of roadwork design, but often at a diminished level.

### 3.3.2 Basic Traffic Functionality and Operation

Construction necessarily alters the pre-project roadway configuration. Assessing the following information for each alternative will show the probable effects on basic traffic and road operations:

- Freeway
  - entrance ramps closed;
  - entrance ramp acceleration lane length reductions;
  - exit ramps closed;
  - exit ramp deceleration lane length reductions;
- Bridge deck width available compared with approach road;
- Horizontal clearance to bridge piers, above-ground lighting hardware, signs, and other roadside furniture;
- Impact on existing drainage systems;
- Location and control of affected intersections;
- Number of lanes per direction;
- Rail crossings affected;
- Roadway lighting affected;
- Lane widths for each affected road; and
- Vertical clearance (based on temporary roads and including construction operations).

Physical alteration and occupation by construction operations can affect traffic operations in many ways. Example impacts include increasing the response time of emergency services and rendering facilities unsuitable for oversized vehicles. The identification of undesirable features may be used to mitigate the condition or, if the condition is unmitigated, to serve as an evaluation factor.

### 3.3.3 Capacity and Queues

Construction roadworks often reduce the capacity of a facility below its pre-project capacity level, and below the capacity level of the approach roadways. Capacity is related to the number of travel lanes and free-flow speeds; thus, construction related factors that reduce either will reduce capacity. Although the number of travel lanes is a substantive control on capacity, many additional factors can also influence traffic flow and capacity, including access, lane width, lateral clearance, and activities that result in speed reduction (i.e., enforcement and construction-related activities).

When demand exceeds capacity, two undesirable consequences follow: delay and queue formation. Delay results in user costs. Queues are considered a safety risk. Although measures exist to warn
drivers approaching queues, avoidance is preferable. In some cases it may be necessary to impose conditions whereby the contractor must take action to limit the projected queue length for roadwork strategies involving a reduction in the number of travel lanes. Various techniques have been employed to estimate roadwork capacity and traffic impacts.

Most road agencies have simple tools for predicting road impacts but in more complex cases it will be necessary to undertake sufficient traffic modelling and analysis to ensure that impacts remain within defined levels. Current microsimulation software is a favoured tool for estimating the delays and queues arising from a roadwork scheme.

3.3.4 Constructability

The ability to “bid and build” proposed work is a fundamental necessity of every project. When the feasibility of constructing as-designed work comes into question, then delays, disruption, and additional costs often follow. To prevent this situation and in consideration of increasing project complexity, a constructability review is commonly undertaken prior to tender. In some cases, the reviews are conducted entirely with internal agency staff but contract types such as ECI and ETI are being more commonly used.

Rudimentary evaluation factors include the following:

- Traffic movement through the roadworks during all construction phases and the geometric constraints of temporary construction features;
- Separation of through (i.e., nonconstruction) traffic from construction operations, workers, and construction traffic (equipment and vehicles) and stationary construction roadside hazards; and
- Access by construction workers to storage areas (equipment and materials) and to all necessary operations.

Whether a documented constructability review or a less structured constructability review is conducted, design plans and roadwork strategies should be reviewed by personnel experienced in construction operations to evaluate the feasibility and possible cost implications of the design.

3.3.5 Cost

Roadwork strategies have both agency and user cost consequences. In any project the Austroads (various) Guide to Project Evaluation should be applied to establish the total costs to a project including:

- Construction Costs
- Traffic Management Costs
- Road authority costs
- User costs associated with delay.

3.3.6 Human Environment and Other Modes

The category of “human environment and other modes” covers a myriad of factors that may arise at the intersection of construction operations and transportation facilities and that may not be specifically identified under another category. Disruption of pedestrian and social patterns, noise, natural resource impacts, and displacements are matters of public concern, and the impacts often vary with roadwork strategy.
The potential effects of roadworks on disabled populations, public transport users, intermodal connections, and non-motorised travel should be evaluated.

3.3.7 Summary

The strategy that is most responsive to the evaluation factors, on an overall basis, is selected. Only rarely is the same strategy optimal for all factors. Usually, the various strategies will exhibit offsetting considerations (e.g., cost or disruption of commerce) that cannot easily be converted to a common measure. In such cases, road authority policy, preferences, and discretion prevail.

At the conclusion of the identification and evaluation phase, a roadwork strategy and supporting strategies should be selected. The level of information assembled and the evaluation process should be sufficiently detailed to ensure feasibility of the selected strategies.
4 Design Controls and Principles

The design of roadworks involves many of the same factors that pertain to permanent roads, and much of the standards used for highway design is also relevant to design of roadworks. Yet there are substantive differences between permanent roads and roads in construction roadworks that should be reflected in the respective design processes.

Design guidance which reflects these differences for permanent roads and roadways in roadworks is appropriate for two major reasons.

1) Roadworks have short service lives. This therefore impacts on any decision which considers the risk associated with short term exposure compared with a permanent road. For example, short term works involving a culvert or drainage replacement, a detour through a dry watercourse may not require allowance for water flow when rain is not expected. Aspects relating to risk management would consider the reduced exposure and its impacts on design decisions. Service life also affects the cost-effectiveness of investments.

2) Second, the design of roadworks is generally far more constrained than the design of permanent roads. The feasibility of alignment and cross-sectional alternatives for temporary roads is often limited by the necessity to tie in existing facilities and to avoid costs and impacts associated with short-term arrangements.

This information below provides a background to the development of design guidance and to individual design decisions. Many of the same considerations and conventions involved in designing permanent roadways are referenced.

4.1 Design Controls

Design controls are factors that lie outside the designer’s discretion but may affect the design process and the designed solution. Factors can be grouped as outlined below.

4.1.1 Human

The Austroads (2006) Guide to Road Design Part 2: Design Considerations (GRD2) provides a detailed discussion on the range of factors influencing road design and the role that road user behaviour and human factors play in road design. That document should be referred to for a detailed discussion on this topic. GRD2 describes how “Road user behaviour is central to almost all decisions required in the design of roads. The efficient and safe operation of the road system depends more than anything else on the performance of drivers of vehicles, riders of motorcycles or bicycles, and pedestrians.”

Road user behaviour then provides the basis for design parameters such as

- Speed selection
- Horizontal curve selection, including road crossfall and super-elevation
- Lane and shoulder widths
- Provision for all road users including cyclists, pedestrians and public transport
- Provision for those with disabilities
4.1.2 Material

The engineering and physical properties (e.g., friction, resistance to deformation, and retroreflectivity) of roadway components and devices affect some design criteria.

4.1.3 Vehicles

GRD2 describes how in relation to vehicles, road users can be divided into three categories

- users of motorised vehicles such as trucks, buses, cars and motorcycles
- users of non-motorised or low-powered vehicles such as bicycles and powered wheelchairs
- users without vehicles, that is, pedestrians

The vehicle factors that impact on road design include the following

- Turning swept path of heavy vehicles.
- Stability of high vehicles on tight turns and on roads with high crossfall.
- Vehicle stopping properties and impact on sight distance and intersections
- Vulnerability of non-motorised and pedestrians to motorised traffic and the clearances needed between each group of road users.
- Intersection and crossing forms.

The designer of a roadworks site therefore needs to pay close attention to all the likely road users within the project and the impacts that accommodating each group places on the roadworks layout. Alternative mitigating strategies may be required to accommodate each road user group separately. For example, pedestrians may be accommodated on a sidetrack while road traffic is detoured.

4.1.4 Setting

Roads are woven into communities and natural settings. The characteristics of a project location are referred to as the setting, and they affect design criteria and specific design choices. Examples of setting are detailed in GRD2 and are summarised below.

Planning
- Land use zoning
- Right of way boundaries
- Access restoration
- Local, State and Federal governments
- Public transport
- Rail
- Airports

Site Factors
- Geographical
- Built Environment
- Environmental
- Cultural / Heritage
- Associated Design
- Pavement
- Drainage
- Ultimate Development
- Geotechnical

Statutory Approvals
- Maintenance Factors
- Occupational Health and Safety
- Operational Factors
- Economic Factors
- Financial Factors

4.1.5 Traffic

The traffic volumes on a specific road are generally beyond the control of the design process. These factors (typically measured by AADT, flow patterns throughout the day and percentage of heavy vehicles) have a substantial influence on design criteria and design choices. The traffic management plan for any project must specifically address how the existing traffic volumes will be accommodated
throughout the works. This will then either establish opportunities or provide constraints on how the works are to be undertaken and the traffic controls required to manage traffic.

4.1.6 Facility Type

Roadworks are generally designed and exist within the context of one or more existing road types. Traffic routinely using the road and traffic approaching the roadworks may have expectations based on the quality and form of the road on the approaches. These expectations might involve the number and width of lanes, the shoulder width and type, appropriate speeds, the location of decision points, and access arrangements.

4.1.7 Scope of Construction

There may be some latitude in scope (e.g., pavement overlay and reconstruction), but a project’s basic purpose generally lies beyond the designer’s discretion and has substantial influence on the time and space required for construction. The time and space requirements, in turn, affect roadwork design. The construction factors that may be considered in the development of the project scope include, construction cost, whole of life costs, constructability, availability of materials and provision for traffic.

4.2 Design Principles


All road design needs to consider the various aspects of the complex and interdependent vehicle-road-human system. Road design principles are evolving continuously and include a range of explicit criteria, such as lane widths, and general guidance considering elements such as the combination of alignment elements.

In most road projects, the project is undertaken on the basis of benefits and costs which can be evaluated in accordance with the Austroads (various-eight parts) Guide to Project Evaluation series. In the evaluation of a road construction or maintenance project, the objectives and constraints of the scheme are considered and the highest priority projects selected on the basis of the providing social benefits that exceed their cost.

Temporary reductions in road function will be required in conjunction with construction and maintenance activities. One of the key design objectives for a roadwork project will be the need to minimise any reduction in public mobility and access. Designs for road construction roadworks are often more restricted than designs for permanent roads, as work sites must also accommodate construction operations and be closely aligned with the permanent road.

The principles used to develop design criteria and to make choices at the project level are discussed below.

4.2.1 Safety

The primary reference in considering safety of roads, road designs and road projects is the Austroads Guide to Road Safety, which provides guidance across nine parts detailing the core responsibilities for road agencies. The following is taken from the summary to Part 1 of the Austroads (2013) Guide to Road Safety.
“Safe System principles are the basis for road safety programs in Australia and New Zealand. Safe System seeks to ensure that no road user is subject to forces in a collision which will result in death or an injury from which they cannot recover. It recognises that road user error cannot be completely eliminated (although it can be reduced), so the road transport system must therefore be designed to make collisions survivable. This is achieved through a combination of design and maintenance of roads and roadsides, design of vehicles and their safety equipment, speed management, and having alert and compliant road users.

A primary objective of design policies and processes, including those used for construction work zones, is to minimise the frequency and severity of crashes and to effectively address safety in construction roadworks.

The Austroads (2012) “Implementing National Best Practice for Traffic Control at Road Work Sites: Risk Management, Auditing and Field Operations” identifies that at road work sites, a risk exists for both workers and road users from an uncontrolled interaction between passing vehicles and the road work site/activity. The management of this risk requires the consideration of the likelihood of an event occurring and the consequence of that event occurring.

The particular road environment factors that contribute to risk at road work sites include the:

- proximity to passing traffic to all elements of the roadworks site
- speed of the traffic
- traffic volume and composition
- operating hours of the road work site
- geometry of the road approaching and past the work site

The TMR (2013) MUTCD Part 3 Works on Roads also discusses the primary objective of ensuring safety at worksites. For any roadworks sites, risk mitigating measures must be focused at

a) preventative measures aimed at avoiding an event
b) responsive measures to mitigate the severity of an event after it occurs

4.2.2 Design Consistency

Austroads (2010) GRD1 discusses the importance of road design consistency and the need to ensure that there are “no surprises” for drivers. This then leads to the need that there should be consistency of design for each road classification, in each terrain type, regardless of location. The goal is to ensure that roads are ‘self explaining’ as much as possible to ensure that drivers know what to expect and how to traverse each section of road.

Design consistency can be addressed in three areas:

- cross-section
- operating speed
- driver workload.

Roadworks designs should conform to the reasonable expectations of drivers based on their previous experience. Information sources, including the roadway and associated traffic control devices, should provide positive guidance and be presented consistent with the principle of primacy.
Roadworks designs should also be consistent in their application so that drivers have a reasonable expectation with regards to how they should respond to the roadworks. Similar sites with significant differences in speed limits for example may result in drivers not complying with speed limits at other sites where it is more critical.

4.2.3 Primacy

Primacy refers to how drivers prioritise information they receive from various sources (e.g., traffic control devices, geometry, traffic, and terrain). Construction roadworks typically present drivers with higher information loads than permanent roads. It is therefore important that safety-critical and other important information should be clearly, conspicuously, and prominently presented to drivers. Non-critical information should be avoided to limit the complexity and distractions to the driving task.

4.2.4 Speed Management

Austroads (2008) Guide to Road Safety Part 3: Speed Limits and Speed Management identifies a strong correlation between speed and crash rates and road trauma. This relationship extends to the impact of speeds on crashes within roadworks. Crash severity is related to the change in speed upon impact and increases with speed, substantially so for speeds exceeding 100 km/h. Crash rates and trauma rates have been shown to increase consistently with the speed of individual vehicles. The variation in speeds between vehicles has also been identified as contributing to crash rates.

Speed management, particularly at roadworks is therefore focused on establishing appropriate speeds determined by the roadworks design and the roadside environment. Every effort should be made to design the roadworks to facilitate, and implicitly encourage, a consistent operating speed and one which is self-enforcing. This is then supported with speed enforcement backed by public education to ensure general compliance with speed limits.
5 Design Standards

5.1 Roadworks Design Speed

As with other road types, the design of temporary roads has to suit the operating speeds that occur in practice. Compared with permanent works, there will be markedly different tradeoffs between cost, construction safety, operational safety and operational efficiency.

Designers need to consider these requirements when producing their designs, but the following issues are provided as a guide to assist in the development of temporary works:

- safe operation of the road for road users, construction and maintenance personnel, despite the necessary tradeoffs inherent with temporary works
- appropriate design standard, with provision for all relevant road users
- ensuring that operating speeds and speed zoning are seen as appropriate by drivers
- control of operating speeds, including provision of suitable transition sections between the temporary works and existing road, and retention of sight distances with safety barriers typically in close proximity to the road
- proximity of the temporary works to the permanent works
- the need to accommodate temporary intersections and in some cases, temporary ramps or ramp terminals at interchanges.

Common operational experience has shown that the vehicle operating speed through temporary works is typically higher than the posted speed limit and the choice of design speed should incorporate this. Assuming a design speed equal to the posted speed limit should not be considered without supporting data. It is critical that the speed used in designing the traffic control and delineation devices at roadworks is based on the actual speed of traffic travelling through the site as opposed to a posted speed limit which may not be complied with.

The establishment of a target speed and roadworks design speed, design of traffic control devices, and potential selection of speed management measures are related. Speed-related decisions within specific domains (i.e., design, regulatory, and speed management) should be consistent with an overall strategy.

5.1.1 Establish Reasonable Target Speeds

The MUTCD Part 4: Speed Control (TMR 2012) describe the “design speed” for roadworks as the 95th percentile speed of free flowing traffic which is expected to occur as a function of the adopted design standard of the road. The following principles are described for determining speed limits which also apply to roadworks:

(a) Speed limits should be capable of being practically and equitably enforced by use of speed zones of adequate length, by limiting speed limit changes, and by clarity and frequency of signposting.
(b) Speed limits should not be so low that a significant number of road users ignore it
(c) Speed limits should not be applied specifically for the purpose of compensating for isolated geometric deficiencies
The MUTCD Part 3: Works on Roads (TMR 2013) identifies that speed limits are determined firstly based on the separation between road workers and traffic, and secondly based on the geometric standards of the road. The lower speed limit, determined by both approaches, then defines the limits to be adopted.

Speed limits should be set to encourage, as far as practicable, a uniform speed of travel through voluntary compliance that will reduce the potential for conflicts due to speed differentials between vehicles. Excessive variation among vehicle speeds can indicate either an inappropriately set speed limit or that the road user’s perception of the speed environment is open to confusion. If there is confusion, corrective action may be required rather than a reassessment of the speed limit.

Where a speed zone at a roadworks site is to be implemented for an extended period of time it is preferred not to reduce the roadworks speed limit more than 20km/h less than the approach speed limit. However at particular locations, limits must sometimes be reduced substantially below approach speeds. On high-speed roads, this is undesirable yet may be unavoidable.

5.1.2 Employ Measures to Attain Significant Speed Reductions

The requirements for construction operations and other factors such as lane width restrictions typically requires speed limits at road works sites that are not comparable to those on the approaches or that prevailed on the same road prior to establishing the roadworks. In some cases significant reductions in speed limits at roadworks sites may be required. In such a case, the roadwork target speed is based on the restrictive features and drivers need to be given a sufficient warning of the speed reductions.

Where a speed limit at a roadwork site is reduced by more than 30km/h, advance warning of the works and buffer zones should be applied to step speeds down from the normal road speed. Driver notification should be provided through consistent, credible, and complementary information sources and speed limits should be applied consistently at similar sites.

Although static (i.e., advisory and regulatory) signage is a fundamental and important source of information, it should not be presumed as independently sufficient and appropriate enforcement and technology strategies should be considered. Additional speed management measures may include automated enforcement (if applicable), dedicated enforcement patrols, portable variable message signs, rumble strips, speed trailers, warning devices, and variable speed limits. The selection of speed management measures should also consider the magnitude of speed reduction, exposure (i.e., traffic volume and duration of condition), and experience with comparable situations.

Where the temporary road is short (e.g. less than 1 km long), the desired speed of the driver is unlikely to reduce significantly, even with the support of appropriate speed zoning. The addition of visible cues however, will highlight the need for a reduced operating speed to the driver, and the speed zoning. This may be achieved by a combination of:

- signage, safety barriers and anti-gawking screens that reinforce the presence of the road works
- narrower cross-section elements where practical to give the appearance of lower standard of road
- different pavement surfacing appearance and/or type
- active traffic management, including temporary traffic signals and stop/go traffic control.
Where possible, the horizontal curvature should be used to control operating speeds through a transition section, since horizontal curvature has the greatest effect on operating speed. Besides the transition section, it is good practice to use horizontal curvature to control the operating speed on the temporary road proper. The most common design problems occur where the alignment of the temporary road is controlled by the permanent works or existing roadway, thus limiting the amount of curvature that can be introduced. Sight distance constraints are also prevalent around curves where safety barriers are installed and where the temporary roadway has to cross over from one part of the existing roadway to another.

5.2 Sight Distance

Drivers acquire most of the information they use to control and navigate their vehicles visually. Therefore, facilitating driver visibility of the roadway, other traffic (e.g., pedestrians and vehicles), traffic control devices, appurtenances, and other conditions is imperative. Austroads (2010a) Guide to Road Design Part 3: Geometric Design (GRD3) identifies four types of sight distance:

- **Stopping** - is the distance to enable a normally alert driver, travelling at the design speed on wet pavement, to perceive, react and brake to a stop before reaching a hazard on the road ahead.
- **Overtaking** - is the distance required for the driver of a vehicle to safely overtake a slower moving vehicle without interfering with the speed of an oncoming vehicle
- **Manoeuvre** – has been omitted in general design but can still be adopted where Stopping Sight Distance cannot be practically applied.
- **Intermediate** – equal to twice the stopping distance and measured from 1.1 m to 1.25 m may be appropriate in some circumstances where two-way travel may occur in the same path

Each of these sight distance types may be applicable to roadworks, although providing for overtaking opportunities is generally not a priority.

Roadwork designs that provide extensive visibility of their existence and features are desirable. Stopping sight distance is the primary sight distance required on a road. It is defined based on a range of different parameters based on the size and location of a hazard. It accommodates the distance needed by a driver to (a) perceive information, (b) recognize the condition or its potential threat, (c) select an appropriate path, and (d) initiate and complete a stop or manoeuvre safely and efficiently.

Traffic Controls and other driver information strategies should be used in conjunction with extended sight distance to mitigate roadwork conditions that are atypical or involve complex driver decisions.

Austroads GRD3 provides an approach for determining the minimum sight distance value for permanent roads. At roadworks, the appropriate approach is considered to be to use the value associated with the permanent road design criteria and the roadworks design speed.

At worksites, it is expected that sight distance on the approaches to the worksite would be based on the same parameters (approach speed, reaction times, driver alertness, etc) for the permanent situation. Within the worksite, given a higher level of traffic control and driver alertness, it is expected that sight distance parameters may be able to consider shorter reaction times and different pavement deceleration parameters. For example, deceleration on roads generally is based
on allowing for wet pavement conditions. However, the current guides and TMR guidance allow for
the use of higher deceleration rates in certain circumstances. At worksites therefore where a
greater control of the road is provided, and wet road conditions may be avoided, the use of other
parameters can be considered.

In conclusion, extended sight distance approaching and within roadworks is desirable from an
operations perspective. Safety considerations also point to the need for some minimum sight
distance. For roadwork design speeds less than 60 km/h the stopping sight distance values
tabulated in Austroads and corresponding to roadwork design speed are recommended.

5.3 Forgiving Roadside

Austroads (2008a) discusses the need for a forgiving roadside in the Guide to Road Safety Part 9:
Roadside Hazard Management (GRS9). It is identified that vehicles leave the traveled way for a
variety of reasons. Regardless of the reason for the departure, ideally a roadside environment
should be free of any hazards that may increase the severity of a crash. Such a roadside would
prevent injuries in run-off-road crashes by providing drivers with enough space to regain control of
their vehicles and stop safely without colliding with any objects or the vehicle rolling over. However,
it is acknowledged that it is not usually possible to construct a road environment completely free of
hazards.

A strategic approach therefore needs to be taken to provide a forgiving roadside environment to
minimise the risk of death or serious injury. Austroads (2008a) GRS9 and (2010b) Guide to Road
Design Part 6 (GRD6) provide guidance on clear zones and their dimensions.

The types of hazards that may be encountered on roadsides can be categorized as;

- rigid objects – trees, utility poles, culvert end-walls, etc.
- medians (cross median crashes)
- embankments and cuttings
- open drains
- bodies of water
- kerbs.

In priority order, the following approaches should be taken with these hazards:

- removal of the roadside hazard
- redesign of the hazard so as to make it traversable
- relocate hazard to a location where it is less likely to be struck
- replacement of the hazard so that it breaks away or is impact absorbing
- shield the obstacle with an appropriate barrier and/or a crash cushion
- if none of the above is attainable, delineate the obstacle.

Each option for hazard reduction is to be ranked according to benefit cost analysis techniques and
engineering judgment. At temporary roadworks sites a higher level of roadside risk may be
acceptable on the basis that the exposure is only for a limited period of time.
5.4 Roadway Surface

Roadway Surface relates to the pavement surface. Austroads Guide to Pavement Technology (various – ten parts) provides extensive guidance for the design of permanent pavements but does not distinguish for temporary pavements.

Driving surface characteristics, especially roughness and friction, have an influence on motorist comfort and tire-road interaction.

Unpaved surfaces may be used for temporary roadways in roadworks. In most cases, the guiding principal establishes exposure as the principal consideration, referring to short durations, low volume, or a combination of duration and volume as factors under which unpaved traveled way surfaces may be used. Unpaved driving surfaces are difficult to maintain. Therefore, some form of speed control may be appropriate when gravel or aggregate driving surfaces are employed. Prevailing environmental conditions and maintenance requirements should also be considered in selecting temporary traveled way surface types and their ongoing compatibility with high-speed traffic.

However in most cases on all but low volume rural or local streets, the design criteria for temporary roads require a paved road surfaces. The design of these pavements is as for permanent pavements in accordance with Austroads Guide to Pavement Technology. However, due to the shorter life span and hence the design load, thinner pavements can be used.

At roadworks, the pavement structure provided with higher-volume diversions should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. For this condition, providing a highly durable pavement structure should be considered.

5.5 Alignment Principles

Although there are similarities in the design of permanent road alignments and alignments through roadworks, there are also substantial differences. A key difference is that of service life, permanent versus temporary. Costs, impacts, and land acquisition are more difficult to justify when the corresponding usefulness is short lived. Roads designed in conjunction with roadworks are typically more constrained by setting than permanent roads.

Yet temporary roads must connect to existing roads and provide sufficient space for construction operations. Consequently, there is a strong and appropriate motivation to use and integrate permanent infrastructure elements (e.g., embankments, pavements, structures, and drainage structures) into roadwork roadway alignments. Constructing and removing temporary infrastructure is warranted when doing so is necessary to provide the desired levels of access, mobility, and safety.

The degree to which roadworks requires temporary infrastructure and imparts impacts is influenced by the horizontal and vertical alignment. The service a roadway provides is also influenced by its horizontal and vertical alignment. The design of temporary roads, including alignments, is an exercise of balancing cost, impacts, and service provided over a finite period of time.

The following information addresses horizontal and vertical alignment design of temporary roadways in roadworks.
5.5.1 Horizontal Alignment and Curvature-Superelevation

Horizontally curved roads are routinely designed and analyzed using the following basic curve formula.

\[ R = \frac{v^2}{127(e+f)} \]  

(2.1)

Where

\[ R = \text{Curve Radius (m)} \]
\[ V = \text{Vehicle Speed (km/h)} \]
\[ e = \text{pavement superelevation (m/m)} \]
\[ f = \text{side friction (between the tyre and the pavement)} \];

The background and derivation of this formula are discussed in Austroads GRD3.

For a specific radius and speed (actual or design), the equation can be satisfied by a range of combinations for the superelevation \( e \) and side friction \( f \). Both \( e \) and \( f \) have practical limits (i.e., maximum values) and Austroads GRD3 provides guidance on selecting limiting values.

For speed-radius combinations that require less than a maximum \( e \) and \( f \), a range of values can be selected within applicable limits. Austroads GRD3 should be referenced to establishing values for superelevation and side friction where speed-radius combinations that require less than a maximum \( e \) and \( f \).

Some of the key aspects relevant to superelevation in the construction of temporary roads include,

- For construction expediency, superelevation values are normally rounded (upwards) to a multiple of 0.5% so that there is a corresponding adjustment of side friction.
- Other methods have been used in the past so that there are likely to be many cases where the reuse of existing pavement will dictate a different superelevation. This is acceptable if the resultant side friction is suitable for the curve design speed and consistent with that for any adjacent curves.
- Use of maximum values of superelevation will need to be applied in steep terrain or where there are constraints on increasing the radius of an individual curve in a group. Maximum values of superelevation are listed in Table 5-1.

**Table 5-1: Maximum values of superelevation to be used for different road types**

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Speed Range (km/h)</th>
<th>Maximum Superelevation ( (e_{max}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>All speeds</td>
<td>5%</td>
</tr>
<tr>
<td>High Speed Rural</td>
<td>Greater than 90</td>
<td>6%</td>
</tr>
<tr>
<td>Intermediate Speed Rural</td>
<td>Between 70 and 89</td>
<td>7%</td>
</tr>
<tr>
<td>Low Speed Rural</td>
<td>Less than 70</td>
<td>10%</td>
</tr>
</tbody>
</table>

- Typically constructed superelevation is limited to a practical maximum of 6% for most roads.
- Superelevation exceeding 7% is rarely used.
- In an urban situation superelevation up to 10% may be used on loop ramps at interchanges.
In mountainous terrain there is normally insufficient distance to fully develop steep (more than 7%) superelevation.

In less rugged terrain the use of steep superelevations is questionable considering the potential adverse effect on high centre of gravity vehicles.

The theoretical maximum superelevation \( e_{\text{max}} \) of 10% should not be used to justify the use of small radius horizontal curves, except in restricted situations.

Superelevating roadway curves necessitates superelevation transitions, which bring alignment and other (e.g., drainage) complications. The use of sufficiently large curves so that adverse crossfall can be maintained and not require superelevation may lead to a road alignment which does not encourage compliance with temporary speed limits.

Where superelevation is to be introduced on temporary roadways, the superelevation transition techniques used for high speed permanent roads should be applied to roadways within construction roadworks on high-speed highways.

In addition to crossfall and superelevation, sight distance is a consideration in designing horizontal alignments. Crosssectional and other features common to construction projects (e.g., barriers, material stock piles, and equipment) may limit sight distance on the inside of horizontal curves.

5.5.2 Vertical Alignment Considerations

Generally, the same maximum grade criteria applicable to the highway under construction should be applied to roadworks. However, marginally exceeding these criteria is often justified in consideration of all factors. Grades below the maximum are desirable.

When designing roadwork temporary roads, the potential effect of grades on operations and capacity should be considered. Austroads GRD3 provides a discussion on the effect of grades on various vehicle types. When speeds are substantially reduced in advance of a temporary road (e.g., in conjunction with a reduction in the number of lanes), the temporary road capacity may be controlled by heavy vehicles attempting to accelerate on grade. Grades in the range of 3-6% can result in some reduction in the speed of heavy vehicles on normally high speed roads. Capacity, in turn, influences queue formation.

Austroads GRD3 provides the following guidance with regards to maximum grades.

<table>
<thead>
<tr>
<th>Operating Speed (km/h)</th>
<th>General Maximum Grades (%)</th>
<th>Desirable maximum length of grades</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flat</td>
<td>Rolling</td>
</tr>
<tr>
<td>60</td>
<td>6-8</td>
<td>7-9</td>
</tr>
<tr>
<td>80</td>
<td>4-6</td>
<td>5-7</td>
</tr>
<tr>
<td>100</td>
<td>3-5</td>
<td>4-6</td>
</tr>
<tr>
<td>120</td>
<td>3-5</td>
<td>4-6</td>
</tr>
<tr>
<td>130</td>
<td>3-5</td>
<td>4-6</td>
</tr>
</tbody>
</table>

The minimum length of vertical curves for crests on permanent roads is typically established on the basis of sight distance considerations. When minimum sight distance design criteria are adopted for...
roadworks, minimum vertical curve length criteria on that basis are appropriate. The most common basis for sight distance design criteria is the Austroads GRD3 stopping sight distance values.

The Length of a crest curve is given by \( L = KA \).

Where “A” is the change of grade

\[ K \] is a vertical curve value as determined according to GRD3.

The minimum sag vertical curve length is determined on the basis of comfort. In designing the vertical profile of a temporary road other criteria such as headlight sight distance and hidden dips should also be considered (refer Austroads GDR3)

5.6 Cross Section

Temporary roadway cross sections should generally follow the guidance applicable to permanent roadways as given in Austroads Guide to Road Design Part 3. Within this document guidance describes the preferred arrangements for;

- Road crossfall
- Road crown
- Traffic lane widths
- Shoulders width and pavement surface
- Verges
- Batters
- Roadside Drainage
- Medians
- Special Road User requirements
  - Cyclists
  - HOV Lanes
  - Bus Lanes

In determining the cross section for temporary roads, each of the above criteria should be considered.

The MUTCD provides recommendations for lane widths as shown in Table 5-4. Values above those shown in this table, up to those used for permanent roads of the same functional class, provide desirable service, but the additional cost is not necessarily justified.

<table>
<thead>
<tr>
<th>Posted Roadworks Speed Limit (km/h)</th>
<th>Minimum Lane Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td></td>
</tr>
</tbody>
</table>

Source MUTCD
The minimum recommended width is therefore 3.0m but Austroads (2010a) notes the range of practical lane widths can be as little as 2.75m with only a small effect on crash rates for urban arterial roads.

Paved shoulders may not be required but allowance for vehicles to pull clear of traffic should be allowed for where possible.

Of additional consideration in the design of temporary roads is the clearances to delineation which is described in the MUTCD. This requires an additional 0.3 to 1.0m clearance between the edge of the traffic lanes and delineating devices or road safety barriers.

Temporary roadway shoulder widths vary by volume and type (i.e., crossover and sidetrack) and are often not paved. Shoulder cross slopes may be difficult to control because of width and material type. Generally, shoulder crossfalls should be greater than the slopes of the adjacent traveled way, particularly if the shoulder is unpaved.
6 Roadway Design

Chapter 3 identifies common roadwork strategies. Several of these, including alternating one-way operation, full road closure, intermittent closure, and lane closure, are normally implemented exclusively or primarily through the use of temporary traffic control devices. Table 6-1 identifies the preferred applicability for each roadwork strategy.

Table 6-1: Applicability of Roadwork Strategies

<table>
<thead>
<tr>
<th>Roadworks Strategy</th>
<th>Motorway</th>
<th>Multilane non-freeway</th>
<th>Two Lane Urban</th>
<th>Two Lane Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternating One-Way operations</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>At Grade Intersections</td>
<td>NA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Detours</td>
<td>Yes but not preferred</td>
<td>Yes but not preferred</td>
<td>Yes</td>
<td>Yes but often not practical</td>
</tr>
<tr>
<td>Diversion / Side Track</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes but usually not practical</td>
<td>Yes</td>
</tr>
<tr>
<td>Full Road Closure</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes but often not practical</td>
</tr>
<tr>
<td>Interchange Ramp Closure</td>
<td>Yes</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Intermittent Closure</td>
<td>Yes but only for short term</td>
<td>Yes but only for short term</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lane Closure</td>
<td>Yes</td>
<td>Yes</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Lane Constriction</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Median Crossover</td>
<td>Yes</td>
<td>Yes</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Use of Shoulder</td>
<td>Yes</td>
<td>Yes</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Implementation of a detour may or may not require temporary roadway infrastructure. When temporary roadways are needed, the guidance provided for sidetracks is generally applicable. Other work zone types generally involve the design of roadways, including geometric design and the provision of supporting infrastructure. This chapter addresses the roadwork roadway design elements of specific roadwork strategies, including temporary roadway infrastructure and existing roadways that are geometrically altered within roadworks.

6.1 Diversions / Sidetracks

Diversions or sidetracks, are a specific type of temporary roadway. This strategy allows traffic to be removed from the existing road to allow for roadwork activities to be undertaken well clear of
traffic. When the number of existing number of lanes on the permanent road is maintained on the sidetrack, travel is the same as the affected roadway and speeds are comparable, the mitigation is nearly complete. Sidetracks can carry one-way or two-way traffic. Two-lane, two-way sidetracks, such as the one illustrated in Figure 6-1, are the most common type.

The sidetrack design must reflect the operational road requirements and site constraints. Sidetracks are often used in conjunction with bridge construction and may involve grade separation or hydraulic structures (temporary bridges, culverts, etc.), which strongly influence the overall geometric design. Selection of the roadwork design speed for the sidetrack should follow the guidance in section 5.1.

Sidetrack alignments commonly consist of a series of horizontal and vertical curves. Lateral sight obstructions and crest vertical curves should be reviewed.

Sidetracks are most common on two-lane roads, and the traffic guidance scheme elements for that situation is the outlined in the MUTCD. Sidetracks are sometimes used on other facilities types, as well. Appropriate traffic guidance schemes should be based on general direction and guidance in the MUTCD and with reference to the Typical Application for a two-lane road diversion.

6.1.1 Horizontal Alignment and Superelevation

The cost and impacts of a sidetrack may be directly related to the length of the alignment between tie-in points on the permanent carriageway. To achieve the optimal cost for the sidetrack this therefore results in the horizontal radii selected for the ends of the sidetrack typically being the smallest curve radii that satisfy the design criteria, particularly the roadworks design speed.

A common sidetrack design (see Figure 6-1) includes pairs of opposing-direction horizontal curves. It is common design practice for short term sidetracks to provide curves that are sufficiently flat to not require superelevation. This describes the typical two-lane, two-way sidetrack.

Where a substantial sealed sidetrack is constructed for use for prolonged periods then superelevation requirements should be applied in accordance with superelevation design criteria. Where superelevation is provided, the alignment should provide for adequate transitions. In the case of superelevated reverse curves, a tangent between the curves is needed.
Figure 6-1 Typical Sidetrack Arrangement
6.1.2 Other Design Criteria

The vertical profile of the sidetrack should be developed in accordance with section 5

From a traffic operations and safety perspective, the diversion cross section should be the same as the approach roadway. However, this expectation is often not reasonable or practical. The duration of service, traffic volume, vehicle mix, construction cost, and impacts of the diversion are relevant considerations.

6.2 Lane Constriction

It is desirable to maintain the approach road travel lane width through construction work zones. However, “lane constriction” implies a width reduction, and desirable dimensions are generally not attainable. Reducing lane widths through roadworks may increase crash rates.

Individual lane widths are an important consideration however, the behavior of drivers is also influenced by operations in adjacent lanes. Where adjoining travel lanes occasionally have different widths the total carriageway width. For example, a 3.0-m wide lane adjacent to a 3.6-m lane is more desirable than a 3.0-m wide lane adjacent to a lane of the same width. If designing for roads which carry heavy vehicles an arrangement with a wider left lane and narrower right lane may be appropriate. In this case trucks should be instructed to use the wider lane and consideration should also be given to introducing signage prohibiting overtaking on the narrow lanes.

A number of factors should be considered in determining the minimum acceptable lane and carriageway width, including the presence and proximity of roadside features. As indicated by the Austroads GRS9 vehicle speeds and position (i.e., lateral vehicle location) may be affected by roadside features. The minimum desirable offset from the edge of the travel lane to the temporary road safety barrier is 0.3 m.

However, lane constrictions are less-than ideal conditions must sometimes be provided as a matter of practicality. Factors that are sometimes considered in determining acceptable lane width include:

- Traffic volumes,
- Heavy-vehicle (i.e., truck) volumes,
- Lateral constraint,
- Speed,
- Horizontal curvature,
- Duration of lane constrictions,
- One-way or two-way roadway, and
- Number of lanes.

Lane widths of 3.2 m are fairly common in roadworks, while lesser lane are generally not used for roadwork zones on high-speed roads.

Section 5 outlines the current guidance in the MUTCD on minimum lanes widths dependant on design speed through the roadworks.

Lateral constraint may also restrict sight distance, which should be reviewed.

Lane constrictions are often used in conjunction with lane shifts, lane closures, and shoulder closures. Guidance on traffic control for each of these is provided in the MUTCD. With the use of a
constricted lane, the use of a Road Narrows sign should be considered in coordination with other applicable traffic control devices.

### 6.2.1 Barrier Placement and Traffic Separation

For a discussion of the principles guiding roadside design and safety for roadwork zones, see Chapter 7 of this report. In these conditions, a design decision that must be made is how to distribute the remaining carriageway for temporary lanes and shoulders.

### 6.3 Median Crossover

A median crossover, as defined in this document, is the infrastructure used to support two-way traffic on a normally divided facility. The core requirement in establishing the length and limits of two-way traffic flow on a single carriageway is to remove traffic from the portion of the infrastructure where works are required.

Although a specific absolute maximum length cannot be established, the length of two-way flow on a single carriageway in these circumstances should be limited. This strategy imposes more constraint on drivers than the approach roadway with the key constraint generally being a reduction in the number of lanes. Additionally, cross-sectional arrangements often involve operation near barriers, reduced lane and shoulder widths and reduced refuge opportunity for disabled vehicles. These factors increase driver anxiety and may require an increased level of monitoring to address incidents quickly. In recognition of these considerations, guidance from TMR is that the maximum length of two-way traffic flow on a one-way carriageway is 2km.

The temporary roadways should be sited to avoid unnecessary proximity to bridge structures; substantial grade differences between carriageways; complex, sensitive, or formidable geologic features (e.g., rock outcrops or wetlands); and other attributes that require extensive roadbed preparation. Interchange ramps are another potential location control.

Selection of the work zone design speed for the median crossover should follow the guidance in Section 5. Horizontal curves and grades, particularly those on the temporary median roadways, should be designed in recognition of their potential effect on speed. Median crossovers include a series of horizontal and vertical curves usually in combination with road safety barriers. The effect of crest vertical curves and lateral sight obstructions should be reviewed.

Diagram 6-2 schematically depicts a median crossover.
Figure 6-2: Typical Median Crossover Arrangement

<table>
<thead>
<tr>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term</td>
</tr>
<tr>
<td>Road Type</td>
</tr>
<tr>
<td>Traffic Volume</td>
</tr>
<tr>
<td>Travelled Path (a) Direction</td>
</tr>
<tr>
<td>(b) Width</td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Operation</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>Taper</td>
</tr>
</tbody>
</table>
6.3.1  Temporary Roadways Connecting the Permanent Roadways

Median crossovers are not particularly common in Australia although they are used more extensively in other Countries. The temporary roadways used to connect normally divided highways represent a departure from the default path, the permanent alignment through travel lanes. Hence, driver familiarity and expectancies are not uniform, particularly just after implementation of the cross over. As all traffic is diverted from its normal path, the combined and complementary use of geometry and traffic control devices is needed to provide positive guidance for a distinctive departure from the permanent road alignment. The geometry should provide extended sight distance, a well-aligned and delineated path, and a forgiving cross section.

Road Safety Barriers in conjunction with other traffic control are frequently used to delineate travel paths and to separate opposing directions of travel in the areas where the permanent roadway carrying two-way traffic and temporary connecting roadway converge and diverge. In cases where a Road Safety Barriers are used at the convergence and/or divergence points and terminated within the limits of the two-way roadway, a crashworthy end treatment is required.

6.3.1.1 Horizontal Alignment and Superelevation

Refer to Section 5 for details which apply median crossovers. When practicable, the horizontal alignment should be flat enough to avoid the need for superelevation.

6.3.1.2 Vertical Alignment

Section 5 is applicable to temporary roadways connecting the permanent roadways of a normally divided road. The discussion on the potential effect of grades on heavy vehicle performance and capacity is especially relevant to crossovers.

6.3.1.3 Cross Section and Surface

Where median crossovers provide more than one travel lane in the same direction, the road cross-sectional configurations should be selected to maximise the use of the existing carriageway.

The appropriate cross-selection depends on several factors. It is desirable that once constructed, the crossovers be retained for future use, rather than remove them at the conclusion of a project. Under a subsequent project, or for maintenance activities, the same crossover might carry traffic in the opposite direction.

Curves may or may not be superelevated, depending on policy and specific design features (e.g., radius and roadwork design speed).

The factors discussed above affect cross-sectional design, and agencies have developed a variety of cross-sectional design practices. Lane and shoulder widths should be in accordance with section 5 but consideration needs to be made to the swept path of long vehicles at curves. On high speed divided carriageways with typically high traffic volumes, including heavy vehicle volumes, the temporary road alignment should favour a wide cross section.

For temporary roadways that will carry traffic only in one direction, consideration should be given to a wide left shoulder to reinforce the customary role and driver expectancy of the left shoulder as the location for emergency stopping and refuge. Additionally, emergency stops on the left side reduce potential conflicts with temporary barriers that are often located on the right side in the areas.
where temporary crossovers converge with and diverge from the one-way road carrying two-way traffic.

A road crossfall transition may be needed between the permanent one-way road and the temporary crossover. The direction and magnitude of temporary roadway superelevation are principal considerations.

The median crossover temporary road pavement structure should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. This is especially so where the crossover is to be retained for future possible roadwork events.

6.3.2 One-Way Roadway Used for Two-Way Traffic

One-way carriageways are not specifically designed to carry two-way traffic. Using a one-way carriageway for two-way traffic requires reapportioning the cross section and other adjustments.

A typical two lane divided road layout can have a total width of between 12 and 13 metres. Where a Road Safety Barrier is used to separate the two directions of traffic, the carriageway width available for use in each direction would be approximately 5 to 5.5 metres due to the barrier width footprint and its shy effect which is too narrow to accommodate two lanes in each direction. An alternative asymmetrical arrangement would be to retain two lanes in the original carriageway direction and a single lane in the opposite direction. In this case an evaluation would be required as to whether a single lane is sufficient for operational capacity or whether a single lane can be retained on the original carriageway as well.

When all or part of a shoulder is temporarily used as a travel lane, complications may arise as the shoulder pavement structures may not be capable of supporting heavy and sustained traffic. This may therefore result in the situation where only a single lane can be maintained in each direction.

Vehicle incidents are possible within the roadworks and as this particular arrangement reduces capacity by a reduction in the number of travel lanes (i.e., two instead of four); therefore, further impediments are unwanted. Emergency turnouts (i.e., intermittent shoulders) are responsive to these conditions and are discussed in Section 8.

If rumble strips or similar marking are present, they may require removal to ensure that drivers remain in the correctly designated lanes. Depending on their location in relation to temporarily designated travel lanes, the rumble strips may interfere with two-way operations on the one-way roadway. This condition is further discussed in Section 8.

When a one-way roadway is used for two-way operation, the probability of an errant vehicle striking certain median hazards may increase substantially. For example, what is normally the departure end of a bridge becomes the approach end. Median roadside hazards should be evaluated.

6.3.3 Barrier Placement and Traffic Separation

For a discussion of the principles guiding roadside design and safety for roadworks, see Chapter 7.

6.4 Use of Shoulder

There are numerous variations of this strategy for different facility types and work requirements. A typical example is shown in Figure 6-3.
This use of shoulder involves limited design decisions and is implemented primarily through traffic control devices. The transitional path of traffic from the permanent lanes approaching the roadworks to the shoulder (as a temporary travel lane) is delineated by shifting traffic. Adoption of a roadworks design speed may be appropriate. Because the shoulders will be part of a permanent high-speed roadway, no horizontal or vertical alignment decisions are generally needed. Temporary roadworks features can affect sight distance, particularly around barriers on horizontal curves and the design should be developed and evaluated from that perspective.

6.4.1 Cross Section and Surface

The adequacy of the existing shoulder pavement for use as a travel lane may be assessed in terms of crossfall, structure, and surface characteristics. In some cases, pavement rehabilitation or reconstruction may be needed.

If the shoulder being used to carry traffic is on a horizontal curve, the magnitude and direction of its crossfall should be evaluated against superelevation requirements, particularly if the shoulder crossfall is greater than the crossfall on the remainder of the carriageway.

If the shoulder crossfall is not suitable, the most comprehensive measure is to extend the cross slope of the adjacent travel lane to the shoulder through pavement reconstruction or surfacing. Other potential mitigation measures include reducing the speed limit appropriately. Detouring trucks and buses or prohibiting these vehicles from the shoulder that is temporarily in use for traffic and restricting them to the adjacent lane is an option but is difficult to sign and enforce.

Some shoulders have the same pavement structure as the adjoining travel lane; others do not. Travel lanes are subject to more intense service loads than shoulders. These factors, the age of the existing pavement, and the expected temporary pavement service requirements (e.g., traffic volumes, composition, and duration of use) should be considered in evaluating the potential use of existing shoulder pavements as travel lanes. The decision to reconstruct, rehabilitate, or retain an existing pavement structure should reflect the difficulty of performing surface maintenance and repairs within a complex operational environment. Providing a highly durable pavement structure should be considered.

Roadway design is based on the assumed availability of certain minimum friction between vehicle tires and the roadway surface. A shoulder being considered for use as a travel lane should meet or exceed the assumed values.

Before using an existing shoulder as a travel lane without modification, it should be considered adequate in each category: cross slope, structure, and surface conditions (i.e., friction and smoothness).

Where rumble strips are present, drivers may be preoccupied with steering to avoid contact with rumble strips which may induce unwanted distraction and tendencies. If this condition is anticipated, temporary rumble strip eradication and subsequent restoration should be considered. The feasibility and cost of these treatments (eradication and restoration) depend on the rumple strip configuration and shoulder pavement structure.
Figure 6-2: Typical Arrangement with use of the Shoulder

AAPA QTMR Strategic Alliance Safety Project
Design of road worksites for traffic accommodation
Draft for Industry Review
6.4.2 Barrier Placement and Traffic Separation

When a shoulder is used as a lane, the probability of an errant vehicle striking certain existing, permanent roadside hazards may increase. However, for most common roadwork conditions, provision of additional roadside barriers to shield existing permanent (preproject) hazards may not be cost-effective. However, an evaluation is required to justify this assessment.

6.5 Interchange Ramps

Access provisions are a significant factor for any construction involving motorway interchanges. Maintaining existing access points and associated traffic movements reduces the negative impacts of interrupting established traffic patterns. However, avoidance of these impacts should be weighed against the feasibility of providing adequate infrastructure for traffic to enter and exit the mainline motorway.

Where works require the closure of an interchange ramp, the decision on interchange access during construction should comply with the following order of precedence:

i. Provide temporary connections when adequate arrangements are feasible.
   - This may include connection of the ramp to/from adjacent service roads or local roads to allow for access to be maintained.
   - An alternative ramp alignment may be justified in cases where the ramp closure will be required for an extended period of time.
   - The adequacy of the arrangement will need to consider the speed environment, the change in speed between separate road elements, the lane length and the traffic controls at the ramp interchange.

ii. Close access points when adequate arrangements are not feasible. When ramps are closed the impacts on the traffic patterns at and between adjacent interchanges should be assessed.

A temporary single-lane interchange ramp should have a travel lane of approximately 5.0m to allow a stopped vehicle to be passed. However, different cross-sectional arrangements may be appropriate when considering project-specific factors (e.g., traffic volume, mix, and duration of service).

6.5.1 Entrance Ramps

Maintaining service on existing entrance ramps is often feasible, regardless of roadwork strategy (e.g., median crossovers, lane closure, or use of shoulder).

The feasibility of maintaining an entrance during construction often hinges on providing an adequate combination of roadway geometry and traffic control to facilitate merging. Acceleration lanes enable entering traffic to increase speed while simultaneously selecting a gap in through-lane traffic. The basic principles and considerations associated with permanent entrance ramps pertain to temporary arrangements. Therefore, acceleration lanes in roadworks that meet the design criteria for permanent facilities are desirable. However, attaining these lane lengths is often not practical but by reducing speeds on the mainline motorway lanes a reduced acceleration lane is required. Traffic volumes (mainline and entrance ramp) and sight distance should be considered in determining the minimally acceptable acceleration lane length for a specific location.
When the combination of traffic, geometric, and traffic control factors indicate an adequate entrance is not feasible, the entrance ramp should be closed. Advance coordination with the community, public information, and implementation of Traffic Control Devices are needed.

6.5.2 Exit Ramps

The issues surrounding maintaining service on existing exit ramps is similar to that for onramps although the issue of merging is not a concern. An adequate combination of roadway geometry and traffic control is needed to facilitate diverging from the mainline, negotiating the ramp, and meeting the operational requirements at the intersecting road. Deceleration lanes enable exiting traffic to reduce speed after departing the mainline through lane and prior to encountering features that require lower speeds or stopping. The basic principles and considerations associated with permanent exit ramps pertain to temporary arrangements. Therefore, deceleration lanes in roadworks that meet the design criteria for permanent facilities are desirable. It is desirable for exiting traffic to depart the through lanes at mainline speed and not reduce speed while occupying the mainline through lane. When this is not practical, the geometry of the ramp should be reviewed to determine if the ramp’s length, horizontal alignment, and grade allow for gradual deceleration before reaching speed-critical features.
Figure 6-4: Typical Motorway Exit Ramp closure

Table 6-4: Application

<table>
<thead>
<tr>
<th>Term</th>
<th>Long/Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Type</td>
<td>Multilane</td>
</tr>
<tr>
<td>Traffic Volume</td>
<td>High</td>
</tr>
<tr>
<td>Travelled Path (a) Direction</td>
<td>Past</td>
</tr>
<tr>
<td>(b) Width</td>
<td>Nil</td>
</tr>
<tr>
<td>Control</td>
<td>Nil</td>
</tr>
<tr>
<td>Operation</td>
<td>Exit closure</td>
</tr>
<tr>
<td>D</td>
<td>Table 4.2</td>
</tr>
</tbody>
</table>
6.6 At-Grade Intersections

The general approaches to designing construction roadworks that encompass at-grade intersections can be grouped into the categories described below.

In each case, coordination with the affected community and development of appropriate traffic management plans are keys to successful performance. Traffic Controllers may be required in providing positive guidance in a potentially complex and dynamic setting.

6.6.1 Intersection Closure

The feasibility of intersection closure depends on the availability of a reasonable alternative detour routes. If a detour is feasible, access to the main road can be temporarily terminated.

A detailed traffic management plan and consultation with local affected parties can allow a successful short-duration closures that interrupts access to a limited number of properties. When intersections are closed, the associated roadwork function can be undertaken more efficiently without needing to accommodate the full range of intersection movements.

6.6.2 Intersection Relocation

Intersection relocation should be considered when there is no suitable detour and when extensive work will take place within the intersection area. An example is shown in Figure 6-XX. The feasibility of this option is dependent on the available land for the deviated road.

![Typical Intersection relocation](image)

Figure 6-5: Typical Intersection relocation

6.6.3 Maintain Movements with TTC

Maintaining movements with traffic control devices is usually the most desirable option.

Intersections are inherently points of conflict. Even in cases where intersections are closed or relocated, drivers face choices and uncertainty. Therefore, positive guidance should be applied to
the roads approaching and through intersections within roadworks. Additionally, at the intersection location, the design features and traffic control devices should be developed with consideration given to use of temporary channelising features that

- Separate conflicts,
- Control the angle of conflict,
- Regulate traffic and indicate proper usage,
- Provide preferential treatment of predominant turning movements, and
- Protect stored and turning vehicles.

These options are not always needed or practical in the context of roadworks. However, their applicability should be considered.

Additional traffic control measures—including changes in intersection control type, warnings, variable message signs, and pavement markings and restrictions—are often used at intersections within roadwork zones.
7 Roadside Design and Barrier Placement

7.1 Introduction to Roadside Safety in Construction Roadworks

The Austroads Guide to Road Safety (various – eight parts) includes the foremost principle of the forgiving roadside concept, which holds that “Regardless of the reason for a vehicle leaving the roadway, a roadside environment free of fixed objects with stable, flattened slopes enhances the opportunity for reducing crash severity.”

A critical step in translating the forgiving roadside concept to practical guidance was the establishment of a clear zone, a traversable and unobstructed roadside area.

If objects are located on the roadside, and especially within the desired clear zone, a series of alternative actions should be considered to reduce the risk to errant vehicles. The order of preference for addressing roadside obstacles follows:

1. Remove the obstacle;
2. Redesign the obstacle so it can be safely traversed;
3. Relocate the obstacle to a point where it is less likely to be struck;
4. Reduce impact severity by using an appropriate breakaway device;
5. Shield the obstacle with a longitudinal barrier designed for redirection, or use a crash cushion;
6. Delineate the obstacle if the above options are not appropriate.

Options 4 and 5 introduce the concept of crashworthiness. Where conditions require the presence of an obstacle or barrier near the traveled way, the obstacle or barrier should be designed to perform appropriately if struck. Signs, signals, light poles, and utility poles should use breakaway supports.

Roadside safety concepts (i.e., forgiving roadside, clear zone, prioritized treatment of hazards, and crashworthiness) apply to roadworks. While the principles governing roadside design are generally the same, the roadway environment and permanent road environment are very different. Equipment, materials, and workers are inherent to roadworks but are not normally present for permanent roadway conditions. Depending on the setting, several of the prioritised roadside hazard treatments (e.g., removal or relocation) may not be a practical option.

The assessment of roadside risk involves two factors, the probability of an errant vehicle encountering a roadside feature and the probable harm that will result from an encounter. The amount of traffic on the roadway is a key indicator of the probability of an encounter. Unlike permanent roadway conditions, which may exist for an indefinite time period, the duration of roadworks is definite. The shorter the duration of an observation period, the less likely it would be for vehicles to strike a roadside feature. Therefore, undesirable conditions that would warrant intervention on a permanent roadway may not justify an investment for a safety treatment in a construction roadworks. These considerations were important in the development of the following roadside safety and barrier placement guidance.
Austroads Best Practice for Risk Assessment at Roadworks should be used to establish the relative risk of hazards within a roadworks site.

At roadworks, safety barriers may be required for situations where any of the following are cause for concern:

a) Inadequate safe clearance between moving traffic and workers and plant on site
b) Hazardous traffic conflicts (e.g. head-on collisions).
c) Collisions with hazardous fixed objects, construction works or falls into excavations close to the travelled path.
d) Inadequate separation of temporary footpaths, shared paths or bicycle paths from vehicular traffic paths.

Requirements and recommendations for the selection, positioning and end treatment of safety barriers are given in AS1742.3

Road safety barrier systems are designed to provide a physical barrier between the travelled path and the work area, which will inhibit penetration by an out-of-control vehicle and will have vehicle redirecting properties. They are typically used between traffic and a severe hazard such as a deep excavation, a bridge pier or a hazardous stockpile, and for the protection of workers and non-vehicular road users in vulnerable situations where lateral clearance to moving traffic would otherwise be insufficient for safety. They may also be used to separate opposing traffic.

The satisfactory performance of a barrier system will depend on its being struck by a vehicle no larger than the ‘design’ vehicle for which it is to be designed. Selection of the design vehicle should be subject to a risk assessment taking into account traffic mix past the site and the nature and length of the works.

Vehicles can be protected from collisions with hazardous fixed objects by crash attenuators as an alternative to safety barrier systems.

The type selection and installation of a temporary road safety barrier system including positioning and end treatments shall be in accordance with AS/NZS 3845. For the protection of workers from dynamic deflection of the barrier in a crash, if the work area is close to the rear of the barrier a containment fence or longitudinal channelising barricade shall be placed behind the barrier a clear distance equal to the likely dynamic deflection. Data on the dynamic deflection of the barrier type used when impacted by the selected design vehicle will be needed to determine the positioning of the containment fence.

The positioning of barriers in relation to high obstructions such as power poles, bridge piers or underpass scaffolding shall take into account the likely extent of body roll of a high vehicle striking the barrier.

Fittings other than delineators shall not be attached to safety barrier systems unless they have been designed to accommodate the fitting.

Hazardous fixed objects that have become exposed to traffic due to roadwork, such as bridge piers or safety barrier ends, may need to be equipped with purpose designed energy absorbing terminal devices to reduce the severity of collision by an out-of-control vehicle.
The need should be determined from a risk assessment that takes full account of the additional risk due to works on roads.

7.2 Identification and Treatment of Construction Work Zone Hazards

Due to limited data with regards to crashes within roadworks, a risk assessment process is used to identify hazardous features. In addition to considering the potential severity for an encroaching vehicle driver and occupant, in construction roadworks, the designer must firstly consider the severity of crashes involving workers. Besides workers, other roadside hazards that may be present in construction roadsides include

- Construction equipment and materials;
- Edge drop-offs;
- Severe roadside slopes;
- Existing permanent guardrail/concrete barriers;
- Exposed ends of temporary concrete barriers;
- Bridge piers;
- Bridge rail or parapet ends;
- Structure foundations;
- Excavations and rock cuts;
- A gap in the median between dual bridges; and
- Untreated guardrail ends in two-lane, two-way operations.

This list is not exhaustive, and designer experience and judgment should be used to identify other potential hazards introduced by construction activities, roadworks plan, and traffic control. In assessing potential work zone hazards, it is important to keep in mind that traffic may be rerouted via sidetrack or median crossover. Such a change may alter the relationship (i.e., separation) between traffic and fixed features and different traffic streams (i.e., opposing traffic).

7.3 Roadside Safety and Economics

Once an obstruction or potential hazard in the work zone roadside has been identified, the question then becomes selecting the most appropriate treatment (if any) to mitigate the obstruction or hazard.

In Australia the decision to consider a road safety barrier at roadworks is determined according to

a) Roadworker safety requirements
b) Traffic safety requirements

Australian Standard AS1742.3 contains clear guidance with regards to the separation of road workers from traffic. The clearances to edge of work area in the following Items shall be measured from the traffic-side edge of the line of delineating devices or barriers. Barriers are required where the work area if workers are between 1.2m and 3m to traffic and speed of traffic is greater than 60km/h, or where workers are within 1.2m of traffic and the speed of traffic is greater than 40km/h.

For Traffic Safety requirements the use and selection of barriers is in accordance with AS3845.
7.4 Barrier Placement Guidance for Roadworks

Temporary road safety barriers shall be used to contain and redirect errant vehicles so as to reduce the likelihood of them entering the work site. They may also be used to separate opposing traffic.

Provision for Temporary Barriers is generally allowed for where identified by the road authority or where a risk assessment determines that temporary road safety barriers are the most appropriate method of separation between traffic and the work site or other hazards.

Opposing flows of traffic may be separated with temporary barriers with sufficient offset provided to reduce the likelihood that barriers deflect into opposing traffic flow in the event of impact.

Where the approach and/or departure ends of barriers are not tapered outside the clearzone and are exposed to on-coming traffic, the exposed ends shall be treated with an approved end treatment. If the end is tapered outside the clear zone then no further treatment is required.

The performance of a barrier system is dependent not only on the design of the barrier segment, but also in the correct design of the entire barrier system including the minimum length of barrier and the location and form of end treatments.

Any barrier placement shall be designed in accordance with the requirements stated in:

- AS 3845
- AS1742 Part 3
- Road Authority requirements

When a need for temporary barriers is identified, the barrier type shall be determined on the basis of:

a) the type, shape, deflection performance and test characteristics of the barrier
b) the speed of traffic travelling through the work site
c) the clearance between the traffic and the work area

7.5 Other Considerations

Various other considerations are associated with traffic barriers and roadside safety features at roadworks. Some of the following sections reference parts of the Austroads Guides, which “describes the safety, functional, and structural aspects of traffic barriers; traffic control devices; and safety features used in work zones; and provides guidance on their application.” Information contained in the Austroads Guide is not repeated or summarised here.

7.5.1 Traffic Barriers

Only those temporary road safety barriers which are included in the Transport and Main Roads – Road Safety Barrier Systems and End Treatments (Assessed as compliant with AS3845:1999) and Other Related Road Safety Devices shall be used. Where barriers are manufactured according to TMR standard drawings referenced within this document, they shall be manufactured in accordance with MRTS14A.
Steel Beam Guardrail, in accordance with Standard Drawing numbers 1474 and 1475, may be used instead of temporary road safety barriers in some locations subject to the approval of the Administrator. End treatments shall be in accordance with Standard Drawing numbers 1462, 1470, 1474 and 1475, or with an approved proprietary end treatment listed in the Transport and Main Roads – Road Safety Barrier Systems and End Treatments (Assessed as compliant with AS3845:1999) and Other Related Road Safety Devices.

Steel Beam Guardrail shall not be used for temporary erection where posts have to be installed through pavements which remain part of the permanent works.

7.5.2 Length of Need

Refer to AS3845

7.5.3 Flare Rates

Refer to AS3845

7.5.4 End Treatments and Crash Cushions

The ends of temporary barriers shall be protected through the use of appropriate end treatments.

Only those end treatments listed in the Transport and Main Roads – Road Safety Barrier Systems and End Treatments (Assessed as compliant with AS3845:1999) and Other Related Road Safety Devices shall be used.
8 Ancillary Design Information

This chapter covers a variety of additional roadwork design elements which are not covered by the geometric design of the road.

Much of the information within this chapter cross-reference other publications, particularly the MUTCD (TMR 2013), The Queensland Road Planning & Design Manual (TMR 2013) and the Austroads Guides (various dates). The information in those publications is not repeated here, due to the periodic updating of those publications and designers should ensure that the current editions in their complete form are reviewed. This chapter provides limited supplemental information that provides specific guidance related to roadworks but does not supersede any information in either of the cited publications.

8.1 Drainage

Drainage in the road context is specifically focused at the “treatment of water (moisture) as it affects roads, the surrounding land and development, and the environment” (Austroads Guide to Road Design Part 5 (GRD5): Drainage Design, 2010). These outcomes also apply in the design of drainage for construction roadworks. In addition at roadworks specific provision needs to be made for construction phase erosion control, sediment control, bank protection, and storm water management. The associated design techniques and provisions vary substantially by geographic location.

Similar to the design of permanent drainage systems, at roadworks the need for drainage will commonly address one or more elements, namely:

- accommodation of rainfall on road surfaces
- underground drainage
- subsurface drainage for road pavements
- overland water flows.

8.1.1 Basics

A well-drained road surface, during and after construction, is needed for continued and safe operations during adverse weather conditions. The measures used to provide for drainage of permanent roadways also apply to roadworks; however, the relatively short life span of temporary roadways in roadworks can result in some modifications both in the form of the drainage infrastructure and in the level of risk that can be accommodated.

The Austroads GRDS (2010) is the primary reference describing the methodologies for undertaking drainage design at roads. Each project has a range of different attributes that may impact on the drainage outcomes for the project both during construction and during permanent operation. The following key drainage design considerations are described which should be assessed at every stage of a project:

- the appropriate ‘recurrence interval’ for various parts of the system (i.e. the statistical frequency of flood events which the system in whole or in part is designed to handle)
- the quantities of water to be handled
• how these can be most efficiently captured
• the environmental consequences of road operation and design options
• how the drainage design impacts on other aspects of the project
• what external constraints affect the design choices
• future operational costs and requirements of the drainage system
• occupational health and safety issues in construction, operation and maintenance
• the consequences of failure of the system

In urban projects, the built environment may impose constraints on the permanent and temporary drainage options that are available. This then requires consideration of short but intense rainfall events that could have serious social, economic or even life threatening consequences if the drainage system does not perform to requirements.

Rural projects tend to be less constrained in the development of drainage design systems and options, but may be influenced more by rainfall events that occur somewhere in a vast catchment. In these areas, the design may be governed more by the need for contingencies in the event of large rainfall events impacting on the road construction.

Austroads GRD5 (2010) identifies that the fundamental input for drainage design is the determination of the total volume of water to be handled, and the time distribution of the discharge. The definitive Australian reference is Australian Rainfall and Run-off (Engineers Australia, 2001), which forms the basis of most drainage design manuals developed by State Road Authorities.

8.1.2 Considerations Unique to Work Zones

Typically, drainage infrastructure for each phase of roadworks is not detailed to the same level as for permanent roads. At any given point in the construction of a road, the driving surface and adjacent area may be a quilt-like combination of pre-project, new permanent, and temporary pavements. It is important that drainage systems are designed to accommodate each phase.

Maintenance and upgrade projects on existing roads need to place specific emphasis on the impact that construction activities have on existing road drainage systems such as shoulders, swales, and medians. Roadwork strategies may have an impact on the operation of existing drainage systems. For example, the use of the road shoulder as a temporary lane may alter the design of the existing drainage system with an elevated potential for surface water encroachment into the temporary lane. The following roadwork drainage issues are common:

• Temporary infrastructure (e.g., temporary concrete barrier, temporary curbs, and sandbags) may affect roadway drainage patterns, including spread into traveled lanes.
• Existing culverts may require extension to accommodate temporary roadways.
• Positive drainage for temporary roads, sidetracks and pavement widening should be provided.
• Temporary pavement surface interfaces with permanent pavements can trap surface water or lead to linear flow along the pavement.

In urban projects, kerb and channel, drainage inlets and a connecting pipe network are the principal means of capturing surface flow from roadway and roadside surfaces. Temporary works may impact on the existing drainage system and to avoid expensive temporary redesign of a large area of...
drainage, may require temporary inlets within and between temporary lanes. These inlets need to be carefully designed to consider the needs of all road users, particularly cyclists and motorcyclists.

The analysis and design techniques provided in Austroads GRD5 (2010) provide the tools needed for designing both permanent and temporary roadwork drainage. The anticipation of construction phase conditions and the ability to adapt the drainage to dynamic construction sequencing and weather conditions is a key element of the road design task.

At roadworks sites, the primary differences relating to design of drainage will be the adopted peak rainfall intensity which should be subject to a risk analysis dependent on the duration of the works. In particular at shorter term sites, a risk assessment of the likely rainfall events may lead to a lesser level of drainage provision than for the permanent site. For example, a temporary sidetrack across a dry watercourse to undertake short term bridge or culvert works may not require any specific drainage provision if the risk of a rainfall event during the works is low (e.g. during the dry season in tropical areas).

### 8.2 Emergency Stopping Bays

At roadworks sites, there is often the need to maximise the use of the existing road cross-section to more efficiently undertake the works. This often results in the reduction or elimination of shoulders and lane widths. As shoulders are the traditional refuge for disabled vehicles, drivers of disabled vehicles may be faced with unfamiliar conditions and a set of poor choices. The provision of emergency stopping bays or intermittent shoulders therefore needs to be considered to mitigate for these cross-sectional reductions.

The factors to be considered in determining the need for emergency stopping bays include the road type, traffic volume, vehicle mix, and length of road without a shoulder. Roadwork sites which result in the loss of the shoulder for less than 1 km often do not require any additional specific facilities.

The design of a typical emergency stopping bay is shown in Figure 6-1.

![Figure 6-1. Emergency Stopping bay layout](source: Main Roads WA)

The key elements in the design of the emergency stopping bay are as follows;

**Sight distance**

Preferably Entering Sight Distance (ESD) to the exit point (downstream taper) should be provided for approaching through traffic for the design speed of the major road. In constrained situations typical at roadworks sites this sight distance can be reduced to the Safe Intersection Sight Distance (SISD) to the exit point for approaching through traffic.

Given the increased complexity of the driving task typical within roadworks sites, provision of extended sight distance aids driver performance in resolving potential conflicts between...
traffic in the through lanes and traffic that is entering or exiting an emergency stopping bay. Traffic departing the emergency turnout and merging into a lane also benefits from extended sight distance.

Locating emergency turnouts on flat, tangent sections of the road to maximise available sight distance is desirable but not always feasible. When emergency turnouts must be located near crest vertical curves, locating them in advance of the curve will maximise available sight distance for approaching traffic.

**Location**

Emergency stopping bays should be located on the left side of the travel lanes as right-side pullout areas are not typically expected.

Spacing of bays within roadworks sites where shoulders are not retained should typically be approximately 1 kilometre.

Sites selected for emergency stopping bays should not be provided within 100m upstream of the start of an exit ramp, 100m downstream of the end of an entrance ramp, within a freeway merge area or within 100m downstream of the end of a merge area.

On lit sections of road, sites shall be located between street lighting poles.

**Signing**

Advance signing of emergency stopping bays can improve the use and safety of the bays. They can also assist drivers experiencing emergencies to make informed decisions on the approach and exiting maneuvers.

**Other facilities**

Sites should have an emergency telephone or other signage to advise drivers regarding contacting emergency assistance.

Preferably sites shall be within 400 metres and in view of an existing or new CCTV camera.

Systems for the identification and assistance of disabled vehicles should be included within the Traffic Management Plan.

### 8.3 Speed Enforcement

A key element of the roadworks traffic management scheme, is the speed of traffic travelling through the site, and the degree of compliance with the posted speed limits. With correctly implemented speed limits, reflecting the speeds required for road worker and road user safety, it is desirable that self-compliance is achieved through the design of the roadworks and roadside environment. However, at some sites the reasons behind the reduced speed limits may not be immediately obvious to drivers at all times under all traffic conditions and/or there may be a level of non-compliance which cannot be addressed safely through the design of traffic management alone.

There remains the need therefore to allow for mechanisms for speed enforcement to be undertaken and in cases significant enforcement is desired to achieve compliance with regulatory roadworks speed limits. Visible roadwork speed enforcement presence encourages compliance with speed limits and overall safe driver behavior.
8.3.1 Enforcement Bays

The most visible form of speed enforcement remains the presence of police undertaking and penalising drivers. Although this methodology is generally being replaced with either fixed or mobile camera enforcement, it remains the most common method for random enforcement.

Effective enforcement by this method is generally hindered at roadworks by the absence of locations where police or speed enforcement vehicles can safely position themselves and/or pull violators over. Therefore consideration should be given to including provisions for temporary enforcement bays in the construction and traffic control plans. These bays may double as emergency stopping bays as discussed above.

Enforcement Bay design - To be both safe and effective, any area used for police enforcement should be wide enough to allow the undertaking of enforcement activities. This may require width additional to that provided for a typical emergency stopping bay to allow an enforcement officer to stand next to a vehicle. The remaining design of the bay should be in accordance with the design of an emergency stopping bay.

The use of other available facilities (e.g., rest areas and weigh stations) can also be used to implement enforcement efforts.

8.3.2 Speed Camera Enforcement

The use of speed cameras is becoming more common in undertaking speed enforcement and may be undertaken through the use of either fixed or portable speed camera installations. Roadworks schemes considering the use of camera installations may include the following elements.

- Fixed enforcement camera sites throughout the length of the works which can be used either on a permanent or rotating basis for camera.
- Portable enforcement camera sites, either in a vehicle or on a tripod or similar stand.
- Point to Point camera sites which issue infringement notices on the basis of average speeds through the worksite.

8.3.3 Other Implementation Considerations

Enforcement is not the only means of facilitating roadwork speed compliance. On long lengths of roadworks, consideration should be given to for dividing the works into segments of 5 km long or shorter. Provision should then be made to avoid emergency shoulders in adjacent segments being eliminated at the same time during the project.

In addition to undertaking speed enforcement, an important aspect in ensuring speed compliance is an high expectation by drivers of being issued an infringement if they are speeding. At roadworks sites this may require additional signage and mechanisms to ensure that the speed enforcement is visible and that drivers are aware that enforcement is being undertaken in the case of camera enforcement which may not result in receipt of an infringement for some days.
8.4 Screens

8.4.1 Glare Screens

An antiglare screen which reduces excessive headlight glare to an acceptable level should be considered where temporary diversions result in directly opposing traffic, particularly in cases where a road may normally have been divided. Screens should be provided where oncoming headlights could mislead drivers as to their correct travel path. The screen supports should be of sufficient strength to ensure the stability of the screen in windy conditions but frangible under vehicle impact.

8.4.2 Construction Anti-Gawking Screens

Anti-gawking screens are used to minimise visibility of the construction activities to the travelling public. This then assists in reducing the visual distraction to drivers which could cause traffic delays adversely affect the safety of the roadworks site.

The characteristics of a work-zone anti-gawking screen include the following:

- is of adequate height and opacity to function as a screen.
- Are fitted to the top of safety barriers and do not adversely affect or alter the performance of the barrier system.
- will not present an undue risk to workers and other traffic during an impact, for example, by spearing/penetrating the passenger compartment.
- performs in a predictable manner when impacted and does not shatter or create debris which would become a hazard.
- is resistant to vandalism and vehicle damage.
- is easy to repair.
- does not protrude or lean into vehicle path, especially when subject to wind loading.

Queensland Transport and Main Roads provides further details with regards to Anti-gawking screens in the Transport and Road Use Management Manual 7.5 (TMR 2013)

8.5 Variable Message Signs

Variable message signs provide a useful supplement at many roadworks sites to convey more complex messages to drivers that cannot be delivered through use of traditional temporary roadworks signage. However care should be taken to ensure that messages are relevant and do not cause additional distractions to drivers.

The requirements for the use of variable messages signs at roadworks sites to carry warning or other messages relating to the works are detailed within AS1742.3, the MUTCD (TMR 2013) and TRUM Manual (TMR 2013). The requirements within these references detail;

a) Word legends and number of words on the screen
b) Letter forms and legend height
c) Number of separate screens
d) On time of each screen
e) Use of Symbols
f) Relevance of messages
g) The nature and positioning of the messages
h) Colour of messages and symbols

8.6 Lighting

Lighting at roadworks typically needs to meet the lighting requirements for permanent roads and is detailed in AS1158. Flood lighting is sometimes provided in roadworks sites to illuminate nighttime construction activity (e.g., paving operations and traffic controllers). Factors that must be considered in this decision are the vision and comfort of drivers and the ability of the workers to perform different types of tasks.

Conventional road lighting that is present in pre-roadwork conditions should normally be maintained during construction projects. If individual lighting units are removed from service during construction, temporary units should be considered.

The provision of temporary road lighting generally considers the same warrants and criteria used for permanent lighting to address issues such as high night-to-day crash ratios, high traffic volumes, high traffic speeds, substantial queuing, complex maneuver areas, restrictive roadway geometry, and high pedestrian volumes.

8.7 Rumble Strips

Rumble strip configurations may be used at roadworks in situations where it is necessary to ensure that drivers are alert to the speed limits and traffic control devices. Rumble strips are generally created with additional pavement material (e.g., asphalt) or manufactured materials (e.g., removable neoprene or multiple layers of traffic tape) fastened to the road surface.

Several clusters of temporary rumble strips are generally placed in advance of a segment or feature where reduced speed or elevated driver awareness is desirable.

Several roadworks strategies (e.g., median crossover or use of shoulder) reallocate the roadway cross section, which changes the relationship between wheel paths and the existing edge or shoulder rumble strips. Depending on the pavement material, type of rumble strips, location of wheel paths relative to rumble strips, and duration of temporary reallocation, existing rumble strips may need to be modified, such as by paving over portions of the rumble strips.
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