Guide to Road Design Part 2

Design Considerations

Austroads

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Austroads

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Guide to Road Design Part 2: Design Considerations

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Changes contained in this version of the Guide include updates that discuss how the Safe System approach can be incorporated into the road design process. Updates to references and cross-references to other Austroads Guides have also been made, along with changes to the commentaries section.

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Abstract

Guide to Road Design Part 2 provides a detailed description of the three critical aspects of road design: the design objectives that apply to a road design project; context-sensitive design; and the factors that influence the road design, including road design in the context of the Safe System philosophy. Guidance is provided to practitioners on the range of influences, information, data, criteria and other considerations that may have to be assessed in developing a road project. The Guide also describes the basis of the guidelines and the context in which they should be applied. It also provides links to other Austroads Guides and the resources that give further guidance on design inputs.

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About Austroads
Austroads' purpose is to:

- promote improved Australian and New Zealand transport outcomes
- provide expert technical input to national policy development on road and road transport issues
- promote improved practice and capability by road agencies.
- promote consistency in road and road agency operations.

Austroads membership comprises:

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Transport Northern Territory
- Territory and Municipal Services Directorate, Australian Capital Territory
- Commonwealth Department of Infrastructure and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry. It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road transport sector.

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Summary

Part 2 of the Guide to Road Design provides a detailed description of the three critical aspects of road design: the design objectives that apply to a road design project, context-sensitive design and the factors that influence the road design, including road design in the context of the Safe System approach philosophy. Guidance is provided to practitioners on the range of influences, information, data, criteria and other considerations that may have to be assessed in developing a road project. The Guide also describes the basis of the guidelines and the context in which they should be applied. It also provides links to other Austroads Guides and the resources that give further guidance on design inputs.

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1. Design Objectives

1.1 Introduction

Roads will continue to be an important part of our transport system for the foreseeable future, providing for the safe and efficient movement of people and goods. Road projects are developed to meet increasing travel demand, address crash problems, rehabilitate existing infrastructure, or for a combination of these reasons. A balanced approach towards road planning and design can improve operational efficiency, road safety and public amenity, and minimise the effects of noise, vibration, pollution and visual intrusion on the areas through which a road passes.

Road designs should incorporate the Safe System approach which ensures that the needs of all road users are considered in all aspects of the design process. The objectives of new and existing road projects should be carefully considered to achieve the desired balance between the level of traffic service provided, safety, whole-of-life costs, flexibility for future upgrading or rehabilitation, and environmental impact. These objectives should address areas including:

- strategic fit with relevant government policies, strategies and plans
- the nature and magnitude of transport demand
- road safety to reduce death and serious injury to all road users
- community views and expectations
- travel times and costs
- freight costs
- public transport provision
- provision for cyclists and pedestrians.

Objectives under each of these areas are discussed in the following sub-sections.

1.2 Strategic Fit

As well as satisfying local requirements, the objectives for a road project should support transportation outcomes required by governments (federal, state and local) and the community. The required outcomes may be reflected in:

- government policies
- investment strategies
- planning schemes
- network operation plans.

These outcomes may influence the function that a road is required to perform within the road network, and hence its design objectives. The design should consider the principles of the Safe System approach.

Relevant government policies may be transport-specific, for example, addressing the desired balance between road-based transport and other modes of people or goods movement, or between private and public transport for passenger travel. Alternatively, they may be more general, for example, directed towards desired patterns of land use and economic development in urban and regional areas.

Investment strategies may similarly be transport-specific or broad. Broad strategies may be concerned with the allocation of funding between different economic sectors such as education, health, national security and transport, while transport-specific strategies may address such questions as the roles of the public and private sectors in road or rail infrastructure development, the distribution of government funding between different transport modes, or the relative merits of investing in transport demand management schemes as opposed to infrastructure expansion.

Road project objectives may also reflect and support strategic transportation and development plans for the country, state, city or area through which the road passes. Ideally, planning will integrate consideration of transport, land use and environmental objectives and will address multi-modal issues, which are often outlined in network operation plans. Network operation planning, as described in Part 4 of Austroads *Guide to Traffic Management* (Austroads 2015a) can define the context in which the road will operate, particularly with respect to ITS operations and therefore aid in the design of the road by providing guidance on how to design the road for its operations. Further discussion about planning integration and road project objectives is provided in the Austroads *Guide to Road Transport Planning.* These aspects, in the context of road design are briefly discussed in Commentary 1.

[see Commentary 1]

Policies, investment strategies and planning schemes will influence objectives for both planning and design of road projects through their implications for such aspects as the spatial distribution of transport demand, feasible corridor locations, required traffic capacities, freight routes and on-road public transport.

Project objectives must relate specifically to the issues or problems being addressed. It is important to evaluate design options for road projects and the assessment criteria used must have the capacity to address a project's specific objectives and its impacts. It is desirable that assessment criteria include all economic, environmental and social consequences of each option. 'Triple bottom line' is a term commonly used to describe the joint consideration of these aspects (refer to the *Guide to Project Evaluation*).

1.3 Nature and Magnitude of Transport Demand

The prime requirement for any road is to carry a designated volume of traffic in a safe and efficient manner. This of course requires an estimate of the traffic it is expected to carry, in terms of absolute volume, type of vehicles, and time distribution.

Given the long-term nature of any road investment, traffic estimates will commonly cover a period of 20 to 40 years. Many factors will impact on the actual traffic growth compared to the best estimates that can be made, including local and regional land developments, demographic changes, the broad economy, and technological changes in the vehicle fleet.

Future traffic flow for roads is determined through traffic forecasting, either by estimating growth from historical data in the case of rural roads or by the use of traffic modelling techniques and computer software packages for urban road networks.

Estimates of traffic flow for particular road user groups are also important, as it may be necessary to provide special facilities for public transport in urban corridors and freight movements may determine design standards for use in some rural corridors.

Information on the estimation of traffic volumes is contained in the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013b). Reference can also be made to the US *Highway Capacity Manual* (Transport Research Board 2010).

1.4 Safety

1.4.1 Safety Objectives

Safety is a prime objective in road design, and is pursued in accordance with the Safe System approach which underpins the national road safety strategies in Australia and New Zealand. The Safe System approach recognises that humans make errors, that crashes will continue to occur and that humans have a limited tolerance to impact forces. The approach aims to provide a safer road and traffic environment in which alert and responsible road users should not be killed or seriously injured as a result of a crash. It is structured around the basic pillars of safer roads, safer speeds, safer vehicles, and safer road users.

In the context of designing and providing a safer road environment, the Safe System approach aims to ensure that potential collisions are avoided and, if they occur, that the crash impact forces do not exceed human tolerance. On rural roads and major arterials, multi-vehicle and single-vehicle crashes are the prime concern, whereas on urban local roads pedestrian activity, and the potential for vehicle-pedestrian conflicts, is greatest. Pedestrians are particularly vulnerable to serious injury. Design considerations for local roads must therefore strive to ensure that these conflicts are avoided and that design speeds are commensurate with potential impact speeds that are survivable (see also Section 1.9). Further information on this is provided in Commentary 2.

[see Commentary 2]

Without guaranteeing absolute safety, a ‘safe road environment’ is one in which road users can successfully negotiate road alignments and potential conflicts with other road users, and which provides a forgiving roadside environment for errant vehicles. It recognises the realities and limitations of human decision-making – in other words, it does not place demands upon the driver, or any other road user, which are beyond their ability to manage, or outside normal road user expectations. Such a safe road environment will be achieved if it is designed and managed so that it provides:

- a generally consistent design standard
- effective transitions where a reduction in standard is necessary (i.e. there should be no ‘surprises’ in road design or traffic control, and the design should match road user expectations)
- a controlled release of relevant information (the design matches the information processing abilities of drivers)
- repeated information, where pertinent, to emphasise increased risk
- for the safety needs of all road users.

Applying the principles of risk management and the Safe System approach, a safe road should:

- be ‘self-explaining’ to allow road users to readily comprehend the type of road and what could be expected in terms of the elements of the design
- warn road users of any substandard or unusual features
- inform road users of conditions to be encountered
- guide road users through unusual sections
- control road users passage through conflict points or conflict sections
- be forgiving of errant or inappropriate behaviour.

Designing a road to these principles is not the same as designing a road which simply meets a set of recommended values. A road designed to meet a set of recommended values is not necessarily safe and a road which, in some details, fails to meet these values is not necessarily unsafe. There is no substitute for the application of sound engineering experience and judgement.

1.4.2 Designing for Safety

Virtually all elements of road design have safety implicitly included in their derivation, although this may not necessarily be spelt out. For example, horizontal and vertical alignment designs are based on sight distance and lateral acceleration considerations which are, in turn, derived using the operating speed and the performance characteristics of vehicles to allow for safe operation.

The Safe System approach encourages road designers to consider more deeply the implications of their emerging design solution; by designing a road environment that limits crash impact speeds which acknowledge the limits of the human body, road designers can achieve greater improvements in road safety.

Three areas are particularly considered in the safety performance of roads, namely intersections, mid-block conditions and the roadside environment. Although the term 'mid-block' has strong urban connotations, the principles apply equally to sections of rural roads between intersections.

Intersections

Intersections present multiple conflict points for road users and design and control is a major factor in improving road safety.

[see Commentary 3]

In general, an intersection should be obvious and unambiguous and allow good visibility of traffic control devices and other road users. Care must be taken to select the most appropriate type of intersection in terms of traffic control (priority controlled, roundabout, signalised etc.), as each type has its strengths and weaknesses. Good design will harmonise the geometric layout with traffic control requirements and will minimise both the number of traffic conflict points and the magnitudes of conflict areas.

An intersection design must be viewed from the perspective of each road user group. The needs of drivers differ significantly from pedestrians and cyclists; some intersection types may address vehicle driver/passenger needs very effectively, but at the same time may present a higher risk to the vulnerable road user groups.

For information on the traffic engineering requirements for intersection design, refer to the *Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings* (Austroads 2013c).

For information on detailed geometric design of intersections, reference should be made to the *Guide to Road Design Part 4: Intersections and Crossings* (Austroads 2009a).

Mid-block

Mid-block safety should be considered during the design phase.

On-road safety is influenced by horizontal and vertical alignment and its effects on such things as sight distances and overtaking opportunities, by the dimensions of cross-section elements, by the degree of access control and a range of other factors. Good design will provide road users with geometry that is both consistent along a given route and consistent with other roads of the same type, so that driving requirements can be correctly anticipated.

[see Commentary 4]

For information on traffic engineering aspects of mid-block design, refer to the *Guide to Traffic Management Part 5: Road Management* (Austroads 2014a).

For information on detailed geometric design of mid-block sections, refer to the *Guide to Road Design Part 3: Geometric Design* (Austroads 2010a).

Roadside

Roadside safety typically relates to the area adjacent to the traffic lane where an errant vehicle can recover. When drivers lose control and vehicles leave the road, there is a risk of injury and damage due to collisions with unyielding objects (e.g. trees and poles) or non-traversable features (e.g. drains, berms or rough surfaces) that may cause the vehicle to vault (i.e. become airborne), roll over or stop abruptly.

The roadside areas may need to provide for other road user activity such as pedestrians, cyclists, emergency breakdown and rest areas. The interaction of these activities with road traffic and the risk posed by errant vehicles must be considered in the development of mid-block designs.

Notwithstanding that there are physical, environmental and economic constraints, the preferred treatments of roadside hazards (in a hierarchy-of-control risk management order) are:

- removal
- relocation to reduce the chance of them being hit
- redesign so that they can be safely traversed
- redesign to be frangible or break away, or to otherwise reduce severity
- shield with a safety barrier or impact attenuator
- delineate the hazard if the above alternatives are not appropriate.

It must be recognised that safety barriers are also potential hazards that often have a higher probability of being impacted than the object they are shielding, but have a lower severity of impact. While this crash severity reduction is core to the Safe System approach, the application of a road safety barrier should not automatically be considered to meet Safe System objectives. Research and crash experience have shown that safety barrier performance to reduce crash severity varies depending on the type of barrier, its application in the roadside area and the road user group impacting the barrier.

For information on roadside safety and design, reference should be made to the *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010b), together with the *Guide to Road Safety Part 9: Roadside Hazard Management* (Austroads 2008).

1.4.3 Road Safety Audits

The road safety audit process is a valuable tool to ensure that safety aspects are ‘built in’ to a project from conception rather than attempting to ‘add them on’ at an advanced stage or even retrofit treatments after a crash history develops. A road safety audit serves to review all aspects of the project from concept, design, and during construction and post-construction stages.

For new designs, road safety audit procedures can be applied throughout the design process and become an integral part of the development of the road design. Safety experts work with designers to provide guidance at all levels of the project development process, from the planning stage to the formal opening of the facility. By integrating road safety considerations with the design process, cost-effective opportunities to improve safety in a design can be identified early in the design process and can more easily be incorporated into the work.

Guidelines on the conduct of road safety audits are available in Austroads (2009b) and NZ Transport Agency (2013).

1.5 Community Expectations

The involvement of stakeholders throughout the planning process helps to ensure that all issues and needs are identified and considered, and that outcomes have a high degree of support and ownership. Public consultation is therefore an essential part of all road planning and design activities. The importance of the Safe System approach to road design should be communicated to the community to gain its support and acceptance.

Community expectations may be general or specific in nature. The expectations may relate to economic, social, safety, traffic management or environmental aspects. There may be concern about the visual impact of the project on the landscape or aspects such as traffic noise and air pollution. Design aids to provide three-dimensional impressions and models of the project may assist in providing the community with a picture of the project or project options. Specialist consultant reports describing important archaeological, heritage and natural environment features in the corridor can assist in the resolution of these issues in relation to design options.

Particular stakeholder groups may have specific concerns about the performance of an existing road and the ability of a proposed project to improve the performance. For example, concern may be expressed by:

- motoring associations with respect to travel time costs or significant delays
- freight operator associations about the cost of moving freight
- public transport operators and users regarding schedules and reliability of services.

For projects where the needs of special road user groups have to be accommodated at the expense of other users, community expectation must be carefully managed through the consultation process. Examples include the reallocation of general traffic lanes for use as transit lanes, bus lanes or bicycle lanes, or the provision of tram stops that provide equitable access to public transport for disabled persons.

1.6 Reduced Travel Time and Costs

Travel time and costs for road users can be strongly influenced by judicious selection of locations, alignments and capacities of roads. The maintainability of roads is also an important consideration, as delays caused by roadworks can significantly impact on both the time and cost of travel.

1.7 Reduced Freight Costs

On routes with a significant freight task, it is important to cater for the special requirements of heavy vehicles. Modest grades may be warranted to enable heavy vehicles to maintain speeds, and longer overtaking lanes should be considered to allow long vehicles with small speed differentials to safely overtake.

Overall planning may also indicate the need for rest stops and for the provision of service facilities or areas to break up long vehicles prior to entering more restricted or densely trafficked environments.

1.8 Improved Public Transport

In some projects it may be desirable to make specific provision for public transport usage. This may involve reservation of corridors for light or heavy rail, provision for modal interchanges in or adjacent to the road reserve, or dedicated bus or high occupancy vehicle (HOV) lanes.

[see Commentary 5]

The potential benefits of HOV lanes are addressed in the *Guide for the Design of High Occupancy Vehicle Facilities* (American Association of State Highway and Transportation Officials 1992) and largely revolve around the traffic management aspects of the road system. However, some classes of HOVs may have specific requirements in terms of dimensions and swept paths that will impact on elements of geometric design.

1.9 Provision for Cyclists and Pedestrians

In recent years there have been significant developments in policy and strategic planning initiatives aimed at giving greater recognition to walking activity in transport planning, particularly in urban areas. This has arisen from policy settings in the transport and health sectors recognising the need to move towards more sustainable forms of transport (by foot, bicycle or public transport) and towards healthier activity (walking, cycling) by the community generally. This has led to recognition of the need for planning and designing a road network which caters for the potential increase in active travel, and for providing facilities for safe pedestrian activity.

Any road design project must consider the needs of all relevant road users. This will often include cyclists, pedestrians and other non-motorised traffic of all age groups.

Cyclists and pedestrians are particularly vulnerable road users. Design for such users will seek to facilitate their movements by separating them from motor vehicles in time and space:

- along road reserves, either on the road carriageway, by providing on-road bicycle lanes for cyclists, or on roadside facilities such as footpaths and shared use paths
- across road carriageways at intersections or at mid-block locations, with signalised and non-signalised crossings
- along off-road facilities, such as exclusive or shared bicycle and walking paths.

It is not always possible, or desirable, to clearly separate vehicular and pedestrian activity. In some instances the provision of shared areas is a preferred approach, utilising facilities such as ‘shared zones’ and ‘shared spaces’. Further discussion of these facilities is given in the *Guide to Traffic Management Parts 5, 6 and 7* (Austroads 2013c, 2014a, 2015b).

2. Context-Sensitive Design

A road is but one element of a transport system, which operates in the natural and built environment to meet a range of expectations of the users and the broader community. The design cannot be carried out in isolation, but must be sensitive to the context in which the road will operate.

Context-sensitive design (CSD) is an approach that provides the flexibility to encourage independent designs tailored to particular situations. CSD seeks to produce a design that combines good engineering practice in harmony with the natural and built environment, and meets the required constraints and parameters for the project. The US Federal Highway Administration (FHWA) comments as follows:

> Context sensitive design asks questions about the need and purpose of the transportation project, and then equally addresses safety, mobility and the preservation of scenic, aesthetic, historic, environmental, and other community values. Context sensitive design involves a collaborative, interdisciplinary approach in which citizens are part of the design team. (Federal Highway Administration n.d.)

The challenge is to develop a design solution that takes account of the competing alternatives and the trade-offs that might be needed. Factors that should be considered in these trade-offs include:

- mobility and reliability
- environmental impacts
- loss of consistency of design (a safety issue)
- reduction in the life of the infrastructure
- capital costs
- whole-of-life costs (e.g. maintenance costs, vehicle operating costs)
- aesthetics.

The end product must be internally consistent, consistent with the expectations for the type of road, and compatible with road design principles presented in this Guide and other relevant documents. The reasons for adopting any particular design criteria and/or parameters must be robust, defensible, fully documented and in keeping with the Safe System approach.

The principles of context-sensitive design have been outlined by the US Federal Highway Administration, and are addressed in Federal Highway Administration (2012).

[see Commentary 6]

2.1 Design Domain Concept

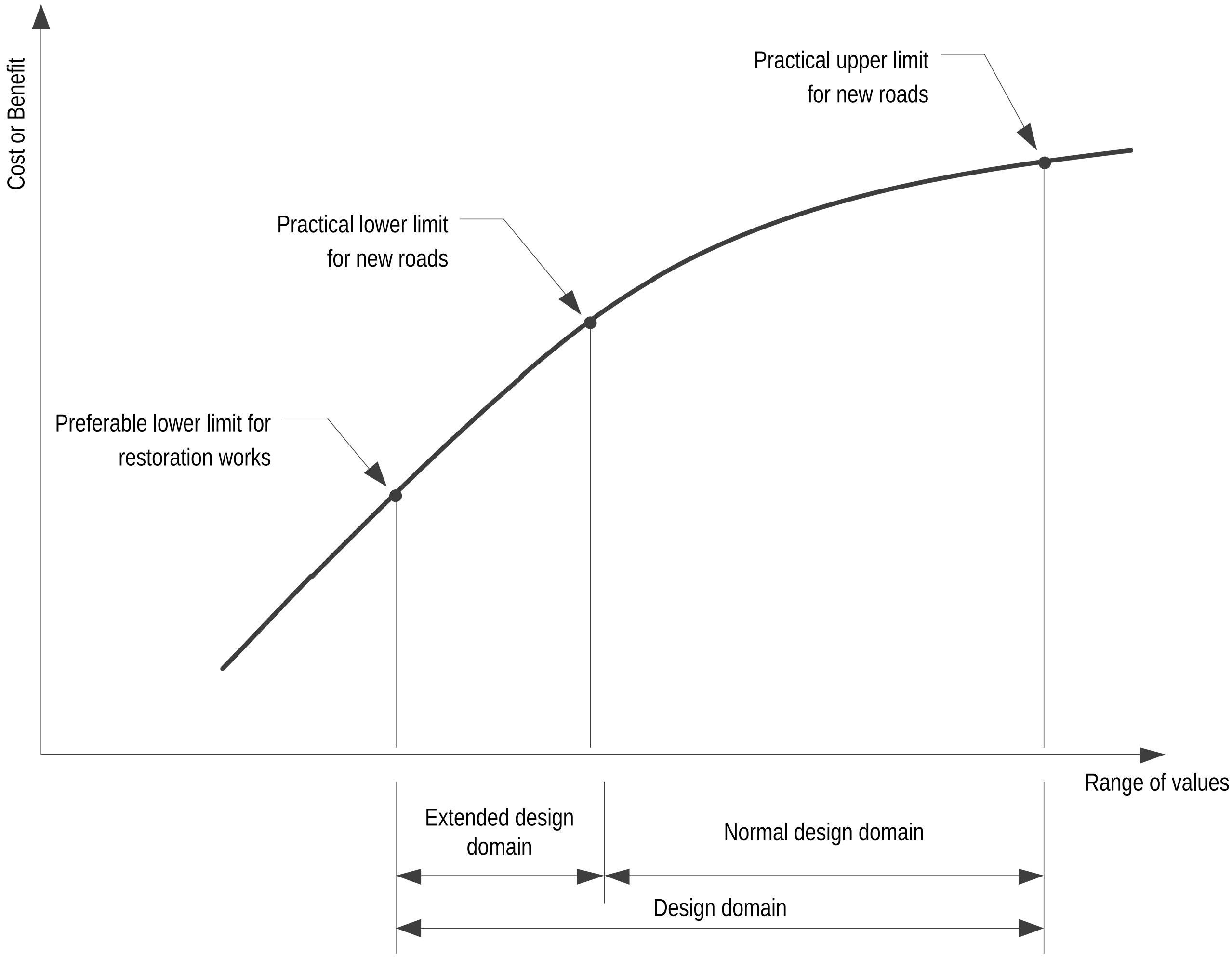
Design domain can be thought of as a range of values that a design parameter might take. It is a range of design parameters that can be justified in an engineering sense (based on test data, sound reasoning, etc.) and therefore can have a reasonable level of defence if questioned.

More comprehensive treatments of the design domain and extended design domain concepts are given in Transport Association of Canada (1999), Cox and Arndt (2005) and Department of Transport and Main Roads (2013), an extract from which is in the commentary.

[see Commentary 7]

The design domain approach places emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets 'standards'. Figure 2.1 illustrates the concept that requires a designer to select a value for each design element from a range of values, considering the benefits and costs of each selection.

Figure 2.1: The design domain concept



Notes:

- The value limits for a particular criterion define the absolute range of values that it may be assigned.
- The design domain for a particular criterion is the range of values, within these limits, that may practically be assigned to that criterion.

Source: Based on Transport Association of Canada (1999).

Figure 2.1, shows that the design domain comprises a normal design domain (NDD) and an extended design domain (EDD). The lower regions of the design domain represent values that would generally be considered less safe or less efficient, but usually less expensive than those in the upper regions of the domain. The decision on the values to adopt should be made using objective data on the changes in cost, safety and levels of service caused by changes in the design, together with benefit-cost analysis.

Such data is not always available, particularly data that relates changes in the values associated with specific design elements and parameters to safety performance. Designers should therefore refer to relevant documents, including this Guide and research reports, to assess the potential effects of changes in values for the various design elements involved. The data chosen should also consider the importance of incorporating Safe System principles in the design.

Using this concept provides benefits to the designer as it:

- is more directly related to the road design process, placing a greater emphasis on developing appropriate and cost-effective designs rather than merely following prescriptive standards
- reflects the continuous nature of the relationship between changes in the design dimensions and service, cost and safety, as the designer must consider the impacts of trade-offs throughout the domain and not just where a standard threshold is crossed
- provides an implied link to the ‘factor of safety’, a concept commonly used in civil engineering design processes where risk and safety are important.

As a general principle, values in the upper part of the design domain should be selected when:

- designing new roads, particularly those in greenfield sites
- designing roads with high traffic volumes
- designing more important roads
- other parameters at the same location are approaching the minimum
- little additional cost is involved in the use of these values
- a significant crash history exists at a particular location.

Similarly, values in the lower part of the design domain may apply to works on existing roads involving improvements or restoration, where there is no significant crash history and where significant constraints exist.

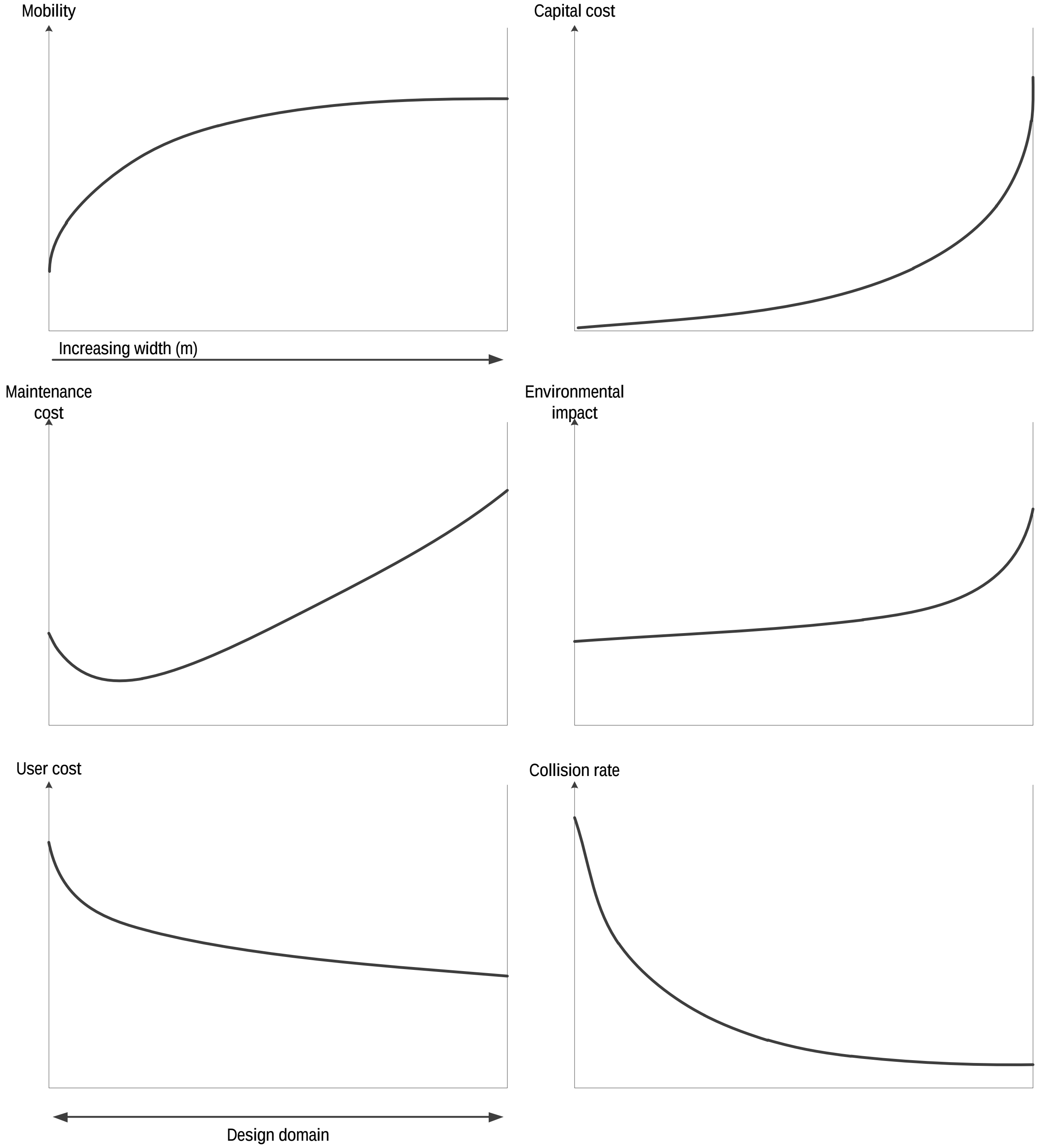
The use of values below the design domain (that is, even lower than the extended design domain) cannot be justified on engineering grounds. Any use of such values constitutes a design exception and must be formally approved by the relevant road agency after due consideration and documentation of all constraints, criteria and risks.

Figure 2.2 illustrates how the design domain concept might be applied to a single design parameter, the example used being shoulder width. The graphs show that a value for shoulder width might be chosen that optimises the balance between costs and safety. Selection of a value within the domain will depend on a trade-off between the various benefits and costs. In other cases, values for several design parameters must be selected, these parameters working together to optimise the design.

However, the designer must take into account the nature and significance of controls and constraints on the design. Often the designer will not be able to choose design dimensions that will satisfy all of the controls and constraints and compromise will be required. These engineering decisions call for knowledge, experience, insight and a good appreciation of community values.

To some extent, the design domain approach formalises the means by which previous manuals have defined the range of values within which the designer should operate. However, the design domain approach clarifies the extent of trade-offs and highlights the inter-relationship between the various elements of design. It encourages a holistic approach to design.

Figure 2.2: Design domain example – shoulder width



Source: Transport Association of Canada (1999).

2.2 Normal Design Domain

The design domain for a new road is referred to as the 'normal design domain '. The extent of the normal design domain defines the normal limits for the values of parameters that have traditionally been selected for new roads.

For any design parameter there is a practical upper limit beyond which incremental benefit diminishes. The practical upper limit for a new road shown in Figure 2.1 corresponds to the maximum value for any particular parameter (where applicable) in the *Guide to Road Design*. For example, the practical upper limit of lane width for a rural road is given as 3.7 m, exclusive of curve widening (Austroads 2010a). In some cases, an increase in a parameter above a particular value may result in a dis benefit in terms of road safety (e.g. shoulder width above 3.0 m).

The practical lower limit for a new road shown in Figure 2.1 corresponds to the minimum values given for any particular parameter in the *Guide to Road Design*. For example, the practical lower limit of lane width for a rural road is 3.5 m (Austroads 2010a). As a general rule, values below the practical lower limit should not be chosen for a new road unless constraints apply and they can be justified.

The extent of the normal design domain within the various manuals and guidelines is usually based on the experience and judgement of practitioners, even where the relationship with safety has been identified by research. This can vary over time, depending on current subjective thinking and on changes in road/traffic characteristics. For example, vehicle fleet changes have led to a decrease in the design value for driver eye height and a consequent increase in the minimum length of crest vertical curves.

2.3 Extended Design Domain

As shown in Figure 2.1, the EDD is a range of values below the lower bound of the NDD. Therefore, EDD is a range of design values below the minimum values traditionally specified for new roads in road design guidelines. Where used, EDD refers only to this extended range of values.

The EDD concept uses values smaller than the practical lower limit in certain circumstances, provided they can be justified and defended on engineering grounds and operating experience. Use of values within the EDD should be supported by a documented risk assessment that:

- justifies and recommends the values to be adopted for various design parameters
- demonstrates that adoption of lower values is in the overall community interest with respect to investment strategies, road safety strategies, and other strategies that relate to roads and road networks
- verifies that responsibility for the use of values within the EDD is taken corporately by the relevant road agency and is not placed on an individual designer.

Most road design guidelines are based on theoretical safety models because of the inherent difficulty in determining standards based on objective safety evidence. The lower-bound values used in the EDD approach recognise that models developed for the design of new roads can produce values that are conservative for some situations. The concept of EDD uses less conservative values for some input parameters on the basis that they can be supported by comprehensive engineering test data and deliver reasonable outcomes.

The use of EDD may be limited to particular parameters (e.g. sight distance) where research has demonstrated that the adoption of EDD will not result in significantly higher crash rates. While the use of design values from within the EDD may not be preferred, it may be necessary in certain circumstances, usually for existing roads in constrained situations. Improving existing roads, particularly the geometry of existing roads, is relatively expensive. Furthermore, the cost differential between upgrading a road to a level within the normal design domain compared to a level within the EDD is likely to be high in these cases. In contrast, the relative cost differential between providing a road that conforms to the normal design domain, compared to the EDD, is likely to be relatively less for a new road (i.e. at a greenfield site).

Table 2.1 lists situations where the use of normal design domain and extended design domain may be applicable.

Table 2.1: Typical use of normal and extended design domain

Normal design domain	Extended design domain
• New construction (greenfield sites) • Significant lengths of reconstruction of existing roads • New carriageway of a duplication	• Assessment of existing roads • Improving the standard of existing roads in constrained situations • New carriageway of a duplication in constrained situations • Temporary situations (e.g. projects where it is known that imminent development will cause a permanent reduction in the operating speed)

Designers should be aware that simply adopting minimum values (including EDD values) for several design elements simultaneously may produce an unsafe and/or unsatisfactory result. For example, combining a minimum radius horizontal curve with a minimum radius vertical curve and a minimum formation width may be a hazard to road users. Where a minimum is adopted for one geometric element, it is desirable to adopt a standard that is above the minimum for other elements (e.g. increase the pavement width to allow vehicles to manoeuvre on an absolute minimum radius vertical curve). This principle is particularly relevant when applying the EDD concept.

2.4 Road Characteristics and Use

2.4.1 Functional Classification and Use

The standards adopted for road projects are usually influenced by the functional classification of the road. For example, roads of higher classification have a major role in the transportation task and therefore require a higher standard of design. Roads fall into a hierarchy of functional classes ranging from major arterial roads to local access roads.

The recent developments in policy and planning initiatives giving greater recognition to more sustainable forms of transport in urban areas (Section 1.9) have led to consideration of a road user hierarchy in addition to the traditional road hierarchy. The road user hierarchy indicates the relative priorities to be accorded to road user categories in the operations of the road network. In accordance with this, pedestrian activity is often identified for priority consideration on some sections. This needs to be integrated and balanced with priorities arising from the prevailing functional road classifications.

Functional classes are not always clear-cut since almost all roads have some degree of local importance.

Rural roads of higher functional class generally cater for a higher (though normally still modest) proportion of longer-length journeys, and it may be appropriate to select higher design standards for such roads so that the quality of service is more appropriate to the longer trip duration. However, designers must beware of placing too much importance on functional class alone where traffic volumes are low. Austroads has defined a system of functional classification for rural roads (Table 2.2).

In rural areas, the Class 1 and 2 roads in Table 2.2 are generally freeways, or major highways that have a high standard for two-way two-lane roads. They are usually roads of national or state importance in terms of communication and the economy. Class 3 roads would generally be main roads of a satisfactory but lesser standard than the Class 1 and 2 roads.

Austroads has also adopted a rural route numbering hierarchy to assist road user guidance. This hierarchy identifies arterial routes as M, A, B or C routes and, similar to the classification in Table 2.2, is also related to the route characteristics. This is discussed in more detail in the *Guide to Traffic Management Part 4: Network Management* and *Part 5: Road Management*.

The functional classification of urban roads (refer to Table 2.3) is usually less clear than that of rural roads, as urban roads generally are flanked by dense development that requires frequent access at the boundary of the road. Historical requirements for kerbside parking and other uses (e.g. public transport routes or bicycle routes) further complicate functional definitions.

Most urban arterial roads continue to function as major through traffic routes but the management of these roads often requires space to be dedicated to public transport or bicycle use in preference to private car travel. There is also a trend on inner suburban roads for speed limits to be lowered to address pedestrian safety issues while sections of inner city streets (formerly through arterial routes) are sometimes converted to pedestrian areas or shared zones. This is discussed in more detail in the *Guide to Traffic Management*. Consequently, the function of particular sections of road may change over time in accordance with community values.

Table 2.2: Austroads functional classification of rural roads

Road class	Route classification	Route characteristics
Arterial roads		
Class 1	M	Those roads, which form the principal avenues for communications between major regions, including direct connections between capital cities.
Class 2	A	Those roads, not being Class 1, whose main function is to form the principal avenue of communication for movements between: • a capital city and adjoining states and their capital cities; or • a capital city and key towns; or • key towns.
Class 3	B or C	Those roads, not being Class 1 or 2, whose main function is to form an avenue of communication for movements: • between important centres and the Class 1 and Class 2 roads and/or key towns; or • between important centres; or • of an arterial nature within a town in a rural area.
Local roads		
Class 4		Those roads, not being Class 1, 2 or 3, whose main function is to provide access to abutting property (including property within a town in a rural area).
Class 5		Those roads, which provide almost exclusively for one activity or function, which cannot be assigned to Classes 1 to 4.

Table 2.3: Urban road functional classification

Type of road	Function
Controlled access highways (motorways or freeways)	Motorways and freeways have an exclusive function to carry traffic within cities and to ensure the continuity of the national or regional primary road system. As they are designed to accommodate through traffic, they do not offer pedestrian or frontage access.
Urban arterial roads	Urban arterial roads have a predominant function to carry traffic but also serve other functions. They form the primary road network and link main districts of the urban area. Arterial roads that perform a secondary function are sometimes referred to as sub-arterial roads.
Urban collector/distributor roads	These are local streets that have a greater role than others in connecting contained urban areas (e.g. residential areas, activity areas) to the arterial road system. Generally, consideration of environment and local life predominate and improved amenity is encouraged over the use of vehicles on these roads.
Urban local roads	These are roads intended exclusively for access with no through traffic function.

2.4.2 Factors that Influence Design Standards

The road traffic system comprises three elements that combine to define how a road or a design will perform, particularly in terms of safety – the vehicle, the human input and the road.

The vehicle

In relation to their mode of transport, 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.

Users in the first category influence road design primarily through the characteristics of the vehicles they operate. For convenience, these are often represented by the characteristics of design vehicles, which are briefly discussed in Commentary 8.

[see Commentary 8]

Among other vehicle factors, the tracking characteristics of the larger design vehicles influence geometric design. These larger vehicles take up a greater width (swept path) as they travel around relatively smaller radius curves (e.g. less than 200 m) or turn at intersections. For curves in mid-block sections, a wider lane may therefore be required to cater for tracking of the design vehicle (Austroads 2010a). At intersections, turning templates must be applied to designs. These are available in the *Austroads Design Vehicles and Turning Path Templates Guide* (Austroads 2013a).

Another heavy vehicle characteristic that relates to geometric design is the height of van-type semi-trailers in terms of stability on tight turns at intersections and also in relation to overhang created on existing roads that have excessive crossfall in the left traffic lane (resulting in reduced clearances to utility poles, trees and road furniture).

Heavy vehicle dynamics can also influence horizontal alignment design (curve size, superelevation and transitions), sight distance provision, grading, traffic signal design, railway level crossings and auxiliary lane provision.

On-road public transport utilises motorised vehicles that may place special requirements on road design. As is the case for trucks, on-road public transport vehicles may be large enough for their turning and tracking characteristics to place particular constraints on design dimensions. In addition, however, the need for frequent loading and unloading of passengers, the possible provision of priority for public transport at intersections or mid-block locations, and the potential for transitions of trams and light rail between on-road and exclusive right-of-way operations are examples of public transport characteristics that directly affect design decisions.

Road users in the second and third categories – users of non-motorised or low-powered vehicles, and pedestrians – influence road design in many ways, but primarily through their two major distinguishing characteristics:

- their vulnerability relative to motorised traffic
- their lower speeds of operation compared to motorised traffic.

Because of these characteristics, it may be desirable to provide separate facilities for these users, in the form of bicycle, pedestrian or shared paths either on the roadside or in their own rights-of-way. Where such facilities are not provided for bicycles and they must operate on the road carriageway, the designer should consider the provision of a bicycle lane, which affords a degree of protection to cyclists and reduces the effects of their speed differential relative to adjacent traffic. The treatment of such lanes at and near intersections requires particular attention from designers.

Cyclists, pedestrians and other road users in the second and third categories also require designers to give specific consideration to their needs in crossing motorised traffic flows, at intersections or at mid-block locations.

Human factors

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 greatly on the performance of drivers of vehicles, riders of motorcycles or bicycles, and pedestrians. Common aspects of road user behaviour provide the basis for many design parameters such as speed selection, curve design, and operation of intersections and crossings. An understanding of road user behaviour may assist designers to better understand the basis of standards and guides and hence to produce appropriate designs.

Driving or riding a vehicle can be considered to be comprised of three essential tasks (American Association of State Highway and Transportation Officials 2011):

- navigation – trip planning and route following
- guidance – following the road and maintaining a safe path in response to traffic conditions
- control – steering and speed control.

These tasks require a vehicle operator to receive inputs (most of which are visual), process them, make predictions about alternative actions and decide which is the most appropriate, execute the actions, and observe their effects through the reception and processing of new information (Lay 1985).

Many geometric design standards are influenced by the sensory ability of vehicle operators and pedestrians, in particular, vision and (especially for cyclists and pedestrians) hearing. Vibration and hearing may be important for some types of traffic control devices (e.g. audio-tactile edge lines, rumble strips and level-crossing bells). Visual acuity, colour sensitivity, and peripheral vision are all important to the driving or riding task. Driver visual sensitivity deteriorates in poor light conditions, with aging and with alcohol consumption. Visual recognition takes a finite time and the total response time of drivers has a significant effect on a range of design elements, including sight distance requirements and sign face design.

Physical abilities (other than vision) that are relevant to the driving/riding task relate to vehicle control, tracking, curve negotiation, and reaction times. Vehicle operators' physical attributes influence standards and guides relating to elements such as deceleration lane lengths, curvature, lane widths (ability to track) and sight distance (reaction time, eye height).

The behaviour of cyclists and pedestrians, as road users, is potentially subject to greater variation than that of motor vehicle drivers because riding or walking does not require a licence and there are thus no formal lower or upper limits placed on the age or the physical abilities of these road users. Children may be particularly vulnerable as cyclists or pedestrians, having wider variations in cycling stability, cycling or walking speeds and general road sense than is the case for the bulk of adult riders or pedestrians. Equally, the elderly may suffer deterioration in vision, hearing, reaction times and/or walking capabilities that need to be taken into account in road design.

Provision for those with physical disabilities, who most often are operating as pedestrians or wheelchair users, also places particular requirements on road design, for example, in relation to footpaths or shared paths, crossing locations and design, and needs for non-visual information transfer.

Road factors

Principles that lead to a safe road environment are described in Section 1.4. Horizontal and vertical alignment, cross-section, surface conditions and roadside design all impact on operating speeds and safety, and the extent of those impacts must be estimated.

The effect of grade on vehicle speeds is a typical example of an impact of a design decision on the performance of the road-traffic system, the following being aspects of that impact that may be taken into consideration:

- the operating speed of cars may be reduced on upgrades longer than 200 m
- the operating speed of laden trucks will be significantly reduced on long up-grades
- cars will generally travel at the operating speed on steep down-grades, however, some increase could be expected toward the end of a down-grade
- trucks may be required to significantly reduce their speed prior to steep down-grades.

Corrections for grade should be considered for each element of the road (Austroads 2013a). This is particularly necessary when there is a significant change in topography.

Speed estimates used in design generally relate to typical road cross-sections (i.e. those with traffic lanes wider than 3 m). On roads with lanes narrower than 3 m, the speed estimates may be reduced to account for narrower lanes (Austroads 2013a).

Average pavement conditions are assumed for the speed estimates used in road design. On roads where a poor or broken surface or a gravel surface is likely to prevail it may be appropriate to assume reduced speeds.

2.4.3 Speed Parameters

Safe speed is central to the severity outcome of any crash. Speed is also an important element in road design, governing a number of principal design parameters, including:

- stopping distance
- sight distance
- horizontal curve radius
- traffic lane width
- pavement superelevation.

As these parameters are related directly to the speed of traffic on the road, one of the first requirements in design is to establish the appropriate speed or speeds to use for design. Austroads (2013a) discusses in detail how this is achieved for both rural and urban roads.

3. Design Considerations

3.1 Factors Affecting Design Decisions

A range of factors influence design choices for road projects. Design characteristics and values adopted must provide a satisfactory service to road users and be economically viable within the financial, topographical and environmental constraints that may exist.

There are many aspects to be considered in the planning and design of road projects. Table 3.1 provides a checklist of factors to be considered in relation to planning, site conditions, construction, maintenance and operational matters.

The table also summarises the type and nature of the information, why it is needed, likely sources and references for further guidance.

Table 3.1: Checklist for design considerations

Design consideration	Type of information	Why needed	Nature of information	Likely source
PROJECT MANAGEMENT				
Project scope and objective	• Extent of the project site • Purpose of the project • Project budget • Project timeline with milestone delivery	• Understand limitation of design brief and basis to the project • Appreciate the financial scope of the project that may need to be applied when selecting design criteria • Clearly define the expectations of the client/project sponsor	• Project brief containing key points such as where, why, purpose and scope of the proposed road improvements • Crash data analysis	• Client/project sponsor, e.g. road jurisdiction, land developer
Risk management	• Written report highlighting issues raised by risk management, safety by design and constructability workshops and road safety audits	• Statutory obligation under the Workplace Health and Safety Act • Provide independent, specialist input about project risks, constructability risks and considerations and road user safety issues associated with the design	• Written report • Marked-up plans • Summary of risk and safety issues • Recommended action	• Independent road safety audit team via the project sponsor

Design consideration	Type of information	Why needed	Nature of information	Likely source
PLANNING FACTORS				
Land use/zoning	• Existing and proposed future adjacent land use	• Alignment and grade-line controls • Clearance/ screening/ landscaping requirements • Social and socio-economic effects (e.g. separation of communities)	• Planning scheme maps • Aerial photographs/ surveys	• State/local planning authorities • Community consultation
Right-of-way boundaries	• Road reserve boundaries	• Alignment and grade-line controls • Cross-section controls • Intersection treatments	• Planning scheme maps • Survey plans	• State/local planning authorities
Access restoration	• Existing and proposed points of access to roadway • Design vehicles for access points	• Alignment and grade-line controls • Intersection design	• Planning scheme maps • Photogrammetric/field survey	• State/local planning authorities • Community consultation
• Other authorities • Local government • Service authorities • Public transport, road and rail • Airports	• Provision for assets in road reserve/on road • Controls on crossing of assets • Drainage controls • Clearance requirements • Rail level crossings	• Alignment and grade-line controls • Cross-section controls • Drainage design • Relocation and protection of public utilities • Economic provision for future public utilities	• Clearance diagrams • Minimum cross-section requirements • Drainage outfall conditions (e.g. maximum discharge) • Policy and regulatory requirements	• Other authorities
SITE FACTORS				
Geographical factors				
Topography/ terrain [see Commentary 9]	• Topography of route alignment and adjoining land	• Alignment and grade-line controls • Drainage design	• Topographical maps • Photogrammetric/ field survey	• Field investigation • State survey/mapping department

Design consideration	Type of information	Why needed	Nature of information	Likely source
Geotechnical conditions	• Location and nature of rock/soil • Location and nature of groundwater • Slope stability assessment	• Alignment and grade-line controls – maximum/minimum cut/fill heights • Cross-section controls – maximum/minimum batter slopes • Pavement design • Subsurface drainage design • Drainage design – erosion, water quality (e.g. saline groundwater) • Construction cost/feasibility assessment	• Geological maps • Seismic investigation • Core samples • Test pits • Laboratory testing of samples	• Field investigation • Specialist reports • Local authorities • State environment protection authority • State survey/mapping department
Runoff and drainage	• Flood levels/discharges • Water management practices on adjoining land	• Alignment and grade-line controls • Drainage design • Water quality treatment facilities • Major waterway structures design	• Historical flood records • Computer modelling of catchments • Calculations of peak discharges • Inundation plans showing flood extent/frequency	• Weather bureau records • Local drainage authority • Australian Rainfall and Runoff (IEAust publication) • Specialist reports
Rainfall	• Rainfall records • Rainfall intensity	• Drainage design • Water quality treatment facilities	• Annual total • Seasonal distribution • Storm rainfall intensities	• Weather bureau records • Australian Rainfall and Runoff (IEAust publication)
Temperatures	• Seasonal variation maximum/minimum	• Alignment and grade-line control (e.g. icy conditions) • Pavement design (maximum/minimum temps for surfacing, treatments for icy conditions)	• Frequency, duration and nature of extreme conditions	• Weather Bureau records • Specialist reports

Design consideration	Type of information	Why needed	Nature of information	Likely source
Built environment				
Utility services	• Location of water, sewer, power utilities, telecommunications	• Avoid clashes with, or adjust, existing infrastructure	• Locations of, or plans for, services	• Utility authorities
Urban design [see Commentary 10]	• Topography • Vegetation	• Co-ordination of horizontal and vertical geometry • Landscape design • Structure type	• Scenic values • Natural landscape • Areas of visual significance	• Planning authorities • National park authorities • Environment authorities
Environmental factors [see Commentary 11]				
Flora	• Location, extent and nature of vegetation in road reserve and on adjacent land	• Alignment and grade-line controls • Cross-section controls by limiting footprint • Approvals for clearing from other authorities • Approvals from state and federal environmental authorities	• Plans showing different vegetation types, tree locations etc. • Aerial photographs	• Field investigation • Specialist reports • Local authorities • State environment protection authority • Special interest groups
Fauna	• Location and extent of fauna habitat • Location and extent of fauna movement corridors	• Alignment and grade-line controls • Cross-section controls by limiting footprint • Approvals from state and federal environmental authorities	• Plans showing different vegetation types – tree locations • Aerial photographs	• Field investigation • Specialist reports • Local authorities • State environment protection authority • Special interest groups
Noise	• Existing noise levels at adjacent properties • Predicted noise levels from proposed roadway	• May influence alignment/grade-line • Determine noise attenuation measures required	• Noise level measurements/ calculations at individual sites • Noise contour maps	• Field investigation • Specialist reports
Air quality	• Existing air quality at adjacent properties • Predicted effect on air quality from proposed roadway	• May influence alignment/grade-line	• Existing air quality measurements • Calculations of impact on air quality	• Field investigation • Specialist reports • State environment protection authority

Design consideration	Type of information	Why needed	Nature of information	Likely source
Water quality	• Condition of adjacent waterways/outfalls	• Location of drainage outfalls • Design of road runoff water quality treatment measures	• Records of previous testing/evaluation • Water sample test results • Pollutant/nutrient levels	• Drainage authority • State environment protection authority • State legislation (e.g. state environment protection policies) • Filed Investigation
Contaminated soil	• Location, extent and nature of contamination	• May influence alignment/grade-line • Treatment measures required – removal, minimum cover etc.	• Records of previous land use • Investigation sample results • Expert reporting	• Local authorities • State environment protection authority • Field investigation
Cultural/heritage factors				
Land areas that may require preservation or protection	• Location and significance of indigenous and post-settlement heritage sites	• Alignment and grade-line controls • Cross-section restrictions • Minimum clearance requirements • Approvals from state and federal heritage authorities	• Archaeological reports • Local historical records	• Field investigation • Specialist reports • State/federal heritage authorities • Local historical societies • Local indigenous communities/ groups
STATUTORY APPROVALS				
Environmental clearances	• Requirements to satisfy environmental legislation	• To develop, exhibit, and determine environmental statements	• Nature and extent of study and documentation required • Exhibition and approval processes	• State and federal environment agencies
ASSOCIATED DESIGNS				
Pavement	• Pavement design	• Impacts on formation and drainage requirements	• Materials, depths, design life	• Pavement designer – road agency or consultant
Drainage	• Volume and nature of runoff	• Possible constraints on geometric design • Obtain necessary environmental clearances	• Runoff quantities, discharge points • Potential spills • Environmental constraints	• Road agency • Environmental agencies

Design consideration	Type of information	Why needed	Nature of information	Likely source
Ultimate development, staging	• Future traffic • Future development	• Assess staging options	• Traffic growth projections • Planning, development proposals	• Road agency traffic section • State and local planning agencies
Geotechnical design	• Suitability of materials for construction purposes	• Formation design • Environmental issues • Construction materials	• Material types and characteristics • Contamination	• Road agency investigations
CONSTRUCTION FACTORS				
Whole-of-life costs	• Design life of elements with finite useful life (e.g. pavements) • Cost estimates for alternatives, replacement and maintenance	• Assessment of alternatives to determine most economical treatment over given time period, and not just initial construction cost	• Design life estimates • Maintenance cost estimates • Replacement cost estimates • Traffic growth estimates	• Road agency project evaluation practices
Constructability	• Construction staging proposals [see Commentary 12] • Traffic management proposals for existing roads • Practical construction practices	• Assessment of feasibility to construct • Assessment of impact on community during construction	• Construction staging plans • Traffic management plans	• Road agency • Local government • Community consultation • Construction industry
Availability of materials	• Assessment local material properties – earthworks and pavement • Local material supplies	• Batter stability, settlement, durability assessment • Pavement design	• Geotechnical reports • Quarry product information	• Field investigation • Specialist reports • Road agency • Local extractive industries
Provision for traffic facilities and Intelligent Transport System (ITS)	• Traffic projections, development potential • Developments in ITS	• Forecast of likely traffic developments and further enhancement of facilities • Make provision for ITS facilities	• Traffic forecasts • ITS state of the art	• Road agency • ITS Australia • Research organisations

Design consideration	Type of information	Why needed	Nature of information	Likely source
MAINTENANCE FACTORS				
Maintainability	• Roadside vegetation management practices • Drainage facility management practices • Material stability assessment • Maintenance budget constraints	• Cross-section – maximum batter slopes • Maximum/ minimum grades for drains • Water quality treatment facility design	• Maximum slopes for operation of maintenance equipment (e.g. mowing) • Geotechnical reports on material stability • Maintenance practices	• Road agency • Local government • Local drainage authority
INDUSTRIAL FACTORS				
Occupation Health & Safety (OH&S) for construction and maintenance staff	• Legislative requirements • Approved work practices	• Cross-section • Road safety barrier positioning	• Clearances between worksites and traffic • Worksite safety barrier requirements • Worksite traffic management practices	• Codes of practice • State OH&S • Road agencies
OPERATIONAL FACTORS				
Ultimate design and staging	• Ultimate traffic volume and cross-section requirements	• Establish cross-section standards and provision for future widening • Provision for future intersection modifications (e.g. signalisation)	• Future traffic volume predictions • Land development proposals/ planning schemes	• State/local planning/road agencies • Specialist reports
Provision for traffic facilities	• Rest area requirements • Intelligent transport systems • Traffic monitoring	• Alignment and grade-line controls • Cross-section restrictions • Minimum clearance requirements	• Highway development strategies • Traffic management strategies	• Road agency • Community consultation
Provision for special users	• Policies/provisions for public transport, non-motorised transport and disabled users	• Bus lanes • High occupancy vehicle lanes • Bicycle lanes • Truck lanes • Crossings	• Proposals for use by specialist modes • Required provisions for disabled users	• Planning authorities • Transport agencies (as distinct from road agencies)
Access control [see Commentary 13]	• Functional road classification	• To determine extent of access control required	• Status of road, current or planned	• Road agency • Planning authority

Design consideration	Type of information	Why needed	Nature of information	Likely source
ITS Operations [see Commentary 1]	• Road ITS operational strategies	• Increases the benefits derived from a given investment • Enables a better designed facility to respond to incidents and road works • Reduces the cost of future deployment of ITS • Improves the effectiveness of operational schemes	• Operational strategies, plans, methods etc. from road operators and other stakeholders • Hierarchy structure with respect to road operations • Considerations of the system engineering approach to ITS and its impact on operations	• Road agency ITS operational staff • Other road user bodies that may require input to ITS operations (e.g. private toll roads, emergency services etc.) (Note: Operational strategies and other policies and strategies should be contained in one document as a consistent source reference for designers and other stakeholders)
ECONOMIC FACTORS [see Commentary 14]				
Geometric design, traffic capacity	• Economic analysis	• Project priority	• Benefit-cost ratio • Net present value	• Road agency
FINANCIAL FACTORS [see Commentary 15]				
Geometric design, traffic capacity	• Financial	• Whether project can proceed	• Available funds	• Road agency • State/federal treasury
TRAFFIC FACTORS				
Geometric design	• Amount of traffic [see Commentary 16]	• Number of lanes • Overtaking lanes	• Traffic volumes • Daily and hourly distribution • Traffic growth projections	• Road agency
Geometric design	• Type of traffic [see Commentary 17]	• Lane widths • Longitudinal design • Overtaking lanes • Curve widening • Bicycle lanes	• Classification counts	• Road agency
Geometric design	• Design vehicle	• Lane widths • Vertical clearances • Curve radii and widening • Provision for oversize vehicles	• Vehicle dimensions • Relevant industrial developments	• Road agency • Planning authority

Design consideration	Type of information	Why needed	Nature of information	Likely source
Geometric design	• Allocation of road space [see Commentary 18]	• Provision for special users	• High occupancy vehicle needs • Public transport demand • Bicycle, pedestrian and disabled provisions • On-road parking needs • Breakdown-lane needs	• Road agency • Public transport providers • Planning authorities
Geometric design	• Design speed [see Commentary 19]	• Curve radii • Sight distance • Intersection design	• Expected and desired speed distribution of vehicles	• Road agency
Geometric design	• Design period [see Commentary 20]	• Provision for enhanced traffic capacity when required	• Length of design period • Traffic growth projections	• Road agency
Geometric design	• Desired level of service [see Commentary 21]	• Determination of initial and future capacity to be provided • Input to economic analysis	• Proposed grade lines • Proposed design speeds • Traffic volume and composition • Daily and hourly distribution • Traffic growth projections	• Road agency
Geometric design	• Associated designs	• Interactions between design requirements	• Structures • Lighting • Landscape	• Road agency
Intersection design	• Amount of traffic	• Type and nature of intersections • Traffic controls	• Traffic volumes on main and intersecting roads • Turning volumes	• Road agency
Intersection design	• Type of traffic	• Corner radius • Bicycle lane treatments • Crossing design	• Classification counts • Pedestrian levels	• Road agency

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Commentary 1

As outlined in Section 2 a road is but one element of a transport system and that the road operates in the natural and built environment to meet a range of expectations of the users and the broader community. The design of the road cannot be carried out in isolation, but must be sensitive to the context in which the road will operate. This is captured in Section 3 by outlining the various factors affecting design decisions which include ITS operations.

This commentary describes the concept of designing for operations, in particular designing for ITS operations. Much of this section is based on work undertaken in the USA as outlined in Federal Highway Administration (2013): *Designing for Transportation Management and Operations – A Primer,* but is also considered applicable to Australia and New Zealand.

C1.1 Designing for Operations

Federal Highway Administration (2013) defined designing for operations as a systematic consideration of management and operation strategies during the design process. To maximise the safety, reliability, and efficiency of the network, it is crucial that roads are designed to better manage demand and respond to incidents and other events. Designing for operations improves the integration of operational considerations throughout the project development lifecycle and addresses some of the limitations in current design practices, including:

- a disconnect between infrastructure design and operations
- sub-optimal performance of roads as a result of 'silo' thinking within an organisation leading to missed opportunities at the design stage
- high cost of retrofitting road infrastructure by ensuring that designs allow cost-effective future retrofitting of road infrastructure for operations improvement
- limited or incomplete understanding by designers of the operational intent of the network, and therefore designers unable to come up with more optimal design options.

Some advantages of incorporating operations into traditional design processes include:

- increasing the benefits derived from a given investment
- designing a better facility to respond to incidents and roadworks
- reducing the cost of future deployment of ITS
- improving effectiveness of operational schemes.

C1.2 Key Success Factors in Designing for Operations

Successful incorporation of operations in the design process includes the following (Federal Highway Administration 2013):

- policies that require designers to elicit input from operators and other stakeholders
- an agency's organisational structure that ensures that operational strategies are formally considered during project development and design
- a strong connection of planning and design at various levels, from state to local level
- incorporation of operational considerations at the start of the design process, i.e. at the scoping and financing stage, and continually through the preliminary design and final design stages
- adoption of the systems engineering approach (covered in Section C1.3)

- bundling basic information on operational strategies and other policies and strategies in one document as a consistent source reference for designers and other stakeholders and establishing a process of review and sign-off of project plans and associated documentation (e.g. strategies).

It is important that consideration of operational strategies in the design process is conducted before the design process actually starts. To ensure or facilitate formal consideration of operational strategies in the design process, it is useful to have policies and procedures that require it.

The agency structure can be made to better foster designing for operations. Leadership in the agency on the promotion of designing for operations emphasises the importance of road user requirements. A road user requirement-driven design process will shift the focus of the design process more towards meeting operational needs. Organisationally, the road agency can foster further collaboration between designers and operations (as well as others, e.g. maintenance) by elevating and providing better visibility on operational initiatives. A team with the appropriate skillsets and entrusted to look after operational strategies and initiatives is recommended to provide the required inputs needed by designers.

An effective approach to facilitating designing for operations is to establish strong correlation of operational strategies and planning at the state and local level. Operational objectives and performance targets established at the state and local level can be articulated at the planning level through a process of collaboration between operators, designers and other stakeholders and agreed by key decision-makers. These operational objectives would form the basis of terms of reference for the design process hence establishing a streamlined approach at various planning levels.

The management of the review process and documentation is an important aspect of a successful application of designing for operation. Given the number of roles involved in designing for operations it is important that all relevant information is in one document. Having a common document also provides common language and terminology that can be consistently used throughout project development. Revisions of the document need to be recorded and the relevant stakeholders need to be promptly informed. The documentation process is also useful as the mechanism for review and sign-off to ensure that all parties involved are appropriately consulted and to ensure that approvals have been given. Finally, the documentation of the designing for operations process serves as the basis for an operational audit of the designs.

C1.3 Systems Engineering Approach for ITS solutions

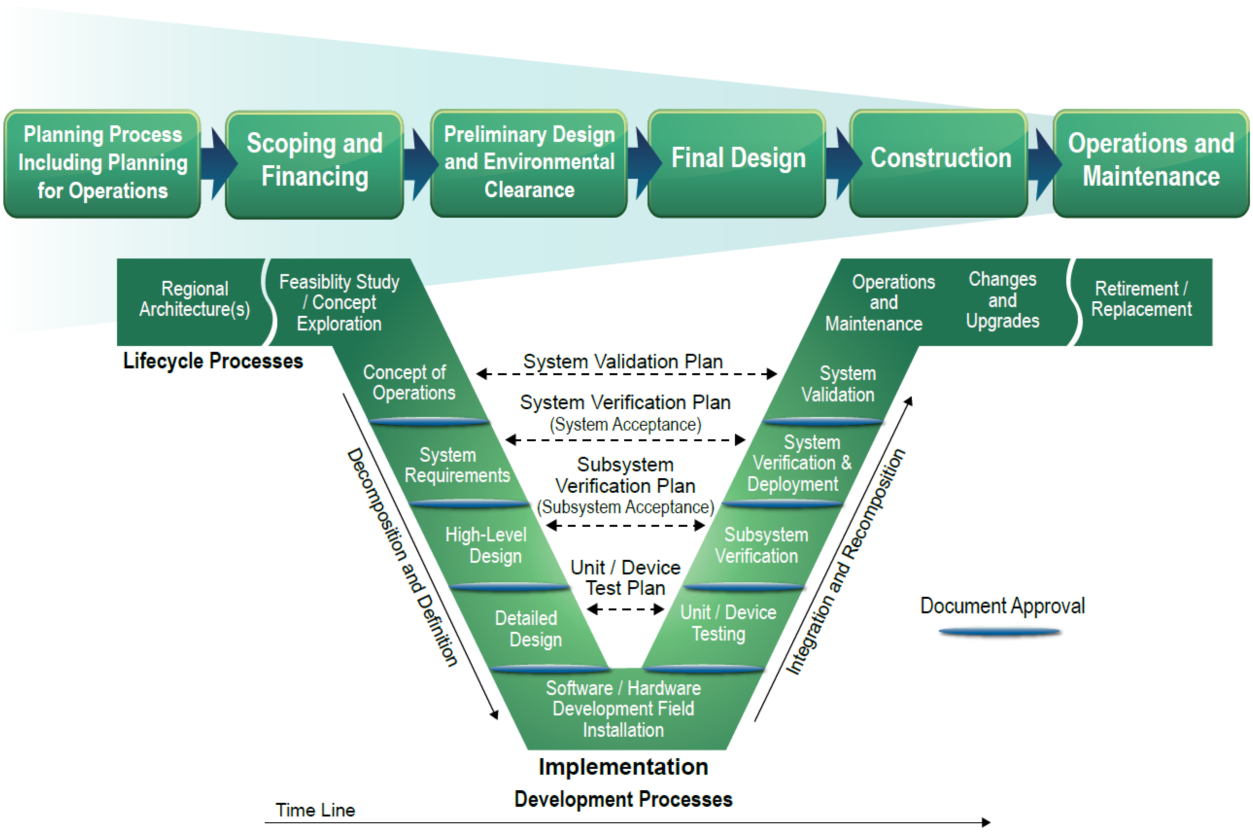
Application of the systems engineering approach supports the application of designing for operations, particularly in the development of projects involving ITS systems (Federal Highway Administration 2013). According to the International Council on Systems Engineering (INCOSE 2004):

> Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: operation, cost and schedule, performance, training and support, test, disposal, and manufacturing

Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

The systems engineering process is illustrated in Figure C1 1.

Figure C1 1: Systems engineering V diagram



Source: Federal Highway Administration (2013).

In Austroads (2014b) report, *Procurement of ITS*, the systems engineering approach was described to define the relationships between the phases of the system life cycle. The systems engineering management plan begins with early planning activities, followed by design and development, and ends with an operations and maintenance plan (as shown in Figure C1 1). For each stage of the system development, it also identifies which documentation is required and decisions that must be made. The life cycle must consider not only the specific steps but also the regional context for the system and the need for system upgrades and enhancements. A rigorous systems engineering process was found to be costly in time and finance; however, this is outweighed by the benefit generated in the life cycle of the project.

C1.4 Examples of Designing for Operations

Examples of the application of designing for operations have been documented by Federal Highway Administration (2013). Design considerations and opportunities for motorways and arterials are in Table C1 1 and Table C1 2, respectively. For example, to better manage non-recurring congestion the design of the motorway needs to incorporate alternative arterial route options and appropriately provide for variable message signs at the optimal locations. This avoids potentially costly retrofits, if operational strategies are not considered early in the design stage.

Table C1 1: Examples of motorway management design considerations/opportunities

Motorway management	Design considerations/opportunities
Managing non-recurring congestion	• Include signing for routing incident-related traffic through adjacent arterials • Include emergency refuge or pull-off areas • Provide for large-scale evacuation through contra-flow lanes and appropriate signing • Include detection to activate special signal timing schemes on adjacent arterials for traffic diverted off the motorway • Provide median breaks • Provide dense kilometre markers for the motorist to support incident location identification
Ramp signals	• Consult with arterial road operators to determine the best way to avoid queues on the feeding arterials • Allow for adequate width in the design to accommodate future HOV bypass lanes
Traveller information	• Incorporate information related to transit operations, such as park-and-ride lot allocations prior to bottleneck locations • Provide travel time information for all available modes of transportation, including rail and bus • Build areas to allow portable VMS to be deployed due to permanent VMS outage or repair

Source: Federal Highway Administration (2013).

Table C1 2: Example of arterial management design considerations/opportunities

Arterial management	Design considerations/opportunities
Collaboration of agencies and local government	• Seek out informal but institutional arrangements related to the management and operation of the corridor and advance them into standards and executed agreements • Uphold the principles and performance measures established in any concept of operations being used to govern the management of the corridor
Manage access	• Consult expertise in traffic operations to evaluate the impacts of adjusting access due to actual site conditions • Have designers and operators jointly review redevelopment proposals containing changes in access to be sure transportation needs are met
Intersection control	• Establish operations objectives and performance measures related to queue management, storage requirements, multimodal impacts and turning restrictions • Use of the systems engineering approach to define the appropriate signal system • Provide traffic monitoring devices to allow for optimum operations, signal timing and progression
Context sensitive solutions	• When constructing or upgrading footpaths, eliminate other barriers to pedestrian access such as pedestrian ramps, pedestrian operated signals, and associated hardware and conduits for these treatments • Contact the appropriate agency to update pedestrian timing at signals • Facilitate transit operations by implementing treatments such as bus turnouts, pre-emption for buses, and directional signing of transit facilities
Transit	Bus rapid transit • Consider additional right-of-way to accommodate stations and access ramps to optimise operations for the station • Pedestrian access from park-and-ride lots and circulation is critical for peak operational efficiency and should be integral to the design process Dedicated transit lanes • Initial pavement design can take into account heavier design loads when transit use is anticipated in the future Bus-on-shoulder • Provide full-depth shoulders during normal paving operations to avoid tearing out the shoulder and sub-base for future lanes • Drainage structures and grates should be initially designed to align with wheel paths; adjustment after the fact can require major reconstruction Arterial bus lanes • Transit agencies need to be involved in the design stage as bus stop locations can depend on the type of service (e.g. local or express) • Transit signal priority works in conjunction with the bus stop locations to optimise express bus operations • Real-time arrival displays needs to be provided with electrical and communication connections • Queue jump lanes can be used at signalised intersections in conjunction with transit signal priority, queue jump lanes can be integrated at the initial design stage

Source: Federal Highway Administration (2013).

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Commentary 2

The traditional approach to road safety in the context of road design focuses on the prevention of crashes between road users and between road users and road infrastructure. But crashes can potentially occur on all roads in use and therefore no road can be considered absolutely safe, i.e. completely crash free. It follows that a road designed to some set of prevailing 'standards' should therefore not be called 'safe'; rather, roads can only be designed with a higher or lower level of safety and this is often influenced by time, cost and environment constraints.

The Safe System approach is a guiding philosophy that has been adopted by leading road safety nations and has been a foundation of the road safety strategies and action plans adopted in both Australia and New Zealand since 2004.

This approach acknowledges the limitations for road design to deliver safe roads in the following ways:

1. A road environment is a system with three interacting elements – road infrastructure, vehicles and road users.
2. Road designers can directly influence safety through just one of these elements – road infrastructure.
3. Road infrastructure design (including traffic management measures) can indirectly influence road user behaviour (i.e. warn, inform, guide).

These limitations require a change in the approach to road design in order to improve the safety performance of roads. At its core, the Safe System approach advocates harm minimisation, i.e. the primary focus is reducing the risk of death and serious injury resulting from road crashes. While preventing road crashes may be the ultimate means of reducing death and serious injury, a level of residual crash risk will always exist – road users are prone to making errors; this should not be at the cost of death or serious injury.

Most design choices affect the expected crash frequency, severity, or both. Some design choices are from a continuum of values (e.g. median width, grade, or sight distance). The change in safety corresponding to a change in these values is also continuously variable. For example, the narrower the median, steeper the grade or shorter the sight distance, the less is the safety of the road. Some safety improvements are not gradual. For example, the decision to illuminate a road will cause an immediate, significant drop in night-time crashes and a (usually smaller) increase in daytime crashes because of the introduction of light poles and the barriers protecting them. In this case, a road designer should ask what more can be done to address the severity of the crashes that may continue to occur and then set about incorporating an appropriate measure to reduce crash severity.

Design choices leading to safety improvements usually cost money. Conversely, cost savings can increase crash frequency, severity or both. When choosing the value for a design parameter from a range of values, a balance must be found between increasing cost and diminishing safety improvements, as the value of the parameter changes. There comes a point at which the safety benefits are so small that money can be spent to better effect elsewhere. When the design choice is to include or omit a feature, a safety gain is bought at a discrete cost. In both circumstances, rational design involves the determination of the potential safety gains, the determination of the attendant costs, and the balancing of costs and safety gains.

Some people may object to the judgement that a point exists beyond which further improvement in safety is not justified, claiming that any improvement in safety is worthy. This position is not tenable. Expenditure of public money can always improve facilities to reduce the probability of collisions. However, unlimited funds are never available, and spending should be concentrated in areas where the greatest safety improvements can be realised at justifiable costs, noting that costs may be in the form of, for example, environmental impact, not only money. It is here that the Safe System philosophy can assist a road designer in making cost-efficient decisions. For instance, measures to reduce crash severity may be a more affordable and practical option than measures to prevent all crashes from occurring. In such circumstances it can be argued that a higher level of safety has been achieved on the road design to the benefit of the community, even though some crashes can be expected to still occur.

To make an appropriate design choice affecting the future safety of a road, the designer has to use the best available information about how the choice might affect future safety. Research into the relationship between crash frequency and road design parameters has been undertaken in Australia, New Zealand and overseas in recent years. This factual information led to the development of analytical tools to evaluate crash risk and the effect of treatment options on crash frequency. This information is available for the road designer to consider in relation to specific road design solutions. Designers of the past, without benefit of this knowledge, often relied on geometric design standards, based on laws of physics, without the necessary data to adequately assess the safety consequences. Reliance on standards will not necessarily ensure that an appropriate level of safety has been built into a road.

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Commentary 3

The main factors in intersection safety include:

- safe approach speed
- number of legs
- angle of intersection
- sight distance
- observation angle
- alignment
- auxiliary/turning lanes
- channelisation
- intersection control
- friction or pavement skid resistance
- turning radii
- traffic lane and shoulder widths
- property access
- signing and road marking
- lighting.

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Commentary 4

The factors that influence mid-block safety include:

- vehicle speeds and speed differential between vehicles
- pavement surface
- delineation
- traffic lane width
- shoulder width
- horizontal and vertical geometry
- degree of access control
- overtaking opportunities
- sight distance.

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Commentary 5

HOV lanes may be provided on freeways and other roadways for the exclusive use of buses and other high occupancy vehicles so they can bypass peak-period congestion on the remaining lanes. Increases in ridesharing can be gained from this option when the time savings are significant. The American Association of State Highway and Transportation Officials (1992) (AASHTO) guide on high occupancy vehicle facilities discusses a number of options for the provision of priority for high occupancy vehicles.

HOV facilities are usually incorporated into existing highway rights-of-way where width and lateral clearances may be limited. While experience has shown that some variance in design standards is possible without serious adverse effects on safety and performance, it has not been extensive enough to firmly establish new standards specifically for these types of facilities. The values presented in the AASHTO guide should therefore not be regarded as absolute, but rather as the best guidance available based on experience to date.

In applying the criteria that are presented, consideration should be given to the possible future use of HOV facilities. It is usually desirable to provide flexibility by designing for all vehicle types that may use a facility in the future. This can usually be done for very little, if any, additional cost.

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Commentary 6

The following principles are presented in Federal Highway Administration (1998).

Qualities of excellence in transportation design:

- The project satisfies the purpose and needs as agreed to by a full range of stakeholders. This agreement is forged in the earliest phase of the project and amended as warranted as the project develops.
- The project is a safe facility for both the user and the community.
- The project is in harmony with the community, and it preserves environmental, scenic, aesthetic, historic, and natural resource values of the area, i.e. exhibits context-sensitive design.
- The project exceeds the expectations of both designers and stakeholders and achieves a level of excellence in people's minds.
- The project involves efficient and effective use of the resources (time, budget, community) of all involved parties.
- The project is designed and built with minimal disruption to the community.
- The project is seen as having added lasting value to the community.

Characteristics of the process contributing to excellence:

- Communication with all stakeholders is open, honest, early, and continuous.
- A multidisciplinary team is established early, with disciplines based on the needs of the specific project, and with the inclusion of the public.
- A full range of stakeholders is involved with transportation officials in the scoping phase. The purposes of the project are clearly defined, and consensus on the scope is forged before proceeding.
- The highway development process is tailored to meet the circumstances. This process should examine multiple alternatives that will result in a consensus of approach methods.
- A commitment to the process from top agency officials and local leaders is secured.
- The public involvement process, which includes informal meetings, is tailored to the project.

- The landscape, the community, and valued resources are understood before engineering design is started.
- A full range of tools for communication about project alternatives is used (e.g. visualisation).

A discussion on context-sensitive design can be found on the US FHWA web site at http://www.fhwa.dot.gov/csd/basic.htm. Other sites providing useful information, including examples of applications of CSD in practice, include:

- http://www.fhwa.dot.gov/environment/csd.htm
- http://www.fhwa.dot.gov/resourcecenter/teams/environment/env_1cs.pdf
- http://www.tfhrc.gov/focus/oct02/02.htm
- http://www.kytc.state.ky.us/design/designmanual/index.htm
- http://www.dot.ca.gov/hq/oppd/context/index.htm.

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Commentary 7

The design domain has always existed for road infrastructure design. Although it may not have been explicitly described, it has been implicit in publications such as the *Guide to Road Design* and *Guide to Traffic Management* series.

As discussed in Section 2.1 to Section 2.3, the design domain is a range within which design parameters fall that can be justified in an engineering sense (e.g. based on test data, sound reasoning etc.) and which therefore have a reasonable level of defence in court. It consists of the NDD and the EDD.

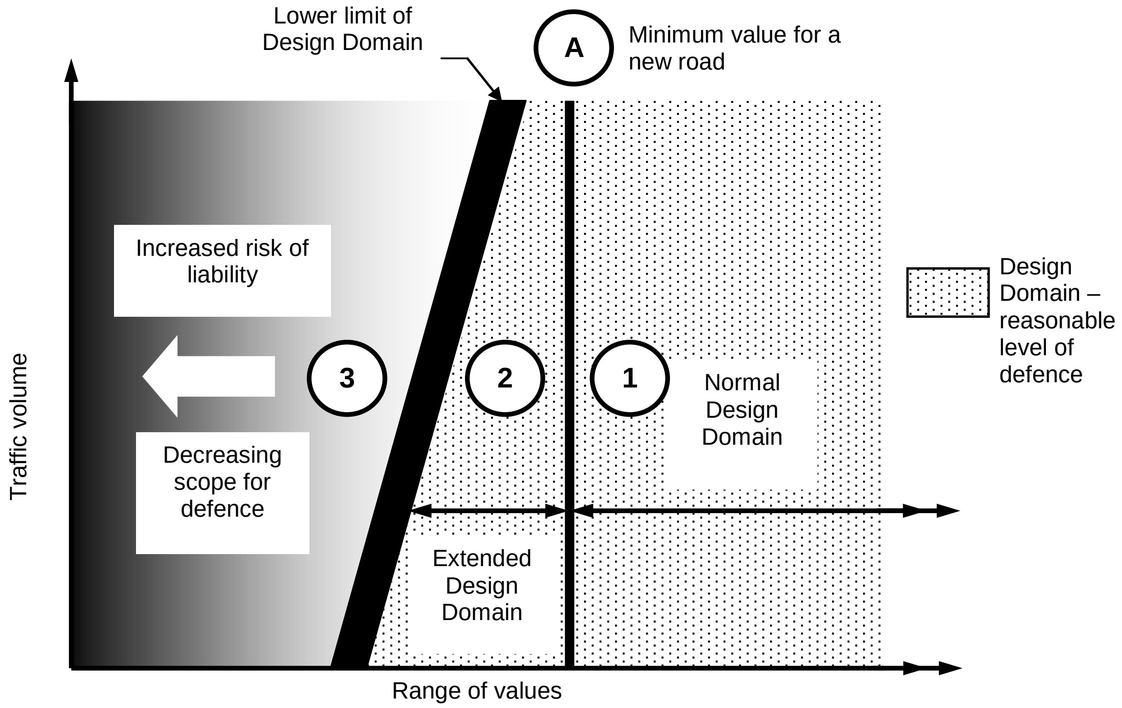
Figure C7 1 is a conceptual diagram showing the NDD, the EDD, and how the level of defence against litigation may change for a given geometric parameter. Defence against litigation needs to be considered when adopting particular values of a geometric parameter for restoration of an existing road.

In the past, the lower bound of the design domain has been seen as the minimum value/s contained in publications such as the *Guide to Road Design*, irrespective of the application (i.e. to a new greenfield road or to an existing road). This is represented by Line A in Figure C7 1. The vertical line denotes a geometric parameter whose value is not influenced by traffic volume (e.g. crest curve radius).

EDD extends the lower bound of the design domain that is used for a new road, based on what can be justified and defended, on engineering grounds, in certain circumstances (Area 2 in Figure C7 1). However, a value within the EDD can be used only with the explicit, corporate approval of the relevant road agency, supported by a documented risk assessment that fully justifies the use of that value.

The design domain in Figure C7 1 (Area 1 plus Area 2) incorporates the NDD and the EDD. The lower regions of the design domain represent conditions that would generally be considered less safe, less efficient and usually less expensive than those in the upper regions.

Figure C7 1: Conceptual diagram



Source: Department of Transport and Main Roads (2013).

Values in the range denoted by Area 3 in Figure C7 1 fall below EDD because they become increasingly less likely to be supported on the grounds of reasonable capability. Any decision to use values in this range would need to be formally approved by the relevant road agency and supported by a well-documented justification and the use/installation of mitigating devices.

Any risk assessment justifying the adoption of a value within Area 3 must be unbiased and supported by crash analysis. It must also show that lower construction costs associated with adopting such a low standard outweigh the potentially higher cost of crashes.

Mitigating devices must comply with the requirements of relevant standards (e.g. signage in accordance with the *Manual of Uniform Traffic Control Devices* (Standards Australia 2009) or the *Manual of Traffic Signs and Markings, Part 1* (NZ Transport Agency 2010), including the posting of advisory speeds (where permitted), fencing to reduce potential hazards, and other devices.

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Commentary 8

The physical and operating characteristics of vehicles using major roads are important factors in geometric design. The design vehicle is a hypothetical vehicle whose dimensions and operating characteristics are used to establish lane width, intersection layout and road geometry. For most design situations on arterial roads the car is used as the design vehicle for horizontal and vertical geometry, while a prime mover with semi-trailer is used as the design vehicle for cross-section elements and intersections. In some cases it may be appropriate to consider expected bicycle usage. However, it is important to ensure that roads are designed to cater for vehicles that commonly use them and the most appropriate Austroads or Land Transport New Zealand standard vehicle should be adopted.

The geometric design should be checked for the largest design vehicle expected to use the road, using the *Austroads Design Vehicles and Turning Path Templates Guide* (Austroads 2013a).

When designing arterial road intersections it is common practice to design for a particular vehicle and then to check that a selected larger vehicle can negotiate the intersection turning from lanes other than the preferred turning lane, or by mounting specially paved areas if necessary (Austroads 2009a). The check vehicle should be chosen according to its potential to use the facility, using a risk management approach. Local knowledge of current or proposed developments or industrial activities in an area may assist the choice of the most appropriate check vehicle.

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Commentary 9

Topography can have a significant effect on the costs of achieving a high-standard road alignment. In flat terrain a high-standard road can generally be achieved at an acceptable cost while in steep and mountainous country a marginal increase in standard may rapidly escalate costs. A higher standard in undulating terrain can also substantially increase costs if larger cuttings and fills are required.

To ensure that limited funds are effectively spent on appropriate designs, due regard must be given to designing with the terrain rather than against it. For example:

- balanced earthworks limit the cost of importing additional fill materials or disposing it off-site
- ensuring that the grade-line stays above non-rippable rock negates the need for blasting
- keeping the grade line above the water table will limit moisture ingress to the pavement and could avoid the need for drainage blankets.

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Commentary 10

Urban design may involve the view of the road from the non-user's perspective as well as the view of the surrounding area from the road. Urban design is particularly important for roads in scenic areas, and may relate, for example, to the co-ordination of horizontal and vertical geometry, the slopes adopted for batters or landscaping within the road reserve. Urban design may also influence the choice of standards – for example, the character of neighbouring land uses may dictate the style and dimensions of noise barriers.

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Commentary 11

Environmental factors need to be considered in major public works such as road construction and are also an essential part of the road design process.

A road is just one element in the environment, as discussed in Section 2. Environment in this sense refers to the total social and natural environment. A road should desirably be located and detailed so as to complement the environment and surrounding communities rather than to harm them. For example, a valuable resource such as an adjacent area of old-growth forest may merit preservation in its own right and this could restrict the land available for expansion of a road's right-of-way.

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Commentary 12

Where land uses are changing and traffic demand is growing it is likely that there will be a need for future road improvements. Where it is obvious that medium-term requirements are different from the best short-term design for a particular road, it is often possible to modify the design slightly to provide better options for the future. While this might commit some funds and prevent their use on other current projects, the effect can be much less than if a longer-term design is adopted in the first instance.

Wherever practicable and appropriate, designers should consider an 'ultimate' layout for a road and use this as the basis for the short-term design. Examples would include at-grade intersections configured to allow for future duplication and grade separation, and unsignalised intersections provided with cable ducting for future signalisation.

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Commentary 13

Abutting landowners normally have a right of access to the road reserve adjacent to their property, but not necessarily to every portion of the reserve. The rights of the owner must be balanced against the right-of-passage of the public on the reserve. In general, the right-of-passage of the public dominates over the rights of the adjoining owner (Lay 1985, p. 51). Depending on the classification of the road, this will generally lead to the road agency having a greater or lesser degree of control over access to public roads. The degree of control, and determination of access points, will frequently be determined by the planning process.

The control may range from freeways with access only via grade-separated interchanges, arterial roads with service roads and/or limited points of access, to local roads with full and uncontrolled access available.

The adjoining local road network may also be modified to reduce the number of intersections with the arterial road and provision may be required for grade-separated intersections.

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Commentary 14

Economic analysis of a project considers the range of costs and benefits that fall to a wide variety of users across the community. Such analysis will often justify a high standard and high-cost project because of the substantial benefits that flow to road users. However, any project must compete for funding with a range of other projects, just as a government funded road program must compete with other government programs for budget funding.

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Commentary 15

Separately from economic benefits and costs, the level of finance available may influence the standard adopted for a road project, depending on traffic demand and the project objectives. For example, the choice of a higher-speed alignment may result in a disproportionate increase in cost compared to an alignment with a marginally lower speed. While it may be justifiable in economic terms, financial constraints may render the higher standard unaffordable.

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Commentary 16

Traffic volume is a basic consideration in the design of roads. It influences the need and justification for works, the comparison of alternative solutions, the selection of road types, and the selection and application of design standards. For intersection designs, the volume of traffic on each leg of the intersection and the turning movements are determining factors in the selection of the type of intersection.

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Commentary 17

The effect of heavy vehicles in the traffic stream is to lower the level of service provided by the road because:

- a heavy vehicle takes up more space than a car so it is equivalent to more than one car in traffic volume terms (more so on gradients)
- the disparity in speeds between light and heavy vehicles leads to increased queuing and overtaking requirements.

The proportion of heavy vehicles also influences the structural design of the pavement and the need for overtaking lanes and widening on curves and turning roadways.

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Commentary 18

Roads, particularly those in urban situations, are required to cater for general traffic flow and also provide for the special needs of public transport, bicycles and pedestrians. Incorporating facilities into the road design to cater for vulnerable road users should follow the Safe System approach.

It is often difficult or impossible to provide special facilities for these competing uses on existing and new roads where the right-of-way or width available for pavement is constrained. In such situations the distribution of road space (and time, in the case of traffic signals) should relate to the network strategy and the role the road is expected to fulfil. For example, on public transport routes the provision of a bus lane or better tram stops may be the highest priority in relation to network strategy and government policy.

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Commentary 19

Design speed is a most important parameter in road design. It is a speed fixed for the design and correlation of those geometric features of a carriageway that influence vehicle operation. Design speed should not be less that the intended operating (85^{th} percentile) speed.

A good design combines all geometric elements into one harmonious whole, consistent with the speed environment, so that drivers will be encouraged to maintain a reasonably uniform speed over as great a length of road as possible.

Speed parameters are noted in Section 2.4.3, and discussed in greater detail in Part 3 of the *Guide to Road Design* (Austroads 2010a).

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Commentary 20

The design of roads is usually based on the traffic expected to use them over their design life. This requires the selection of a design year and the estimation of the volume and composition of the traffic likely to use the facility in that year.

Some elements of a road may have an extremely long life. For example, the right-of-way, basic earthworks and the horizontal and vertical alignment could be expected in many cases to have a life of 50 to 100 years (or even more). Bridges are commonly designed for a life of 100 years, though in practice changes in land use, traffic volume and composition, or road realignment may mean they are bypassed within 30 to 50 years. Pavements could have a life of 20 (normal duty) to 40 (heavy duty) years if adequately maintained.

In terms of traffic service, a period of 15 or 20 years may be chosen for the design of rural highways. For intersection design, the choice of a 20-year period for the design may be unrealistic and many new facilities may reach capacity in a relatively short period of time. However, it is relatively easy to upgrade an intersection in stages to provide additional capacity, provided adequate provision is made in the initial concepts. In some cases, intersections may progress from a basic design, to provision of turning and slip lanes, signalisation, and finally to grade separation.

In some cases a staged approach may be taken where, for example, a divided road is planned and designed for the longer term, and one carriageway is constructed as a two-way two-lane road to provide satisfactory service for the first 10 to 15 years. In such cases the road reservation may be acquired initially or reserved in a planning scheme.

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Commentary 21

Level of service is defined as a qualitative measure describing operational conditions within a traffic stream, and their perception by motorists and/or passengers.

A level of service definition generally describes these conditions in terms of factors such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and safety. In general, there are six levels of service, designated from A to F, with level of service A representing the best operating condition (i.e. free flow) and level of service F the worst (i.e. forced or breakdown flow).

The different levels of service can generally be described as follows:

- Level of service A is a condition of free flow in which individual drivers are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to manoeuvre within the traffic stream is extremely high, and the general level of comfort and convenience provided is excellent.
- Level of service B is in the zone of stable flow and drivers still have reasonable freedom to select their desired speed and to manoeuvre within the traffic stream, although the general level of comfort and convenience is a little less than with level of service A.
- Level of service C is also in the zone of stable flow, but most drivers are restricted to some extent in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience declines noticeably at this level.
- Level of service D is close to the limit of stable flow and is approaching unstable flow. All drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience is poor, and small increases in traffic flow will generally cause operational problems.
- Level of service E occurs when traffic volumes are at or close to capacity, and there is virtually no freedom to select desired speeds or to manoeuvre within the traffic stream. Flow is unstable and minor disturbances within the traffic stream will cause breakdown.
- Level of service F is in the zone of forced flow. With it, the amount of traffic approaching the point under consideration exceeds that which can pass it. Flow breakdown occurs, and queuing and delays result.

Conditions affecting level of service include the roadway, terrain, driver population, traffic mix and characteristics, and traffic controls. The concepts of level of service are well described in the US *Highway Capacity Manual* (Transportation Research Board 2010) and the *Guide to Traffic Management Part 3* (Austroads 2013b), in addition to the *Guide to Road Design*.

For pedestrian facilities, the basic concept of level of service applies but the details are often more complex than a simple translation of the above ‘traffic flow’ approach would provide. For crossing facilities, pedestrian delay is a prime consideration. Many other factors including perceptions of quality and comfort contribute to practical (perceived) levels of service. Further advice on pedestrian level of service is given in the *Guide to Traffic Management Part 3* (Austroads 2013b).

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Guide to Road Design Part 2: Design Considerations provides a detailed description of the three critical aspects of road design: the design objectives that apply to a road design project; context-sensitive design; and the factors that influence the road design, including road design in the context of the Safe System philosophy

Guide to Road Design Part 2

2

Austroads

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