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Chapter 2

Design Philosophy

Manual Contents

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List of Tables

There are no tables in this Chapter.

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Chapter 2 Amendments – December 2005

Revision Register

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	-	First Issue	Steering Committee	Nov 2000
2	2.1	Figure 2.1 - “DR” (District Roads) added	Steering Committee	July 2001
	2.2.3	Extra dot point - future trends in mode selection		
	2.2.6	Reference to new Guidelines added		
	2.4	Figure 2.5 - “DR” added		
	2.4.1	Paragraph about early decision making modified		
	2.4.2	Modified. Figure 2.7 - “DR” added		
	2.4.3	Modified. Figure 2.8 - “DR” added		
	2.4.4	Modified. New section on “Post Construction Review”		
	2.5.2	Modified.		
	2.5.4	Modified.		
	2.5.5	Modified.		
	2.5.9	New section added		
	New	Relationship to Other Chapters		
	Appendix 2A	Modified and new section added.		
	New	Appendix 2B added		
3	-	New Chapter	Steering Committee	August 2004
4	Glossary (new)	Glossary added.	Steering Committee	Dec 2005
	Various sections	Term “standard” changed to design criteria, design parameter or design value where appropriate. Terms “Normal Design Domain” and “Extended Design Domain” introduced where appropriate. Some minor amendments to various sections.		
	Section 2.1	Dot point added.		

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
4	Section 2.3	New section "Context Sensitive Design" replaces former section. Relevant content from former version merged with this new section.	Steering Committee	Dec 2005
	Section 2.4 (old)	Section deleted and relevant content from former version merged with new Section 2.3.		
	Sections 2.5, 2.5.1 and 2.5.2 (old)/2.4, 2.4.1 and 2.4.2 (new)	Former sections renumbered and re-titled. Text amended substantially.		
	Section 2.5.3 (old)	Former section deleted and relevant content from former version merged with new Sections 2.3 or 2.4.2		
	Section 2.6 (old)/2.5 (new)	Former section renumbered from 2.6 to 2.5. Text amended and added.		
	Section 2.6	New section "Normal Design Domain" added.		
	Section 2.7	New section "Extended Design Domain" added.		
	Section 2.8	New section "Below the Design Domain – the design exception" added.		
	Section 2.9	New section "Requirement for geometric assessment and choice of Domain" added.		
	Section 2.7/2.10	Former Section 2.7 renumbered to Section 2.10.		
	References	References added.		

Chapter 2
Design Philosophy

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Glossary

Context Sensitive Design: Context Sensitive Design is a design approach that aims to achieve an appropriate balance between safety, mobility, community and environmental needs when developing solutions. Refer to Section 2.3 for a detailed discussion. A Context Sensitive Design is also known as a Context Sensitive Solution.

Context Sensitive Solutions: Refer to Context Sensitive Design.

Design Domain: A range of design values that can be justified using empirical models, theoretical models or both (e.g. models based on test data, sound reasoning, physics, etc). Therefore the Design Domain is a range of design values that are likely to have a reasonable level of defence whenever it is necessary to defend their use (e.g. in court). Since the design domain constitutes a range of values, it follows that one bound of the range represents lower order or quality while the other bound represents higher order or quality. Refer to Section 2.5 for a detailed discussion.

Design Exception: A case where a constraint makes it very impractical, if not impossible, to upgrade the geometry so that is it within the design domain. A design exception can only be retained where the Main Roads District Director has approved its retention.

Extended Design Domain: A range of design values below the normal design domain (for a parameter where an increase in its value produces a higher benefit) but the values can still be justified in terms of the capability provided. The Extended Design Domain is a subset of the Design Domain. Refer to Section 2.7 for a detailed discussion.

Fit For Purpose: Refer to Context Sensitive Design.

Guideline: A directing principle. To act as a guide to, lead [action]; be principle or motive of [action].

Normal Design Domain: A range of design values that define the normal limits for the values of parameters selected for new roads. The Normal Design Domain is a subset of the Design Domain. Refer to Section 2.6 for a detailed discussion.

Restoration Project: A restoration project is a project where the cross section, structural capacity of the pavement and/or riding quality of an existing road is improved while seeking to retain as much of the existing alignment as is practicable. The nature of the work typically has the potential to change drivers' perception (of the standard) of the road. In many cases road users will not distinguish between a restored road and a new road.

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Standard: Within this Chapter, the term standard simply serves as a comparison of the capability of different road segments/aspects/alignments. For example, a high (geometric) standard road has geometry that permits high operating speeds in free flowing conditions with a high level of service. Conversely a low (geometric) standard road has geometry that results in low operating speeds and probably a lower level of safety. The term is not intended to determine some level of conformance to a prescribed standard.

2.1 Introduction

Design is the process of selecting the elements that, combined, will make up the end product. Geometric design of roads requires the selection of the visible features and dimensions of the road (e.g. lane and shoulder widths, Transportation Association of Canada [TAC], 1999).

All road design is a compromise between the ideal and what is a reasonable outcome (e.g. in terms of cost, safety, driver expectation, economic drivers, environmental impacts and social issues refer to Section 2.3). Judgements have to be made on the value of improving the standard of a road and the impact this might have on the ability to make improvements elsewhere on the road system. These judgements are usually made on the basis of the level of safety of the road in question and the Benefit/Cost Ratio (BCR) resulting from the proposed improvements. Environmental and social impacts are also major considerations, as may be other factors (refer to Section 2.3).

The Geometric Design Guide for Canadian Roads (TAC, 1999) makes the following observation:

"Design is an activity in which judgement and experience play significant roles. Designers choose the features of the road and dimensions of the primary design elements. They may use judgement, technical references and calculations to assist in selecting the appropriate design elements, but selection of design elements in isolation from each other is not design. Designers must also know the effect of combining design elements under different circumstances. Because of the nature of the process, the design that emerges cannot generally be called 'correct' or 'incorrect', but rather more or less efficient (in terms of moving traffic), safe (in terms of collision rate), or costly (in terms of construction costs, lifecycle costs and environmental impacts)" (TAC,1999).

What is clear is that design is a complex task. Design can never be merely the application of numbers from a set of tables developed from the various theoretical constructs used for that purpose. There is a need to apply judgement and experience in arriving at the appropriate design. In the past, the complexity of design gave rise to the development and use of standard values for the various elements to be used in various sets of defined circumstances in order to simplify the process. This approach is not always appropriate, although it allows people of limited experience to achieve an acceptable design in many circumstances. Where more complex combinations of circumstances occur, however, designers require considerable skills and experience to enable them to choose the optimum solution.

This Manual recognises the importance of judgement and experience and provides designers with the background to the methods adopted and the reasons for the approach to selecting design elements. A wide range of dimensions for various parameters (i.e. the "Design Domain", refer to Section 2.5) is provided with comment on the circumstances for their use. The decision on the combination of values to adopt is one to be made in the context of the complex range of issues that apply in individual circumstances. The competing alternatives must be properly considered within the framework of the particular case to ensure that the solution is a context sensitive design (refer to Section 2.3). The final design is the sum of all of the decisions taken, and judgements made, during the design process.

This Manual provides the following to assist designers apply the concept of design domain:

- Numerical guidance in the form of tables and graphs showing upper and lower bounds of the design domain (where practicable).
- Commentary on the design criteria with the underlying basis or technical foundation for the development of the criteria, the various factors affecting them and if possible, the sensitivity of road safety to changes in the criteria. Some discussion of the effects of various design decisions is given to provide qualitative guidance to designers for various circumstances.
- Where necessary, some of the issues to be considered (i.e. design considerations) when applying or selecting design criteria given.
- Where possible, quantitative evaluation of performance is provided for various points in the design domain (e.g. Chapter 13).
- Where possible, quantitative evaluation of safety performance is provided for various points in the design domain using crash rate as the safety measure (e.g. Chapters 13 and 14).

Some worked examples are provided to give further guidance (e.g. Chapters 8 and 13).

2.2 Vision and strategies

Essential to the appropriate application of the requirements of this Manual is the long-term vision for the road network, which includes an objective assessment of the affordable standard appropriate for the various links of the network. The standards to be adopted are based on a large range of issues including the purpose of the road, community expectations, natural and constructed environment, anticipated funding levels and anticipated benefits. Projects are selected to implement this long-term vision.

Projects should be designed in accordance with the overall link strategies developed for the road in question to provide a consistent driving experience over the length of the link. Drivers expect a consistent standard for significant lengths of road in similar terrain. They do not expect significant changes in the standard for no apparent reason (refer to Section 2.10).

Link strategies define the proposed road standard in accordance with the chosen investment strategy for the road. These will take account of requirements for specific traffic needs such as over-dimensional and special vehicles (e.g. B-Double, Road Train, etc), level of access, flooding immunity and travel speeds, etc (refer to Section 2.3). The road function also

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provides an indication of the standard of road that should be available (refer to Chapter 4).

A network approach to safety, and consequently appropriate design criteria (e.g. for geometry), should be taken into account when developing the strategies for the various links and can not be an ad hoc generalisation made at the point of design to justify adopting some low standard feature to “save money”. The basic premise is that spending too much in one location prevents improvements in other locations with a consequent reduction in the overall level of safety of the road network. It is the case that there are limited funds and that these should be spent to achieve the greatest good. However, it is also the case that spreading the funds too thinly will result in too low a level of safety overall with continual rework to repair situations created by inappropriate design. Any overall strategy of this nature must be based on an objective analysis of the situation, not some assumption about it.

A context sensitive design will provide an acceptable balance between level of service (or efficiency), cost, environmental impact, level of safety, etc (refer to Section 2.3). This balance will reflect local values and expectations as well as the overall objectives of Main Roads encompassed in the investment strategies and policies prevailing from time to time.

2.3 Context sensitive design

A road is but one element of a transport system, which operates in the natural and built environments to meet a range of expectations of stakeholders (e.g. 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 is an approach that provides the flexibility to encourage independent designs tailored to particular situations. Context sensitive design seeks to produce a design that harmoniously combines good engineering practice with the natural and built environments, and meets the required constraints and parameters for the project. Within the discipline of road planning and design the term “fit for purpose” has also been widely used as a synonym for context sensitive design. Similarly, the notion that not all roads have to be designed to the same standard (as encompassed by Main Roads’ motto from an earlier era of “adequate roads at minimum cost”) is an example of context sensitive design.

“*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 of the United States of America).*

Planners and designers should always aim to produce context sensitive designs. The challenge is to develop a design solution that takes account of the competing expectations, interests and alternatives and the trade-offs that might be needed. It is important that this, and consideration of the below issues, occurs from the Concept Stage onward. Factors to be considered in making trade-offs include:

- level of service;

- flexibility to provide for a range of possible futures or scenarios, for example;
    - staging (how, when and its effects);
- flexibility for future upgrading/ rehabilitation at reasonable cost (e.g. foreseeable changes in road function or requirements due to changes in land use, operating speeds, design vehicles, designated routes);
- appropriate design criteria and the resulting standard of the road/s;
- mobility and reliability;
- environmental impacts, including noise and vibration;
- safety;
- consistency of design (an issue that can affect safety) along the entire link (not just the road section under consideration – refer to Section 2.10);
- maximisation of the use of existing assets;
- reduction in the life of the infrastructure;
- stakeholder expectations and needs (e.g. community, government, users);
- flood immunity;
- cultural heritage impacts;
- social impacts;
- capital costs;
- the requirements and objectives of the government and Main Roads (e.g. legislation, whole of government requirements, Main Roads' policies, Roads Connecting Queenslanders [Main Roads, 2002]);
- whole of life costs (e.g. maintenance costs, rehabilitation costs, costs of staged construction, vehicle operating costs); and
- aesthetics.

Good designers display the ability to optimise and foresee the repercussions of their decisions on the costs, benefits and impacts of the design. Issues such as the relative importance of these elements and the costs to be applied to the more subjective areas are policy decisions that should be guided by the investment strategy and/or directed by the Main Roads District Director. Within the context of these policy decisions, the designer has the ability to influence these factors.

It is important that the trade-offs are considered at the strategic stage of the pre-construction process since the standard of major elements of the road will be established in these early planning activities. Achieving consistency of design, minimal environmental impact, appropriate level of safety, appropriate aesthetics, future flexibility and optimal costs will depend on the decisions made in developing and analysing the options and preparing the business case. A limited scope for change in these fundamental aspects might be able to be achieved at the preliminary design stage but at the detailed design, designers will not be able to make major trade-offs without major cost implications. On new roads, if desired features are incorporated in the earliest phases, the cost implications (e.g. to provide a higher standard) will often be minimal. Trying to modify the detailed design to improve some features is often expensive.

In making judgements about trade-offs, the life of the project and the life of individual components of the project must be considered and an appropriate balance between capital and maintenance (i.e.

whole of life) costs derived. Adopting a multi-staged approach to some elements (e.g. pavement thickness) can reduce capital costs, with a consequent commitment to additional costs earlier than would be the case for the single stage approach. However, the basic geometry cannot easily be staged and has to be suitable for the life of the facility - the basic geometry will endure long after a project reaches the end of its “design life”.

The experience and insight needed when making trade-offs is dependant upon the designer’s understanding of the technical foundation of the relevant design parameters, how they relate and what the outcome of the resulting combination will be or is likely to be (e.g. what capability will be provided). It is only with this in-depth knowledge that it is possible for a designer to determine if the design is in fact a context sensitive design.

The design challenge is to develop a solution to the problem at hand taking account of the competing alternatives and the trade-offs that might be needed to accommodate the budget available and the circumstances of the project. To this end the end product must be internally consistent, be consistent with the expectations for the type of road, and be compatible with road design principles presented in this Manual and other relevant documents. The reasons for adopting any particular design criteria and/or parameters must be robust, defensible and fully documented.

Risks associated with the above issues must also be considered. Design requires a large element of risk management. The risks involved in the various decisions that have to be made must be assessed and considered according to accepted risk management processes. The risks have to be identified for all stakeholders (e.g. the users, the public and Main Roads) and assessed in accordance with the potential effect on them.

It is a question of balancing cost against risk rather than simply attempting to decide which solution is “correct” versus “incorrect”. Since it is not possible to create a completely safe road (i.e. a road that has no crashes on it), each design will be “more safe” or “less safe” than some other alternative. What the appropriate balance is depends on the circumstances and the combination of design elements. Finding the appropriate balance relies on experience and judgement assisted by objective measurement and research.

This inevitably introduces a significant element of variation in the possible solutions derived for a particular problem. One person’s choice will not necessarily be the same as another’s because of difference in experience and perception, and in the opinion they have on the trade-offs to be made. Some will apply much heavier weighting to the safety element while others will do the same for the cost element. Main Roads can reduce the scope for this variation by applying appropriate policies to define the extent of trade-offs it requires, but it can not reduce the variation to zero.

In considering all of the above it should be noted that:

“The choice between improved safety and increased cost, or reduced safety and lower cost, is not only technical but also requires policy decisions, particularly at the macro level” (TAC, 1999).

Such decisions influence the investment strategies.

Main Roads' investment strategies and policies must be considered when making trade-offs. The requirements of the State are reflected in legislation and Main Roads documents such as Roads Connecting Queenslanders, the Strategic Framework for Road System Asset Management, the Preconstruction Processes Manual, investment strategies, link strategies and this Manual.

2.4 Guidelines and design criteria

Most design guidelines and design criteria in this Manual are based on theoretical safety models (i.e. most are not derived from relationships based on objective safety evidence). Relating road design parameters to crash rates by research is a very difficult and time consuming process and many studies are not particularly successful in identifying relationships. Nevertheless, much useful guidance on the effect of changes in standard on crash rate has been achieved through research (e.g. shoulder widths, horizontal curve radius).

2.4.1 Development of design criteria

In developing design guidelines and design criteria, a range of circumstances must be considered and the result is a balance between competing demands to produce a context sensitive design (refer to Section 2.3). Many road design criteria have been developed from the laws of physics, empirical data and/or objective safety evidence and provided to designers for application to their specific problems. In defining the acceptable limits for the dimensions for various criteria (the "Design Domain" in the Canadian Manual, refer to Section 2.5), the lowest acceptable value for the Normal Design Domain is often labelled the "absolute minimum" and the preferred lowest value the "desirable minimum" (refer to Section 2.6). At the same time the Geometric Design Guide for Canadian Roads (TAC, 1999) provides guidance on a "best practice" solution. The designer then has to establish the "affordability" of the solution recommended and show an acceptable balance between safety and cost.

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Design criteria based on objective safety evidence

Design criteria where research has established a relationship between the various parameters and crash rates are objective in nature. When using these design criteria a minimum or maximum value can be set to limit the crash rates to a particular limit. Often this is prior to a point where the crash rate will increase sharply.

Alternatively, when using these design criteria, a designer can choose an appropriate balance between safety and cost by comparing the estimated/predicted benefits (the reduction in crash costs for the community) with the additional cost of construction (community provided funds) to determine the BCR. Examples where this approach can be used in this Manual are the warrants for safety barriers using the Road Impact Severity Calculator (RISC) program (refer to Chapter 8) and the design of roundabout geometry using the ARNDT program (refer to Chapter 14). One problem with using only a BCR to determine whether to provide a certain standard is that there are no limits for design parameters on low volume roads. This can lead to the provision of road geometry with a high propensity for crashes.

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Often, the funding available will not be enough to enable projects with a BCR of one to be constructed and a higher BCR will be required to justify the project (based on the lowest BCR at the limit of funding). Prioritising projects using this process ensures that Main Roads' funds are distributed efficiently to those areas most likely to give the greatest return.

Design criteria based on theoretical models

Theoretical safety models are often based on physics, the performance characteristics of drivers and vehicles and the experience and judgement of practitioners. This judgement and experience is usually derived from objective measurements of performance and as much correlation with crash history as possible. Further, for design criteria based on theoretical models, BCR techniques cannot be used to compare the benefit of providing a higher or lower standard of geometry (e.g. with current information it is not possible to measure if there is any benefit to be gained by providing a larger crest curve rather than a smaller one).

An example of design criteria based on a theoretical model is the minimum radius crest curve. Driver eye heights and reaction times, vehicle braking performance, and object height are some of the parameters that are used to calculate the required radius. The values of each of these parameters are based on a combination of measured values and subjective judgement. The theoretical model in this example was first developed when vehicle performance was limited and traffic volumes were low. The model was intended to ensure that roads would safely cater for future vehicle performance and traffic.

Many of the design criteria with a theoretical base in this Manual have been adopted from current Austroads guides. These criteria have existed over a considerable period of time and many are based on material from international road design practice. They have also been influenced by many years of Australian research and many design criteria have been modified accordingly. Recent reports (McLean 2000a and 2000b) have shown the range of practice for cross section elements around the world can be wide and Australian practice is within the range but not at the top. At the same time, Australia has the largest vehicles in the world operating regularly on many of its roads.

Whilst theoretical safety models have a strong logical base, their actual effect on safety is often not well known although general effects have been well demonstrated. Most general studies that have attempted to relate geometric design criteria to accident rates have not been successful in showing strong correlation between a specific geometric element and the expected accident rate although trends have emerged. Research by the Australian Road Research Board has been successful in showing the effect of curvature (McLean, 1977) and shoulder width (Armour, 1984; Armour, 1983; Armour and McLean, 1983) on crash rates. This has allowed the development of sensible Australian practice in these areas.

Notwithstanding the difficulty of obtaining direct confirmation of the effect of all geometric elements on accident rates, the methodology is logical, based on sound principles of physics and has produced acceptable results. It is the best method available to develop design criteria in lieu of criteria derived from objective safety evidence.

Because judgement is used inherently in the models, there can be conflicting opinions as to the appropriateness of the chosen values, largely because of differences on the trade-offs to be made.

2.4.2 Application of design criteria and the resulting standard of the road

Guidelines provide information and background material to assist the designer in choosing the appropriate dimensions for the elements of the design. However, the range of combinations of elements is large and these can apply to a large range of circumstances (e.g. local rural road to major urban motorway). This Manual must therefore be general - it cannot take account of specific site circumstances but it does provide guidance to the designer to assist in deciding on an appropriate standard for each set of circumstances/project.

The suggested values or design domains are based on prevailing and predicted vehicle and human performance as well as current technologies. Usually, they are the result of theoretical constructs modified by research into accident performance and/or human behaviour. Technological developments can affect these so the specific elements of the design criteria can vary from time to time.

There has always been a gap between road needs and the budgets to fulfil those needs. Designers sometimes seek to reduce costs on a project by adopting values for design criteria at the lower bound of the relevant design domain, usually on the basis that the application of such values will provide a satisfactory solution. This is not necessarily the case.

In the following quotation about geometric road design, the term standard refers to the design criteria and their design domain.

"Design dimensions that do not meet standards do not necessarily result in unacceptable design - dimensions that meet standards do not necessarily guarantee an acceptable design. In assessing the quality of a design, it is not appropriate simply to consider a checklist of standards. The design has to be reviewed with judgement; standards merely assist the reviewer in making those judgements" (Louis, 2002).

It is also the case that adopting lower order values for all elements in combination at a particular location will not generally give a satisfactory result. The resulting design might be hazardous and/or have operational difficulties. Where the lower order value is adopted for one element, it is usually required that a better than lower order value be used for others to compensate (e.g. wider pavement where a crest vertical curve of low standard must be adopted). As a further example, if a vehicle has to stop on a minimum radius horizontal curve with restricted sight distance, the kinetic friction associated with locked wheel braking on wet roads (part of the stopping distance model) is accompanied by a reduction in available side friction. This means that many drivers are unable to control the direction of their vehicle unless they brake in a manner that requires a longer stopping distance (Fambro et al, 1997 and Olsen et al, 1984).

Experience and judgement must be used in these cases.

Experience is, however, more than a "gut feel" on the designer's behalf. It must be developed from objective application of principles and measurements of performance over a period of time. It is not enough to merely have completed a project - its performance must be measured objectively over an appropriate period of time. The other path to depth of understanding is through objective research of the issues using appropriate techniques and matching of data to actual circumstances and performance. If judgements are to be made, they must be able to be justified on the basis of real data and performance in circumstances similar to those prevailing at the site of the design in question.

To a large extent, this Manual incorporates significant amounts of data from research and experience gained over a period of time by Queensland Main Roads and other Australian authorities. However, this must of necessity be somewhat generalised, as circumstances will vary between sites. A sensible mix of application of the Manual and the practitioner's experience is required to gain the best result (i.e. a context sensitive design).

Roads should be "fit for a particular purpose" in that they should do what the reasonable user expects them to do as well as performing in the way society needs them to perform. A context sensitive design is therefore one that matches the way it will be used (e.g. matches how a road will be driven). It is not a solution generated by making unrealistic design assumptions (e.g. choosing a design speed that is unrealistically high or low).

For roads, the basis of producing a context sensitive design is that the standard adopted for a project reflects the proper purpose of the road in question. The basic purpose determines the level of standard appropriate to that road. For example, a highway provides a connection between major centres giving a high level of service to the traffic on the road; it is a vital part of the economy of the area and is more important for its traffic carrying function than for property access. On the other hand, a local road is primarily for the purpose of access to property and connection to the higher order elements of the road system; it can be a lower speed road with less generous features than the highway counterpart. However, having determined what the appropriate purpose is, the design standards of the elements have to be in accordance with the accepted design practices as defined in this Manual. That is, the application of the principles of design does not change. Anything less than this means the solution is **NOT** a context sensitive design.

To be a context sensitive design, the elements of the design have to meet the criteria for the design of those elements. Context sensitive design is not an excuse for violating the principles of design and not applying appropriate design criteria.

2.5 Design Domain

(This section has been drawn almost entirely from the Geometric Design Guide for Canadian Roads [TAC, 1999] and the assistance of that Manual is gratefully acknowledged.)

The Design Domain concept was introduced into the Geometric Design Guide for Canadian Roads (TAC, 1999) to provide an approach where the designer is required to select design criteria from ranges of values, considering the benefits and costs of the selected criteria. This approach places an emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets “standards”.

Figure 2.1 illustrates the concept. With the example in Figure 2.1 the lower regions of the domain represent criteria that would generally be considered to be less safe, 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 or levels of service caused by changes in the design together with a benefit cost analysis. Such data is not always available and this Manual provides guidance to designers on the potential effect of changes in design of the elements involved.

With the example in Figure 2.1 values towards the upper end of the domain will tend to be selected, for a particular parameter, for the following:

- On roads with high traffic volumes.
- When other parameters at the same location are approaching their respective lower order values. (For a parameter where an increase in its value produces a higher benefit the lower order values are those that approach the lower bound [e.g. Figure 2.4]. For a parameter where an increase in its value produces a lesser benefit the lower order values are those that approach the upper bound [e.g. Figure 2.6].)
- Where little additional cost is required (to provide the higher value).
- Where a significant crash history exists at a particular location.

Conversely, values towards the lower end of the domain will tend to be selected, for a particular parameter, for the following:

- Where significant additional cost is required (to provide a higher value).
- Where there is no crash history at a particular location.
- Where the use of a lower order value is reasonable, defensible and the logic of both of these aspects is documented (as discussed in this Chapter). (For a parameter where an increase in its value produces a higher benefit the lower order values are those that approach the lower bound [e.g. Figure 2.4]. For a parameter where an increase in its value produces a lesser benefit the lower order values are those that approach the upper bound [e.g. Figure 2.6].)
- When other parameters at the same location are above their respective lower order values.
- On roads with low traffic volumes.

Using this concept provides some benefits to the designer:

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

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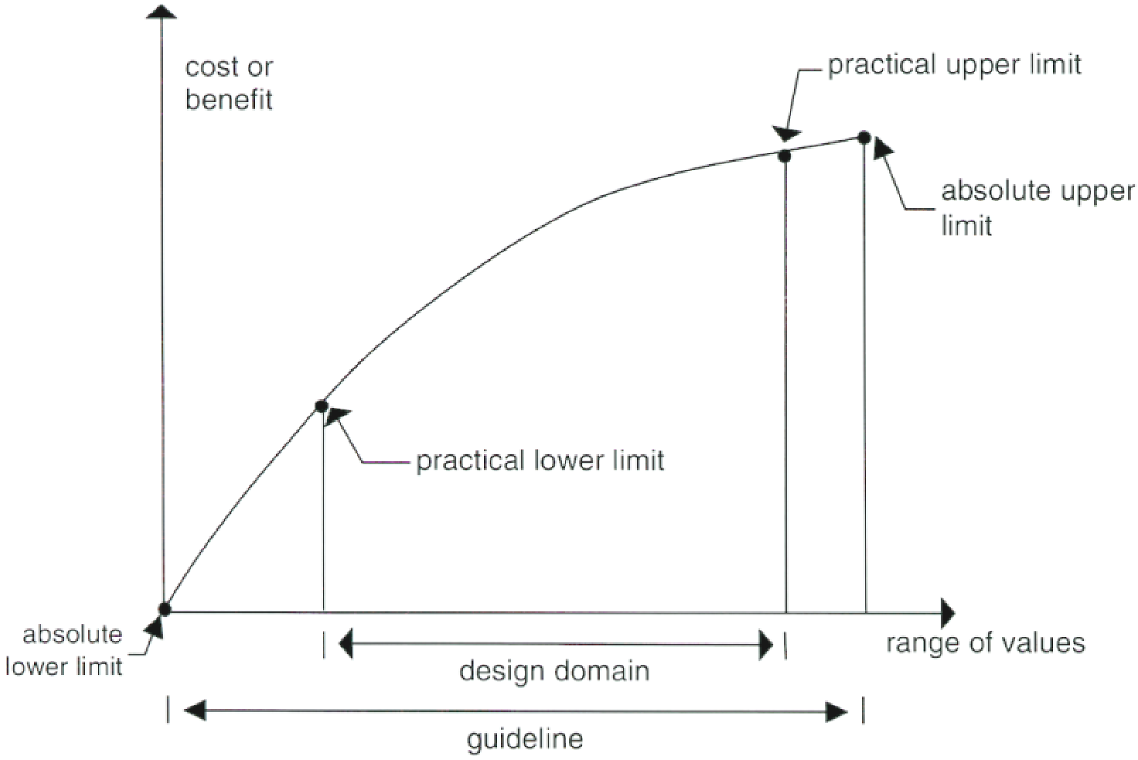
Figure 2.2 illustrates how the design domain concept might be applied to a single design parameter, shoulder width. Selection of a value within the design domain will depend on a trade-off between the various benefits and costs. In other cases, values for several design parameters must be selected, these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

In practice, the concept of a design domain with an upper and lower limit (i.e. bound) with a continuous range of values in between may not be practical or desirable. For example, the lengths of transitions are usually rounded to multiples of 20m for the convenience of set out calculations. In some cases, there may be no upper bound other than that imposed by practicality or economics and the upper bound is defined by typical values found in practice or by the threshold of cost-effective design. With some design parameters, such as the co-efficient of side friction, higher values represent a lower order of service. However such parameters still have a design domain and the benefits gained from having to make decisions on values still apply.

The designer must take account of the nature and significance of controls and constraints. Often, the designer will not be able to choose design dimensions that will satisfy all of the controls and constraints and compromise (i.e. trade-offs) will be required. These are engineering decisions that call for experience, insight and a good appreciation of community values.



Notes to Figure 2.1:

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

Figure 2.1 The Design Domain Concept (TAC, 1999)

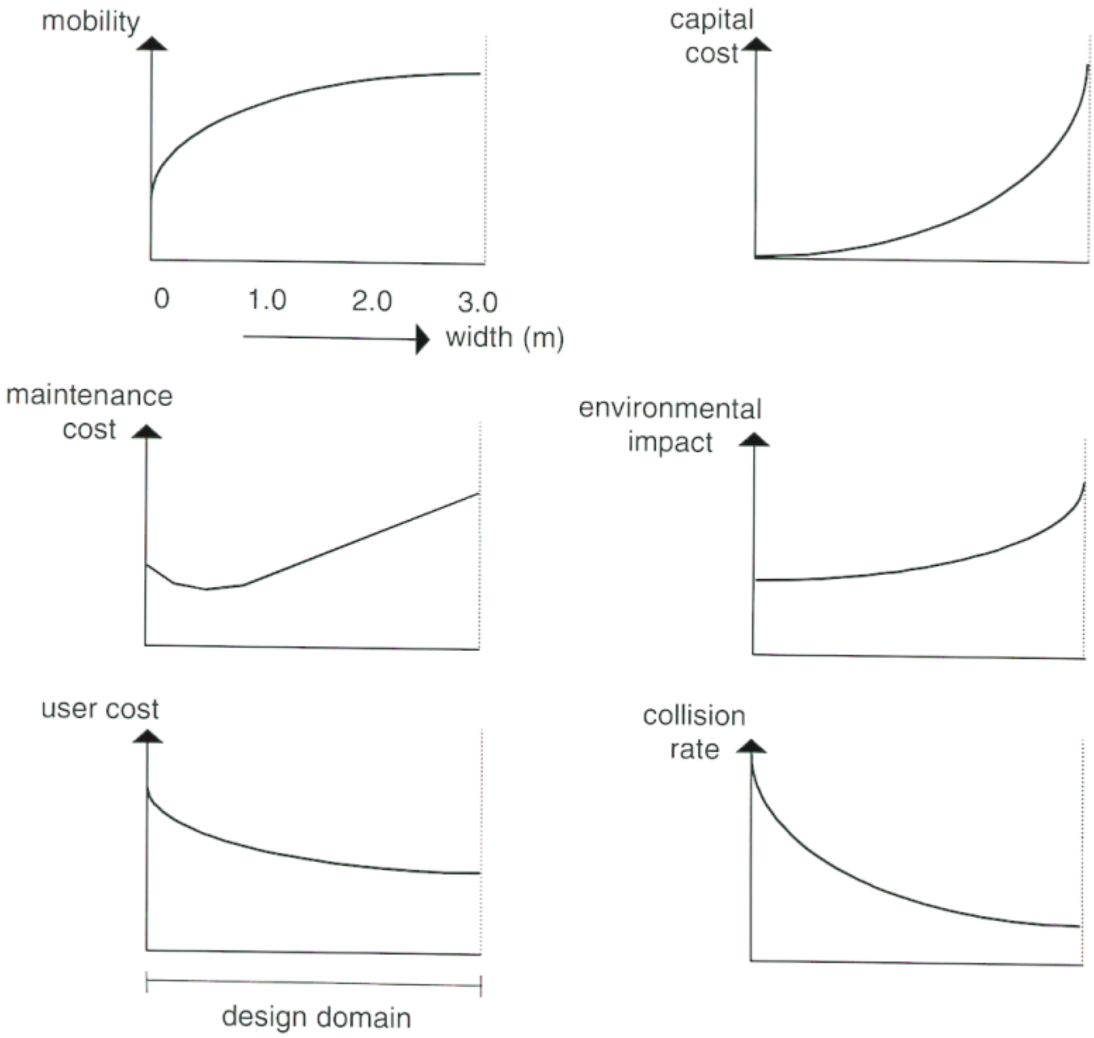


Figure 2.2 Design Domain example - shoulder width (TAC, 1999)

Some design criteria are set by policy (e.g. vertical clearance to structures), while others may be little more than suggestions. Some are chosen on the basis of safety, some on service or capacity, while others are based on comfort and aesthetic values. The judicious choice of design parameters is very important in the design process and it is important that designers have a good appreciation of the background to, and derivation of, the parameters being used. By using this knowledge and understanding, and having regard for community values, a designer will be able to produce a design to the required level of service and safety with acceptable economy.

For many elements, a range of dimensions is given in this Manual and the designer has the responsibility to choose an appropriate value for a particular situation. A designer with economy uppermost in mind may be tempted to apply the lower order value in the range on the basis that so long as the value is within the accepted range, the design is satisfactory. This may, or may not, be the case.

The designer might conclude that it is appropriate to use lower order values for design parameters and this is not necessarily a bad decision. However, if this course of action is followed, the consequences of the action need to be thoroughly understood, particularly with regard to safety but also with regard to costs, benefits and level of service. It is necessary to consider ameliorating measures (e.g. traffic control devices) at the same time as the geometric design. If a design involves compromise, it might be better to compromise several elements a little rather than to compromise one element excessively. The design must be balanced.

This highlights the need for the proper combination of elements and the effect of decisions on one of them by decisions on others. For example, where it has been necessary to adopt a lower order value for one element, it might be necessary to compensate by being more generous with an associated element. The design must always consider the inter-relationship between the elements, adopting a holistic approach to the design (refer also to Sections 2.4.2 and 2.3).

To some extent, this 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 the design.

As shown in Figure 2.3, the design domain consists of the following two elements:

1. the Normal Design Domain; and
2. the Extended Design Domain.

At this stage only a limited number of design criteria have an Extended Design Domain.

Both the Normal Design Domain and the Extended Design Domain are discussed in Sections 2.6 and 2.7 respectively.

2.6 The Normal Design Domain

The part of the design domain normally used 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 selected for new roads.

The extents of the Normal Design Domain within the various manuals and guidelines are usually based on the experience and judgement of practitioners, even where the relationship with safety has been identified by research. These extents can change over time with current subjective thinking (e.g. Austroads’ decrease in eye height from 1.15m to 1.05m has increased Austroads’ minimum size crest vertical curves).

Over time all design criteria in this Manual will be described in terms of their design domain and in some cases their extended design domain. Pending this, Figure 2.4 shows the relationship between the minimum and maximum values traditionally used in road design guidelines and the bounds of the Normal Design Domain for a parameter where an increase in its value produces a higher benefit. As shown by Figure 2.4:

- an “absolute minimum” or “minimum” value corresponds to the lower bound of the Normal Design Domain;
- a “desirable minimum”, “general minimum” or “preferred minimum” falls within the Normal Design Domain;
- a “desirable maximum”, “general maximum” or “preferred maximum”

falls within the Normal Design Domain; and

- an “absolute maximum” or “maximum” value corresponds to the upper bound of the Normal Design Domain.

An example for a parameter where an increase in its value produces a higher benefit follows:

- The lower bound (i.e. minimum) total lane width for a two-lane, two-way rural road is 6.0m from Chapter 7. This is shown as the lower bound of the Normal Design Domain in Figure 2.5. In general, values below the lower bound should not be chosen.
- The upper bound (i.e. maximum) of total lane width for a two-lane, two-way rural road is 7.0m (exclusive of curve widening) from Chapter 7. This is shown as the upper bound of the Normal Design Domain in Figure 2.5.

Further Figure 2.6 shows the relationship between the minimum and maximum values traditionally used in road design guidelines and the bounds of the Normal Design Domain for a parameter where an increase in its value produces a lower benefit. As shown by Figure 2.6:

- an “absolute minimum” or “minimum” value corresponds to the lower bound of the Normal Design Domain;
- a “desirable minimum”, “general minimum” or “preferred minimum” falls within the Normal Design Domain;
- a “desirable maximum”, “general maximum” or “preferred maximum” falls within the Normal Design Domain; and
- an “absolute maximum” or “maximum” value corresponds to the upper bound of the Normal Design Domain.

An example for a parameter where an increase in its value produces a lower benefit follows:

- The upper bound (i.e. absolute maximum) side friction factor for 50km/h is 0.35 from Chapter 11. This is shown as the upper bound of the Normal Design Domain in Figure 2.7. In general, values above the upper bound should not be chosen.
- The desirable maximum side friction factor for 50km/h is 0.30 from Chapter 11. This value falls within the Normal Design Domain.

Longitudinal grade is another example of a parameter where an increase in its value produces a lower benefit.

Unless specifically stated otherwise the terminology described in this Section applies to this Manual (i.e. the minimum and maximum values given define the boundaries of the Normal Design Domain and so apply to the design of new roads). The only exception to this is when the quoted minimum or maximum values specifically state they relate to the Extended Design Domain or restoration projects.

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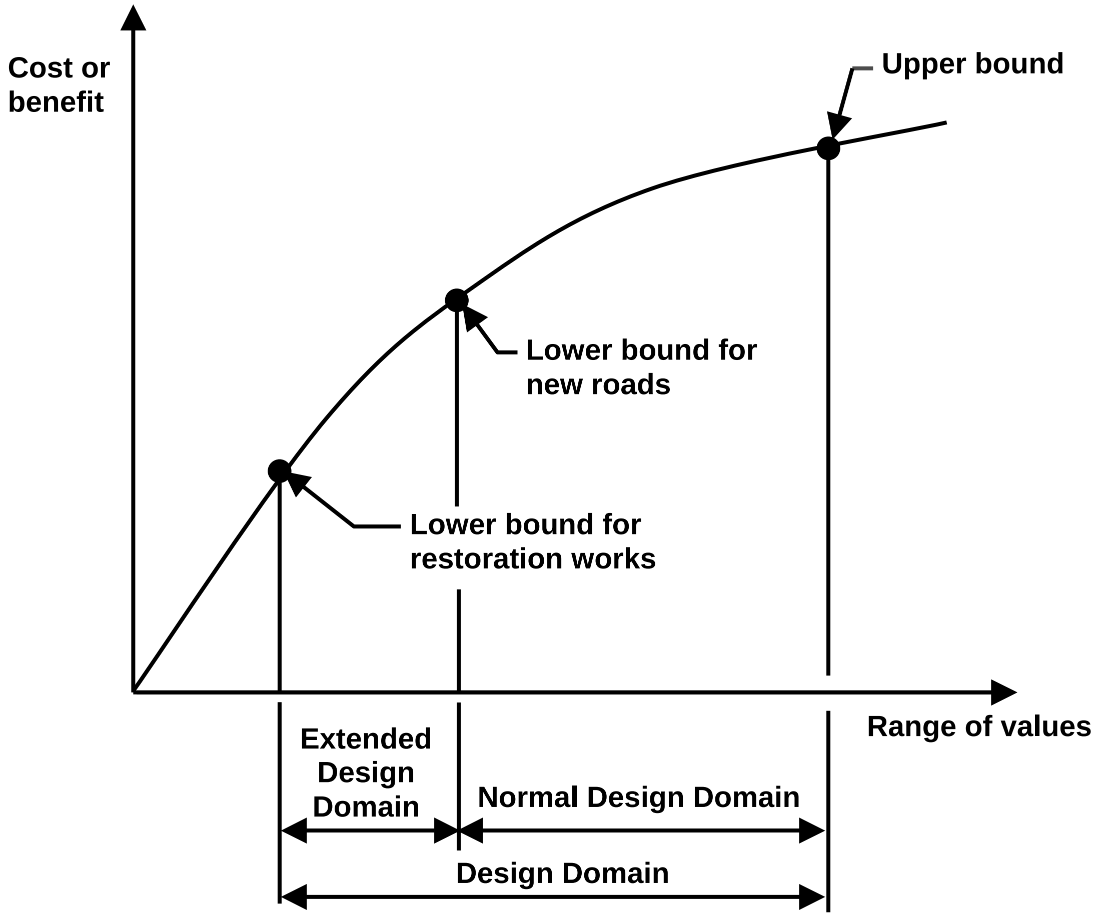

Figure 2.3 Diagram showing the Normal Design Domain and the Extended Design Domain (for a parameter where an increase in its value produces a higher benefit)

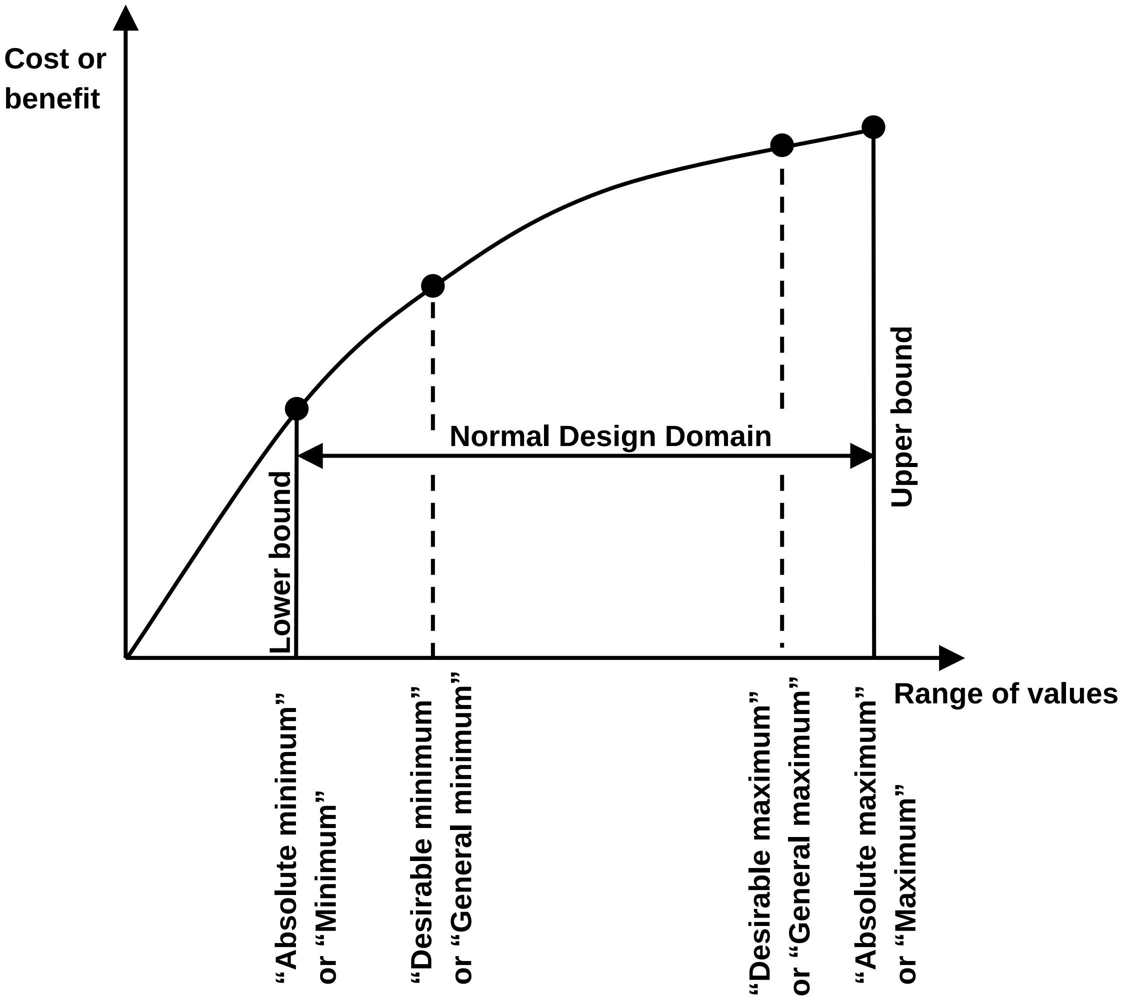

Figure 2.4 Relationship between values traditionally used in road design guides and manuals and the bounds of the normal design domain (for a parameter where an increase in its value produces a higher benefit)

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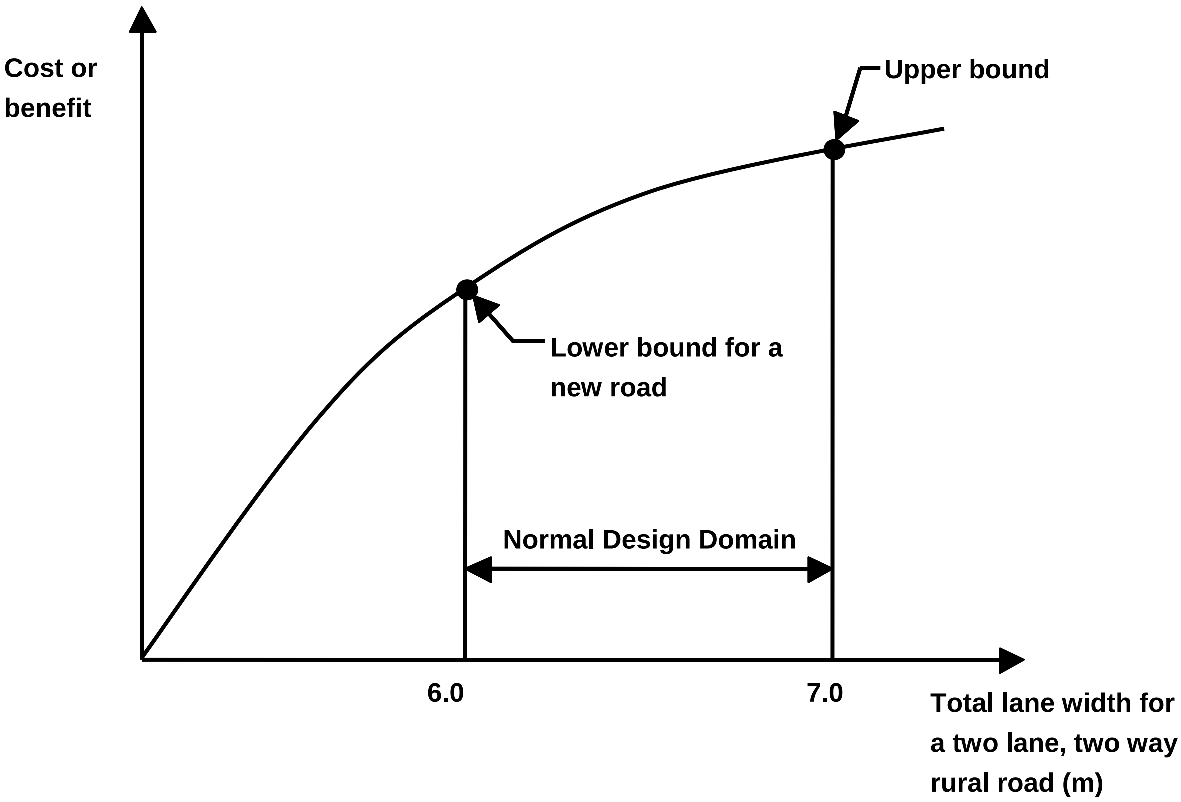

Figure 2.5 Example of normal design domain for total lane width for a two lane, two way rural road

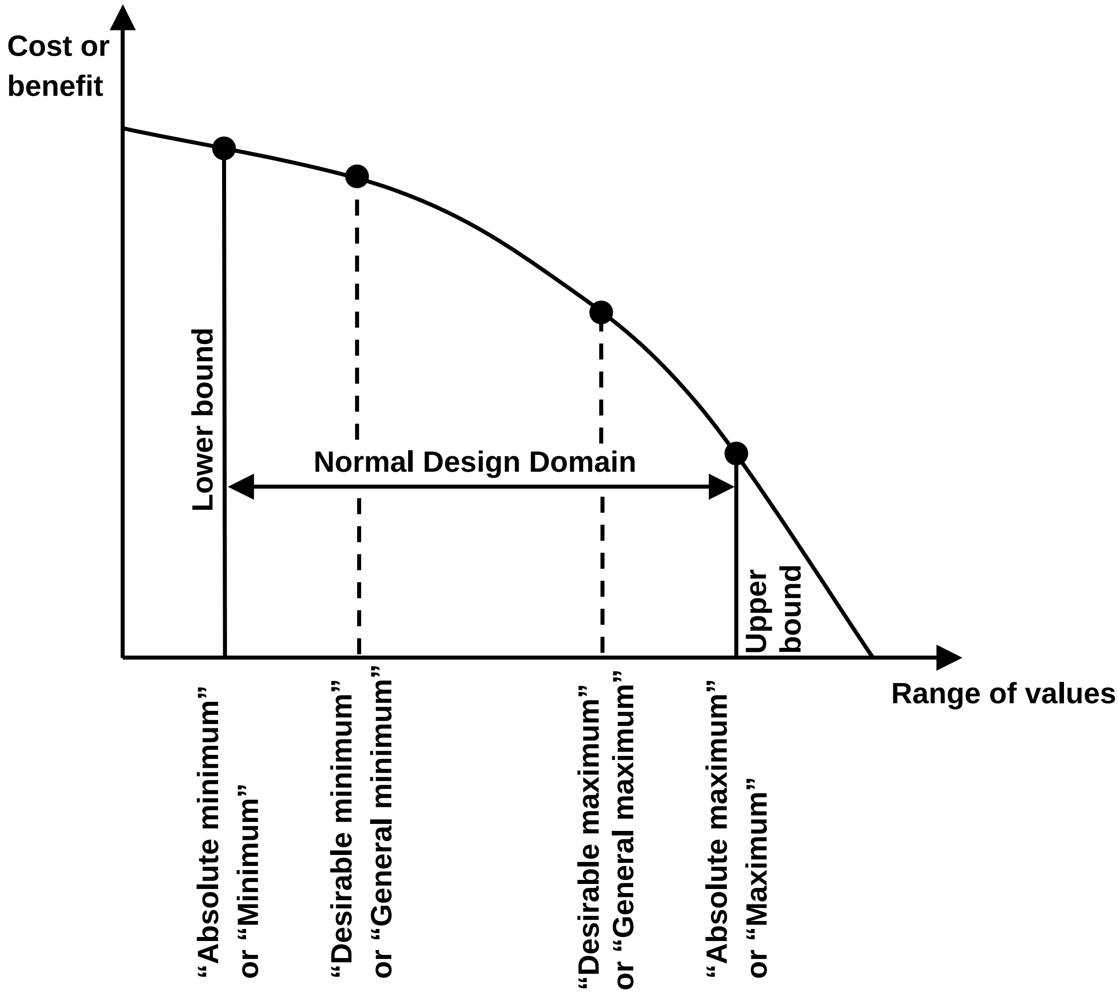

Figure 2.6 Relationship between values traditionally used in road design guides and manuals and the bounds of the normal design domain (for a parameter where an increase in its value produces a lower benefit)

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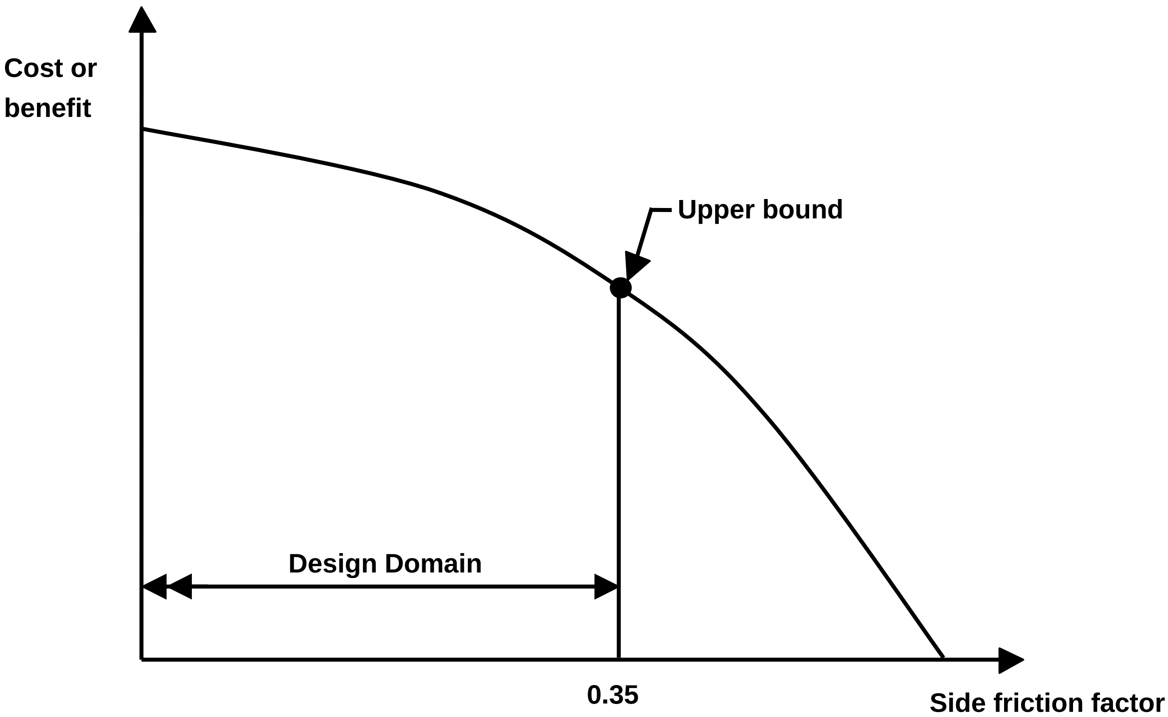


Figure 2.7 Example of design domain for the side friction factor for 50km/h

2.7 The Extended Design Domain

As shown in Figure 2.3, the Extended Design Domain is a range of values below the lower bound of the Normal Design Domain (for a parameter where an increase in its value produces a higher benefit).

The scope to use such lower order values comes when the models used in the Normal Design Domain contain considerable latitude. This is usually due to some conservative assumptions. The new values are based on engineering grounds and use data from modern and comprehensive international research.

(Note: Conversely, for some design parameters where an increase in its value produces a lower benefit, such as the side friction factor, the Extended Design Domain would be a range of design values above the maximum values traditionally used in road design guidelines. However an Extended Design Domain has not been developed for the side friction factor.)

As the name implies, the Extended Design Domain extends below the Normal Design Domain (for a parameter where an increase in its value produces a higher benefit, i.e. below the lower bound of the design domain that is used for a new road). Where there is an Extended Design Domain, the term only refers to the extension (Figure 2.3).

The use of Extended Design Domain may be limited to particular parameters (e.g. sight distance) where research has demonstrated that the adoption of Extended Design Domain will not result in significantly higher crash rates. While Extended Design Domain may be the least preferred design solution, 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 Extended Design Domain is usually high within these cases. In contrast, the relative cost differential between providing a road that conforms to the Normal Design Domain compared to the Extended Design Domain is likely to be much less for a new road at a "green field" site. An existing road also represents a significant prior investment. Therefore, the focus when restoring existing roads should be to optimise the asset to maximise the investment already made and to be made while still providing adequate safety.

The use of the Extended Design Domain will also be applicable in the case of a major re-alignment on a low volume road, as generally the Normal Design Domain for many design parameters has to suit operation at moderate to high traffic levels. Section 2.9 and Chapter 4 discuss situations where the use of Normal Design Domain and the Extended Design Domain may be applicable.

An example of using the Extended Design Domain for a crest curve follows:

- The Extended Design Domain upper bound crest curve radius for a restoration project is 9,500m from Chapter 12. This corresponds to the lower bound of the Normal Design Domain shown in Figure 2.8.
- **The Extended Design Domain lower bound crest curve radius for a restoration project must be determined on a case by case basis.** The designer should refer to the discussion and Appendices in Chapter 4 to do this. An example may be that Norm-day-2s-wet-0.2m stopping is the appropriate minimum capability for a particular crest in a particular restoration project. For a 110km/h design speed this corresponds to a lower bound crest curve radius of about 3,600m.

Designers should be aware that simply adopting lower order values for a parameter (including Extended Design Domain values) for several design criteria may produce an unsafe and/or unsatisfactory result. For example, combining a minimum radius horizontal curve with a minimum radius crest curve and a minimum carriageway width may be a hazard to road users; even though individually they "comply" in combination they may produce an undesirable result. Where a lower order value is adopted for one geometric element it is usually desirable to adopt a value that is above the lower order value for other elements (e.g. increase the pavement width to allow vehicles to manoeuvre on an absolute minimum radius vertical curve). This philosophy is particularly relevant when applying the Extended Design Domain concept.

Figure 2.9 is another conceptual diagram that shows the Design Domain, the Normal Design Domain and the Extended Design Domain, and how the risk of litigation may change for a given geometric parameter. The risk of litigation needs to be considered when adopting particular values of a geometric parameter for restoration of an existing road.

In Figure 2.9:

- "Area 1" represents the Normal Design Domain.
- "Line A" represents the minimum value of a geometric parameter given in a road design manual for the design of a new road.
- The vertical line denotes a geometric parameter whose minimum value is not influenced by traffic volume (e.g. crest curve size).
- "Area 2" represents the Extended Design Domain. It still ensures reasonable capability and safety for road users – capability that can be identified, explained and defended when it is applied appropriately.
- "Area 3" represents design exceptions (refer to Section 2.8).

The use of the Extended Design Domain requires documentation of the decisions about, and/or analysis of:

- possible alternatives;
- design trade-offs (each one);
- any special needs (e.g. road vehicles, road users, etc);
- the capabilities provided and why these are likely to be reasonable;
- the extent to which the intents of design criteria are achieved including:
  - o how well they are achieved;
  - o how relevant the intents are; and
  - o the acceptability of any consequences.

It should also include evidence that there are higher priority safety issues to be addressed elsewhere on the network.

The recommended process for using the Extended Design Domain on a restoration project is described in Chapter 4.

Pending the description of all design parameters in terms of design domain throughout this Manual, guides for the current Extended Design Domain parameters are contained within the Appendices of Chapter 4.

2.7.1 Further information

For further discussion on the Extended Design Domain the reader should refer to (Cox 2003a), (Cox 2003b), Cox and Foley (2003), Cox (2004) and Cox and Arndt (2005). For further information about the Extended Design Domain and unsignalised intersections readers should refer to Arndt (2004).

2.8 Below the Design Domain – a design exception

Values in the range denoted by "Area 3" of Figure 2.9 fall below the Extended Design Domain because they are not likely to be supported on the grounds of reasonable design capability (e.g. can not provide reasonable stopping capability). It is not the prerogative of road designers to decide whether to retain a design exception.

Existing roads can consist of geometry with values that are below the design domain. Strategic planners within road authorities allocate funding, determine investment strategies, and describe the general intent or purpose for road projects based on an economic assessment (e.g. using a benefit/cost analysis), competing network priorities and a range of other factors (e.g. factors discussed in Section 2.3).

A designer, whether from a consultancy or the road authority itself, does not take responsibility for deciding whether to retain a design exception. If a designer is particularly concerned about the adoption of a design exception (e.g. reasonable evidence exists that there is a major safety concern or the designer believes the design exception can be eliminated), the designer must raise the issue with the Main Roads District Director for further analysis and re-approval.

Cases where designers are forced to retain values outside the design domain constitute design exceptions. Any decision to use values in this range must be documented and it must be justified by:

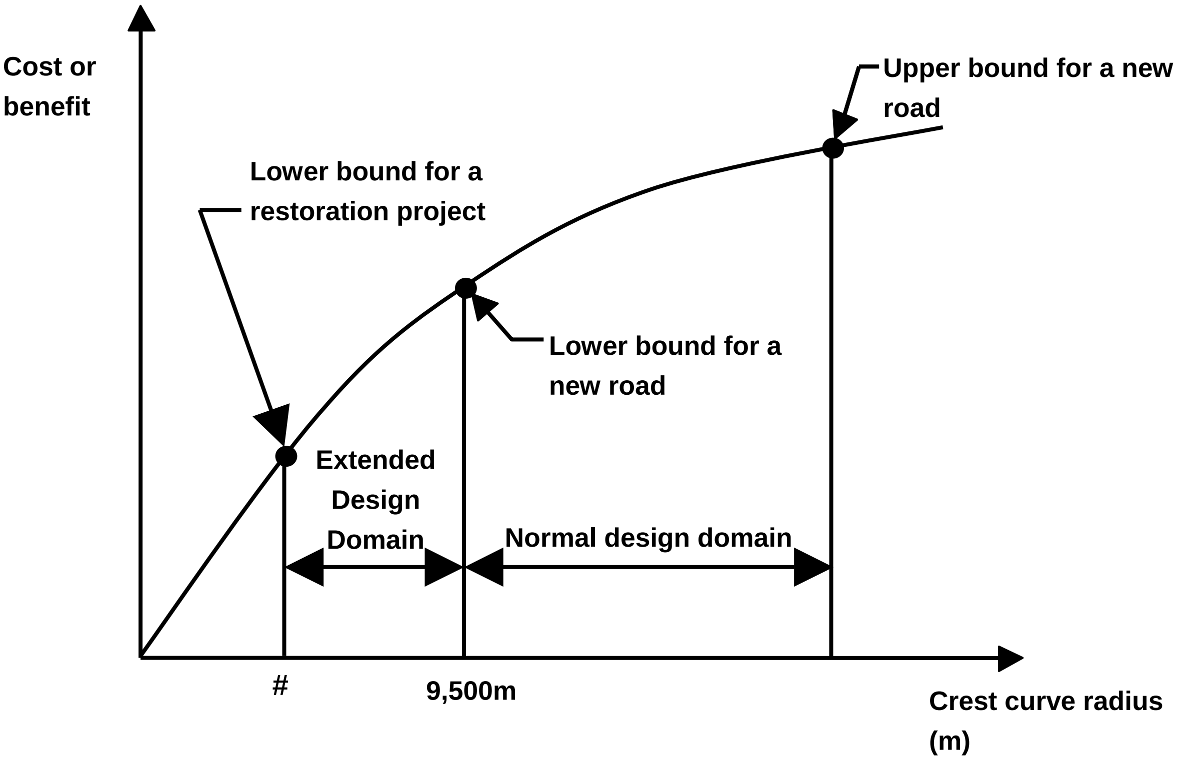
- the level of capability that still exists, if any (and the Extended Design Domain check and optional check cases may help in this);
- any major constraints that apply (e.g. geotechnical issues or prohibitive costs related to relocation of major public utility plant);
- overriding circumstances (e.g. environmental constraints, social imperatives);
- a risk assessment with output justifying the adoption of such a value (e.g. the Project Managers Risk Management Guidelines – Main Roads, 2004: Main Roads officers can also refer to Main Roads "onq" intranet site; the Australian Road Research Board has developed its Road Safety Risk Manager software tool which may be suitable in some instances: Australian Standards, 2004);
- evidence that there are higher priority safety issues to be addressed elsewhere on the network;
- the use/installation of mitigating devices, including the posting of advisory speeds (where permitted), fencing to reduce potential hazards, etc;
- an investigation into, and review of, the crash history relating to the use of the substandard value at the particular location; and
- approval by the Main Roads District Director.

Details for each of above points must be included in the documentation.

Designers may become involved in some of the above tasks (e.g. identifying appropriate traffic management devices for the particular design exception).

2.9 Requirement for geometric assessment and choice of Domain

Chapter 4 discusses when a geometric assessment is warranted and what design domain can be chosen for different types of projects.



Value to be determined by the designer on a case-by-case basis.

Figure 2.8 Example of extended and normal design domains for crest curve radius for a 110km/h design speed.

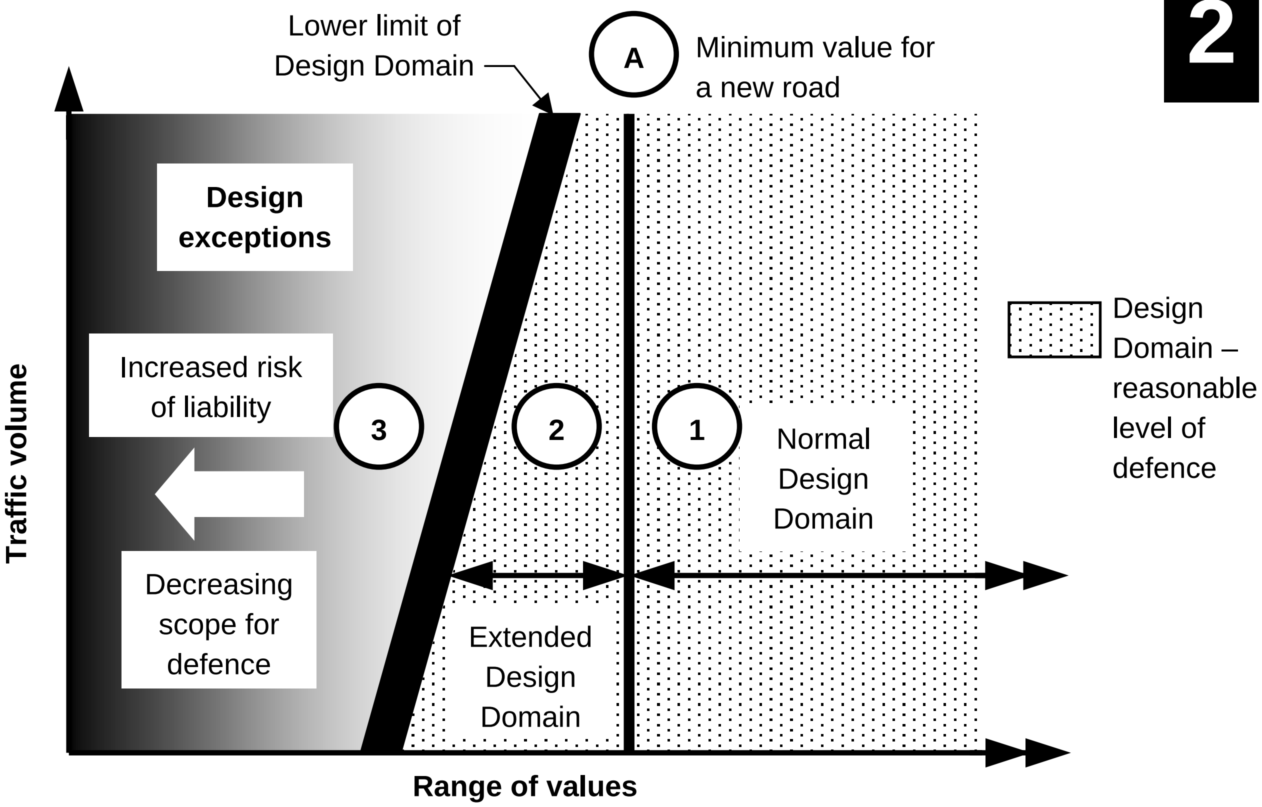


Figure 2.9 Conceptual diagram showing the Design Domain, the Extended Design Domain and the how risk of liability increases (for a parameter where an increase in its value produces a higher benefit)

2

2.10 Design consistency

2.10.1 Background

Safety on roads is closely related to the driver's ability to anticipate events and react to them. Perception and reaction times are critical to the development of sight distance criteria and the other elements that rely on this parameter. In this, the driver's expectations play a major part. Perception and reaction times for matters that accord with a driver's expectations are less than those that are needed when the road ahead does not conform to the driver's expectations.

Designers should account for this by reducing or eliminating uncertainty or the unexpected for drivers (or by allowing for increased perception and reaction times). An important component of reducing or eliminating uncertainty is design consistency. This consistency should be applied over long lengths of road links and as far as possible, over a wide geographic area. The more consistent the designs are, the greater the contribution of the designer to reducing crashes on the road system.

Different road functions exist within the road system; the road function reflects the type of service provided by the road. In addition, there are significant variations in topography from area to area and these need to be accommodated in the designs. There should be consistency of design for each road function in each terrain type regardless of location (TAC, 1999).

This approach leads to the concept of the "self explaining road" (Fuller et al, 2002). That is, a road whose features tell the driver what type of road it is and therefore what can be expected in terms of the elements of the design. This provides a confidence in expectations for the driver, who then operates the vehicle in accordance with those expectations, which in turn are in tune with the standard of road.

Fuller et al (2002) explores in detail the effect of human behaviour and limitations in approaching the driving task. Designers should take note of the following:

- Drivers do not always operate at their optimal level of competence - their performance may be degraded because of several factors (e.g. fatigue, stress, poor motivation, low level of attention or arousal).
- Task performance can be considered on three levels - skill based, rule based and knowledge based:
  - Skill based performance is so well learned that a person performs the task automatically.
  - Rule based performance is guided by a set of rules such as the rules of the road (e.g. a "Stop" sign ahead invokes a learned behaviour of slowing down and stopping at the sign).
  - Knowledge based performance has no rules to guide the driver and actions are taken on the basis of experience of the situation confronting the driver.

"Where events are such that there is no rule to guide behaviour, such as where there is a novel problem with which the driver has to deal, reference must be made to his or her broader representation of knowledge of the vehicle, the highway or traffic system, the behaviour of other road users or even of basic principles, to enable formulation of an appropriate solution as to what to do. This is known as knowledge-

based level of performance. This knowledge base grows with experience so that experienced drivers have recourse to a relatively extensive knowledge base compared to novice drivers. Thus the latter are likely to produce a higher proportion of wrong 'solutions' when faced with a novel situation" (Fuller et al, 2002).

These factors demonstrate the vulnerability of drivers to the driving task and the importance of providing an environment where normal expectations are met and a learned response will be appropriate. One way of providing this type of environment is to provide consistency in the design of the road.

"Therefore, other things being equal, the more predictable the roadway and its characteristics, the easier the driving task and the easier it is to use safely. The implication for the highway engineer is that the design of road features should take account of road-user expectations" (Fuller et al, 2002).

Consistency is a fundamental issue in the development of link strategies. Once the various dimensions have been established, they should be applied consistently (e.g. lane and shoulder widths, clear zone arrangements, road edge guide posts, signing conventions, intersection treatments).

Design consistency can be addressed in three areas:

- cross section consistency;
- operating speed consistency; and
- driver workload consistency.

An example of providing consistency is to use, where possible, a consistent intersection layout/treatment on a link.

Actual crash history can provide insight into the design consistency of a road and this history should be used on existing roads as the basis of any review of consistency.

2.10.2 Cross section consistency

For a given road function, in given terrain conditions, cross section elements should be similar everywhere. Ideally, they should be the same on a specific road since the operating speed can be affected by the cross section. For example, a narrow, confined cross section is likely to result in a slower speed of operation than one with similar geometric characteristics but a wide, open cross section.

A situation to be avoided is the creation of incompatibilities between the road cross section and its horizontal and vertical alignment. For example, improving the cross sectional elements on a road section with a poor standard of alignment without a corresponding improvement in the alignment can result in a driver having an erroneous and potentially hazardous illusion of a road of higher standard than it really is. Drivers might then operate at speeds excessive for the critical alignment conditions.

There will be cases where the cross section dimensions change suddenly (e.g. where a four lane divided road becomes a two lane, two-way road). In these cases, the designer should provide an appropriate transition between the two cross sections with appropriate tapers and advance signing to mitigate the impact of the change. Ideally a transition from four lanes to two lanes should occur in conjunction with another obvious change. When the change is not obvious experience indicates that head on accidents can increase significantly.

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2.10.3 Operating speed consistency

Multiple vehicle crash rates on roads are closely related to the variations in speed between vehicles on the road. These variations can be caused by individual drivers adjusting their speed to negotiate/accommodate property entrances, intersections and changes in geometry. The greater and more frequent the speed variations, the greater the probability of a higher crash rate. The other source of speed differential is by drivers travelling substantially slower or faster than the average speed of the traffic, and this also results in a substantially higher risk of crashes for these drivers. Figure 2.10 illustrates the mean collision (i.e. crash) rate versus speed difference between successive geometric elements.

Designers can therefore enhance the safety of a road by producing a design that encourages a consistent speed of operation.

Chapter 6 discusses in detail the methods for designers to allow for the operating speed of drivers on a road. By applying the concepts of Chapter 6 (i.e. assessing the operating speed on each element) and the detailed design requirements of Chapter 11 (and Chapters 10 and 12 which all include a description of detailed curve design), designers can produce a design that encourages consistency of operation.

Road networks that do not provide an appropriate road hierarchy, thereby forcing short trip local traffic to mix with high speed through traffic, may also result in an inconsistent speed of operation. Such circumstances may include:

- rural subdivisions accessing local services via a high speed arterial road; or;
- changing local roads to high speed arterial roads rather than adding new higher order roads into the network.

An appropriate mix of higher and lower order roads in the network, access control and appropriate integration of development can help to resolve these issues.

2.10.4 Driver workload consistency

Some of the human factors affecting driver performance were discussed in Section 2.10.1. Driver workload also has a marked effect on performance at both ends of the spectrum. If the demand is too low, the driver's attention (i.e. level of arousal) will be too low with probable loss of vigilance and the driver may even fall asleep at the wheel. At the other end of the spectrum, if the arousal level is too high (e.g. stress, information overload, emotional situations) the driver may compensate by ignoring some relevant information leading to unsafe operation of the vehicle.

In these circumstances, driver response to unexpected situations may be too slow or inappropriate. It is important that the designer ensure that abrupt increases in driver workload are avoided as these provide the potential for a higher crash rate.

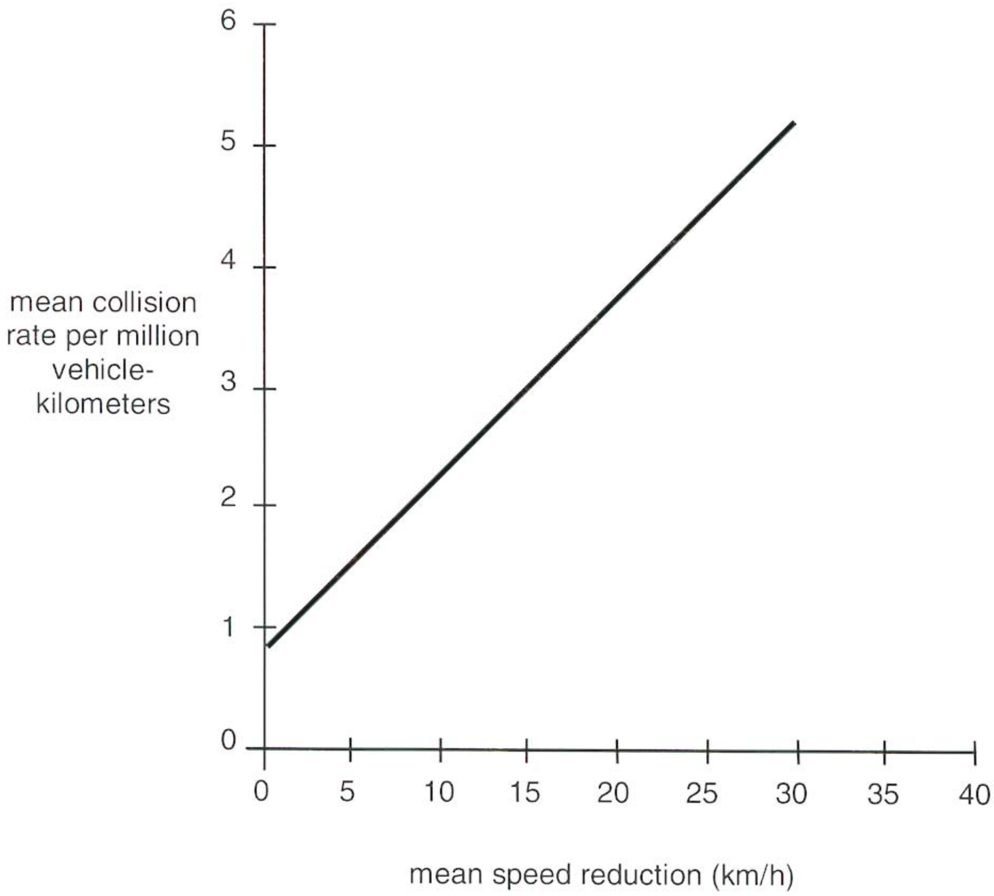

Figure 2.10 Mean collision rate versus mean speed difference between successive geometric elements (TAC, 1999)

These increases can be caused by:

- limited sight distance to the feature;
- dissimilarity of the feature to the previous feature (causing surprise to the driver);
- large percentages of drivers unfamiliar with the road (e.g. tourist road as opposed to a local road);
- a high demand on the driver's attention after a period of lesser demand (e.g. a sharp curve at the end of a long straight)

The criticality of the feature may also influence the crash rate (e.g. an intersection or lane drop is more critical than a change in shoulder width).

Situations where most or all of these factors are encountered simultaneously should be avoided (TAC, 1999).

Designers need to be aware of these factors and provide the driver with a consistent level of arousal (that is not too low and not too high) but with adequate variation to maintain the arousal level. There are implications for design where changes occur and designers should make allowance for additional reaction times where a section of road with low arousal features changes to a situation requiring a higher state of arousal. Some guidelines (based on Fuller et al 2002) to assist are:

- Avoid low arousal inducing road alignments (typically a straight alignment, with unchanging landscaping). Medium complexity helps maintain activation. One device to use is to provide specific "aiming points" for drivers (refer to Chapter 10).
- Consider the needs of fatigued and drowsy drivers (e.g. provide rest areas, provide audible edge lines).
- Avoid stimulus driven high arousal states (e.g. too much critical information on a fast road section).
- Avoid things that compete for, or distract, a driver's attention when critical information is being presented (e.g. other light sources near traffic signals, advertising hoardings near directional or hazard signing).
- Avoid information overload (e.g. avoid excessive signing).
- Avoid memory related errors by placing the necessary information "in the world" rather than rely on it being stored in the driver's head - locate it close to the vulnerable phases of the task.
- Design road features to take account of driver expectations.
- Avoid incorrect speed expectations by using speed guidance at critical road segments.
- Consider controlling the effects of speed adaptation (e.g. drivers will approach the first off-motorway curves and intersections at a higher speed than they imagine).
- Employ practices of error management: prevention, tolerance and recovery (e.g. provide a forgiving roadside environment, refer to Chapter 8).
- Aim for error prevention and error tolerance.
- Provide good information.
- Consider elements of the roadway such as:
    - lighting;
    - signing of hazards;
    - marking of hazards;
    - signing of routes;
    - road marking;
    - control by signals;
    - rumble strips or surfaces;
    - speed controls;
    - traffic calming elements;
    - enforced restrictions;
    - roadway width;
    - hard shoulders;
    - clear zone;
    - breakaway (i.e. frangible) light standards and roadside furniture;
    - roadside furniture;
    - safety barriers;
    - error recovery areas;
    - run out areas;
    - vehicle design;
    - road surface friction; and
    - batter slopes.
- Increase feedback to drivers regarding the quality of their performance (which

may only be feasible where variable message signing is available).

An example of the application of these principles is in the design of rural intersections over an extended length of the road system. It is necessary to provide consistency of experience as the driver traverses the route. Therefore, the dimensions of the elements of the intersection (e.g. tapers, length of auxiliary lanes) should be consistent. Further, the layout of the intersection should be the same for similar circumstances. This might mean that a higher level of treatment should be applied at an isolated intersection to ensure consistent behaviour of drivers.

For example, if most intersections on a road link are of the CHannelised Right (CHR) type then a driver might be caught unaware by a vehicle turning right at an isolated BAsic Right (BAR) type (possibly resulting in a rear end collision or overtaking accident). Similarly, if most intersections on a link are of the AUxiliary Right (AUR) type then an isolated “CHR” or roundabout will be unexpected and greater perception and reaction times could be required in this case to ensure that drivers perceive the additional objects on the roadway surface and the additional complexity involved.

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References

Armour M, Mclean, J (1983): *The effect of shoulder width and type on rural traffic safety and operations - Australian Road Research, Volume 13, 4, 1983-12*, pp 259-70, Australian Road Research Board (ARRB).

Armour M, (1984): *The effect of shoulder design on fatal accident rates on rural highways - Internal Report, AIR 404-1, 1984-04*, pp 29P, Australian Road Research Board (ARRB).

Armour M, (1984): *The relationship between shoulder design and accident rates on rural highways - Australian Road Research, Volume 12, 5, 1984*, pp 49-62, Australian Road Research Board (ARRB).

Arndt, O (2004): *Relationship between unsignalised intersection geometry and accident rates* - Doctoral thesis submitted to the School of Civil Engineering, Queensland University of Technology (QUT).

Arndt, O (2005): *Report on 3rd International Symposium on Highway Geometric Design* - Internal Queensland Department of Main Roads Report.

Australian Road Research Board (ARRB) *Road Safety Risk Manager*: (Current URL http://www.arrb.com.au/index.php?option=content&task=view&id=76&Itemid=96.)

Australian Standards (2004): *AS/NZS 4360:2004 Risk management.*

Australian Standards (2004): *HB 436:2004 (Guidelines to AS/NZS 4360:2004) Risk Management Guidelines Companion to AS/NZS 4360:2004.*

Cox, R (2002): *Two Sight Distance Models for Road Design (But I don't need to see that far! Do I?)* - Main Roads Technology Transfer Forum.

Cox, R (2003): *Reduced sight distance on existing rural roads: how can we defend it?* – 21st Australian Road Research Board (ARRB) Transport Research Conference; 11th Road Engineering Association of Asia and Australasia (REAAA) Conference.

Cox R (2004): *Process for using Extended Design Domain on a Restoration Project* – presentation at Main Roads Extended Design Domain Training course.

Cox R (2005): *Fitness for Purpose and Extended Design Domain Training – Cross Sections* - presentation at Main Roads Extended Design Domain Training course.

Cox R and Foley A-M (2003): Fit for Purpose – *What are the legal liability implications?* - paper presented at the Queensland Department of Main Roads 2003 Planning and Design Symposium.

Cox R and Arndt, O (2005): *Using an Extended Design Domain Concept for Road Restoration Projects* - paper prepared for the 3rd International Symposium on Highway Geometric Design in Chicago, USA.

Fambro D, Fitzpatrick K and Koppa R (1997): *Determination of Stopping Sight Distances - Report 400*, National Cooperative Highway Research Program, Transportation Research Board, Washington DC, USA.

Federal HighWay Administration (FHWA, United States Department of Transportation): *Context Sensitive Design (CSD)/Context Sensitive Solutions (CSS)* URL: http://www.fhwa.dot.gov/resourcecenter/teams/environment/env_1cs.pdf, accessed 04/08/2005.

Fuller, Ray & Jorge A. Santos (2002): *Human Factors for Highway Engineers* - Pergamon (Elsevier Science Ltd, Oxford, UK).

Hauer, E (1998): *Literature Review and Analysis on Collision Rates on Vertical Alignment* - University of Toronto (reported in Geometric Design Guide for Canadian Roads, TAC, 1999).

Juran J, and Gryna F (1988): *Juran's Quality Control Handbook, 4th Edition*, McGraw-Hill, New York, USA.

Juran, J. (1989): *Juran on Leadership for Quality: An Executive Handbook* - Free Press, New York, USA.

Louis, L (2002): *Design standards and approach to "Fit for Purpose"*.

McLean, J (1977): *The interrelationship between accidents and road alignment - Internal Report, AIR 000-68, 1977-04*, pp 18P, Australian Road Research Board (ARRB).

McLean, J (2000): *Effects of Sealed Shoulders on Road User Costs* - report for Austroads.

McLean, J (2000): *Study on Cross Sections for National Highways* - report for the Commonwealth Department of Transport and Regional Services.

New Zealand Ministry of Consumer Affairs (2002): *Web Page Glossary of Terms*.

Olsen P, Cleveland D, Fancher P, Kostyniuk L and Schneider L (1984): *Parameters Affecting Stopping Sight Distance - Report 270*, National Cooperative Research Program, Transportation Research Board, Washington DC, USA.

Pickering M, Cox R and Arndt O (2003): *Fitness for purpose and the extended design domain* – paper included in Queensland Department of Main Roads 2004 Extended Design Domain Training course.

Queensland Department of Main Roads (2002): *Roads Connecting Queenslanders*.

Queensland Department of Main Roads (2003): *Strategic Framework for Road System Asset Management.*

Queensland Department of Main Roads (2004): *Project Manager's Risk Management Guidelines*. (The current link to the document is http://www.mainroads.qld.gov.au/MRWEB/Prod/Content.nsf/b495dab138a6b17a4a256a42001c8f4f/54d1e3a50ece13cc4a256f460017e058!OpenDocument.)

Queensland Department of Main Roads (2005): *onq* - Queensland Transport and Main Roads project management (intranet) website, URL: http://intranet/onq

Queensland Department of Main Roads (2005): *Preconstruction Processes Manual*.

Richmond, A (2002). *"Fitness for Purpose" in Engineering Design* - Paper presented at the Queensland Department of Main Roads 2003 Planning and Design Symposium.

Transportation Association of Canada (TAC) (1999): *Geometric Design Guide for Canadian Roads*.

United Kingdom Department of the Environment, Transport and the Regions (1999): *Achieving Best Value Through Quality Management*.

Veith G, Bennet B and Armistead A (2005): *Austroads Road Design Series Part 2: Design Considerations* – Austroads report on Project Number TP1046.

Relationship to other Chapters

This Chapter sets out the overall philosophy adopted by the Main Roads for the design of roads in Queensland. It therefore relates to all of the other Chapters of this Manual, which have to be read in conjunction with, and applied in light of, the philosophy espoused here.

Chapter 4 in particular provides extra detail regarding the design domain, the Normal Design Domain and the Extended Design Domain. It includes requirements for geometric assessment and choice of domain and guidelines for the use of the Extended Design Domain.