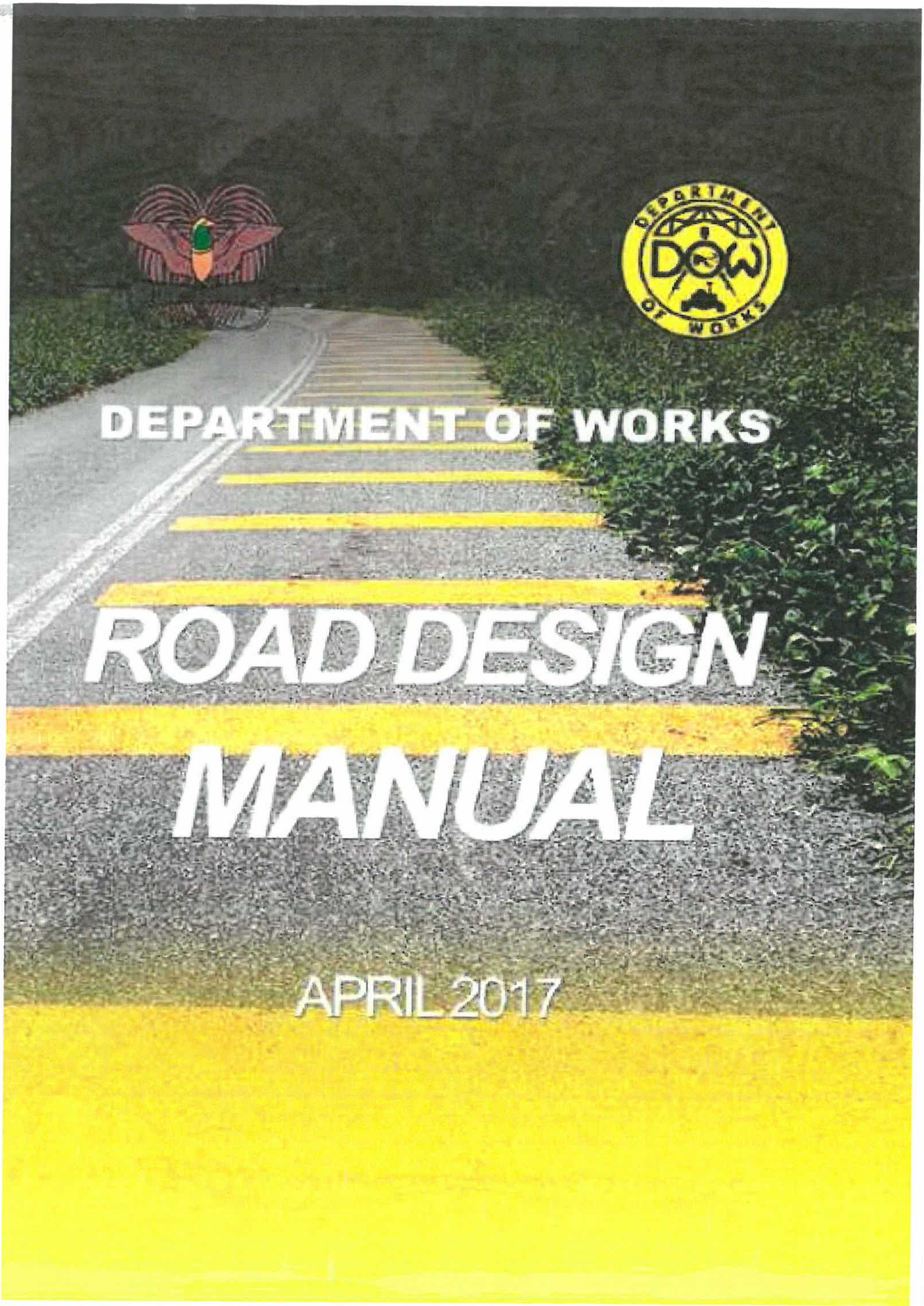

DEPARTMENT OF WORKS

ROAD DESIGN MANUAL

APRIL 2017

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Foreword

Department of Works (DoW) is a technical government department, responsible for management, design, construction and implementation of National Road Network (NRN) infrastructure developments within Papua New Guinea. The department is also responsible for developing and revising all its design standards for all Roads and Bridges engineering infrastructures including Road and Bridge Works Specification for construction as well as building standards developments respectively.

Road Design Manual was first developed and printed in April 1985 as a DoW internal design document for design purposes. The design manual was reviewed in 1994 and approved by the Transport Department in 1995 and issued for use as a design standard rural roads and sub-divisional roads. Urban road design standards and guidelines were not included in the design manual and therefore the department adopted Queensland Government Transport and Main Roads urban road design manuals for urban road designs in Papua New Guinea. Since then the road design manual was used as design standard throughout the country.

DoW has recently revised and updated the existing road design manual, incorporating all design options and best practices from Austroads Design Manuals/Guides for the new Department of Works Road Design Manual, April 2017. The Department gratefully acknowledges Austroads for permitting the use of their design manuals/guidelines in this document and deviations have been made to suit local Papua New Guinea conditions. The Road Design Manual April 2017 is an important part of Department's continuous development drive to achieve its long term objectives of standard practices and compliances in implementing the road and bridge development projects.

Proposed future amendments for consideration on the Road Design Manual should be forwarded to First Assistant Secretary (Design Services Division), Department of Works, P. O. Box 1108, Boroko. National Capital District. Port Moresby. Papua New Guinea. The next review and revising of this document will be in the next 5 years.

Thank you all for your contribution.

DAVID WEREH
Secretary
Department of Works
PNG

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Acknowledgement

The Department of Works (DoW), Papua New Guinea (PNG) gratefully acknowledges the important contributions provided by Cardno (PNG) Ltd in reviewing and revising the Road Design Manual. Gratitude is also provided to Austroads for their contributions and guidance in completing the review.

Document History

Issue/ Rev No.	Description of Revision	Prepared by	Authorised by	Date
0	Original version	Department of Works, PNG	Department of Works, PNG	1985
1	-	Department of Works, PNG	Department of Works, PNG	June 1994
2	Review and revision of all sections	Cardno (PNG) Ltd	Department of Works, PNG	April 2017

1 Introduction

The new PNG Road Design Manual (2016) is a major upgrade of road and pavement design previously undertaken in accordance with the now largely superseded PNG Road Design Manual (1996).

This new Manual incorporates the latest Australian and international approach to road and pavement design as detailed in:

- Austroads Guide to Road Design
- Austroads Guide to Pavement Technology

The two Austroads series of guides have been adopted as the basis of the new PNG Road Design Manual.

The PNG Government has formal approval of Austroads to use the Guides and access was provided to Word versions of the relevant documents to enable them to be amended to suit PNG conditions and regulations.

The generosity of Austroads in providing access to their Guides is acknowledged and greatly appreciated as PNG has a long history of using relevant Australian Standards, Guides and Manuals in road design and related areas.

Reference should continue to be made to such documents (for example, AS 1742 Manual of Uniform Traffic Control Devices) where issues of road or pavement design are not specifically covered in this Manual or other PNG Manuals or Guides.

The Manual excludes several elements of road design:

- The Austroads Guide to Road Design Part 5 Drainage (including pavement drainage) has not specifically been incorporated into this Manual as a new PNG Drainage Manual is to be created. The Austroads Drainage Guides may continue to be used for reference until superseded by a PNG specific manual.
- The Manual does not include the design of local roads in urban areas. (residential, commercial, industrial) which are required in new or redeveloped areas of urban estates or suburbs. For design of these types of roads the designer should refer to the development/approving authority for the design criteria to be adopted.

The Manual is intended to be upgraded as design criteria change or are amended based on further local knowledge.

Any omissions, contradictions or inadvertent errors should be notified to:

Most terminology used in Austroads has been retained. However, where terms such as "bus" has been retained/used it should be taken to include PMV's and therefore a Bus Stop also refers to a PMV stop.

Several sections of the Manual (design of unsealed low speed rural roads and unsealed road pavement design) have been based on old design information. They should continue to be used in their current form until new guidelines are introduced.

The publication of this Manual and its use by designers does not relieve the user of responsibility for their designs which must be based on their own skill, judgement and knowledge of the local conditions.

2 Introduction to Road Design

2.1 Scope of the Manual to Road Design

2.1.1 Status

The Road Design Manual is one of a set of comprehensive PNG Design developed to provide a primary national reference for the development of safe, economical and efficient road design solutions. The Manual was developed by largely adopting relevant sections of the Austroads Guidelines for Road Design. The Guidelines are comprised of 15 parts, practitioners are advised to visit the Austroads website (https://www.onlinepublications.austroads.com.au) to view the latest versions of the relevant parts as well as other Guide series available.

2.1.2 Purpose

Austroads Guidelines seek to capture the contemporary practice of the various member organisations in road design.

Although local conditions and circumstances may sometimes require unique or innovative approaches to design, the bulk of works can be well accommodated by the approach outlined in the *Guide to Road Design*. However, it is recognised that member organisations may develop and publish supplementary guidelines and manuals to cover specific design situations. PNG has now created its own Road Design Manual which incorporates local practices and local references.

The PNG Road Design Manual will take precedence over Austroads Guides.

2.1.3 Application

The PNG Road Design Manual is aimed primarily at practitioners with responsibilities for the design of roads. The documentation is presented in the form of a number of parts covering specific aspects of the design process, with each part providing guidelines underpinned by commentaries and resource materials. The Manual deals primarily with the geometric elements of the road and roadside considerations. The existing and/or new PNG Drainage Design Manual should be consulted for drainage design.

It is expected that, for the experienced engineer or practitioner, the guidelines will provide the necessary key information. Less experienced designers or students will find the commentaries and resource documents particularly useful.

The Manual addresses design practice across the range of road categories, from major roads to local roads, but does not address urban local-access roads. It also recognises that the design of roads should be based on the capabilities and behaviour of all road users, including pedestrians and cyclists, and on the performance and characteristics of vehicles. The different traffic mix and volumes, access requirements, functions and abutting developments that are typical of local roads create a different set of challenges that must be addressed in their own right. Additional guidance on the specific requirements of low trafficked roads is available in AASHTO (2001) and Giummarra (2001).

2.1.4 Parts of the Austroads Guide to Road Design

The Austroads Guide to Road Design has 15 parts:

Part 1: Introduction to Road Design has been incorporated as Section 2 of this Manual. It provides an overview of road design that briefly describes the context of the road design process, the philosophy and principles on which good design is based, and the design considerations that may be required. The use of each part, the relationships between them and their relationships to the design process are also covered. An introduction to the Safe System approach to road design has been included to alert road designers to the importance of applying such principles in every project regardless of size or complexity. Section 2 is particularly useful to designers who are new to road design or are using the Road Design Manual for the first time.

Part 2: Design Considerations has been incorporated as Section 3 of this Manual. It provides guidance on the range of influences, information, data, criteria, and other considerations that may have to be considered in developing a road project. These design considerations must be determined at an early stage of the design process, to properly define the task the road is to perform and the relevant constraints. Section 3 describes the basis of the guidelines and the context in which they should be applied. It also provides links to other Austroads Guides and resources that give further guidance on design inputs.

Part 3: Geometric Design has been incorporated as Section 4 of this Manual. It provides the detailed information necessary to enable designers to develop coordinated road alignments, as well as adequate cross-sections, sight distances and other features that allow safe operation of the design traffic at the required speed.

Part 4: Intersections and Crossings – General has been partially incorporated as Section 5 of this Manual. It contains guidance that provides road designers and other practitioners with information that is common to the geometric design of all at-grade intersections. The Manual needs to be used in conjunction with Austroads Guides Part 4, Part 4A, Part 4B and Part 4C which are the other parts of the *Guide to Road Design* that relate to the design of intersections.

Part 4A: Unsignalised and Signalised Intersections provides road practitioners with guidance on the detailed geometric design of all at-grade intersections (excluding roundabouts). The Guide needs to be used in conjunction with Part 4, Part 4B and Part 4C which are the other parts of the *Guide to Road Design* that relate to the design of intersections.

Part 4B: Roundabouts provides road practitioners with guidance on the detailed geometric design of roundabouts. It covers design principles, procedures, and provides guidelines for practitioners to develop safe and efficient roundabout layouts. The Guide needs to be used in conjunction with Part 4, Part 4A and Part 4C of the *Guide to Road Design.*

Part 4C: Interchanges provides road designers and other practitioners with guidance on the geometric design of freeway and motorway interchanges. It covers design considerations, design process, forms of interchange, and provides some information on structures. The Guide needs to be used in conjunction with Part 4, Part 4A and Part 4B.

Part 5: Drainage – General and Hydrology Considerations should be used as a reference document only as the PNG Drainage Design Manual takes precedence. It provides road designers and other practitioners with guidance on the design of drainage systems. The Guide provides information on the elements that need to be considered in the design of a drainage system. Guidance is provided on the safety aspects of stormwater flows, environmental considerations and water sensitive treatments within a drainage system. The Guide needs to be used in conjunction with Part 5A and Part 5B which are the other two parts of the *Guide to Road Design* that relate to drainage design.

Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface provides road designers and other practitioners with guidance on the design of the collection and discharge of water from road surfaces, pit and pipe systems, basins and subsurface drains. The Guide needs to be used in conjunction with Part 5 and Part 5B which are the other two parts of the *Guide to Road Design* that relate to drainage design. The Guide contains information on major/minor drainage systems and the collection and discharge of road surface flows to support the operation and management of the road network.

Part 5B: Open Channels, Culverts and Floodways contains guidance on the design of open channels, culverts and floodways to support the operation and management of the road network. The Guide needs to be used in conjunction with Part 5 and Part 5A which are the other two parts of the *Guide to Road Design* that relate to drainage design. The Guide provides guidance on the fundamentals of open channel, culvert and floodway flows, and includes methods to undertake the design of these drainage facilities.

Part 6: Roadside Design, Safety and Barriers has been partially incorporated into this manual. It provides an introduction to roadside design and in particular guidance on roadside safety and the selection and use of road safety barrier systems. It includes information to enable designers to understand the principles that lead to the design of safe roads, identify hazards, undertake a risk assessment process of roadside hazards, establish the need for treatment of hazards and determine the most appropriate treatment to mitigate hazards. The Guide needs to be used in conjunction with Part 6A and Part 6B which are the other two parts of the *Guide to Road Design* that relate to roadside design.

Part 6A: Pedestrian and Cyclists Paths provides guidance for road designers and other practitioners on the design of safe pedestrian and cyclists' paths. It focuses on the geometric design of paths and its related facilities. The Guide needs to be used in conjunction with Part 6 and Part 6B which are the other two parts of the *Guide to Road Design* that relate to roadside design.

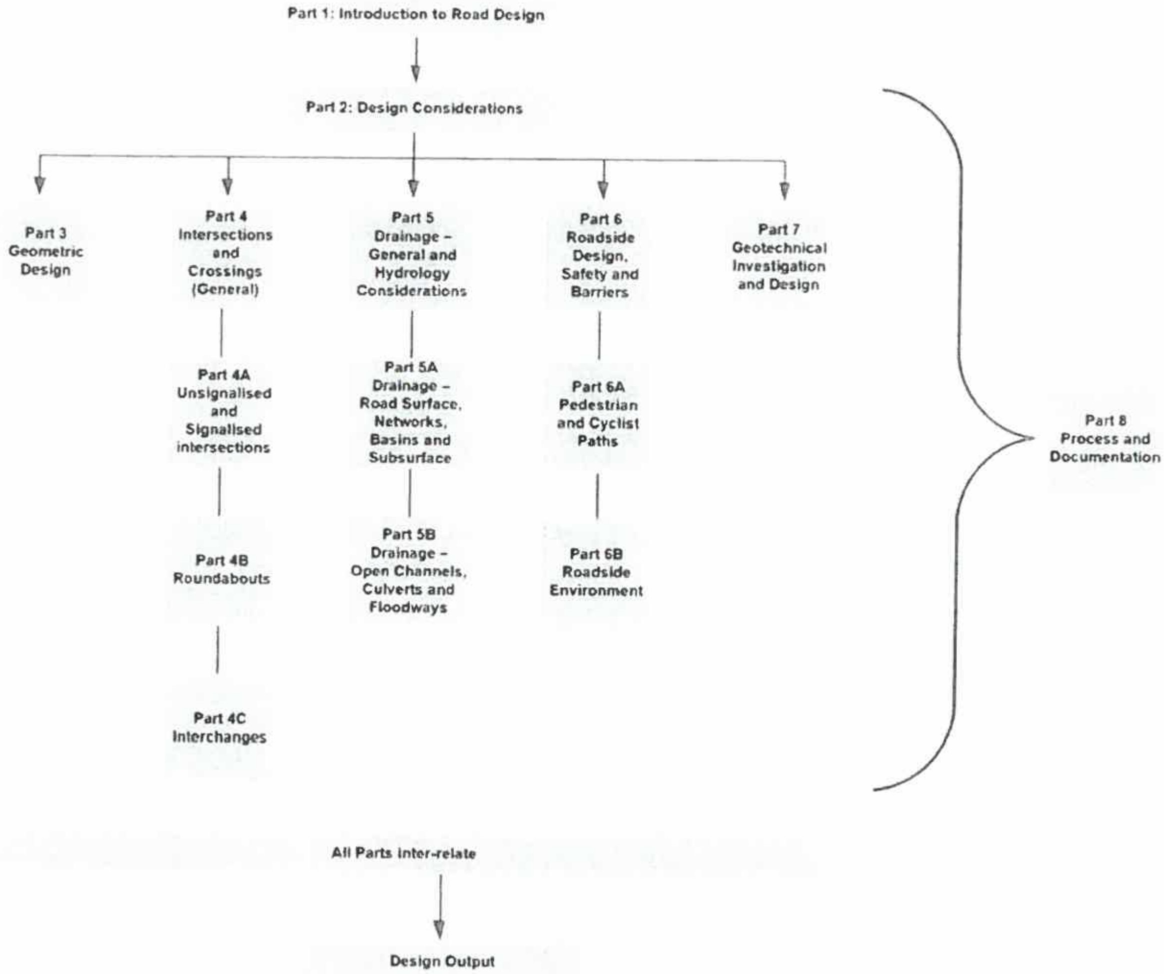
Part 6B: Roadside Environment describes and discusses design objectives, principles and considerations for a diverse range of roadside functions, features and facilities relating to environmental aspects, roadside amenity and roadside infrastructure. It provides guidance for road designers and other practitioners on the types of features and facilities that may need to be accommodated within a roadside. The Guide needs to be used in conjunction with Part 6 and Part 6A which are the other two parts of the *Guide to Road Design* that relate to roadside design.

Part 7: Geotechnical Investigation and Design describes the geotechnical information required for road design and provides advice on how the information should be used. Aspects addressed include geotechnical investigations, earthworks design, construction materials and environmental issues.

Part 8: Process and Documentation is the means by which designs are produced in an efficient manner, and ensures that all factors that should influence the desired outcome are taken into account. Documentation enables the decision-making process to be retraced should this be necessary, and is the basis for quality management. This part describes requirements for quality of documentation and presentation.

Road designers should have a sound understanding of all parts of the Guide and the relationships between them. These relationships are illustrated by the flowchart in Figure 2.1.

Figure 2.1: Flow chart of Guide to Road Design



It is important that practitioners, particularly those new to road design, refer not only to the parts themselves, but also to the commentaries and resource materials that support them.

It is also important that road designers understand the relationship between the Manual and the Guide to Road Design and the other Austroads Guides, including Traffic Management, Road Safety, Road Transport Planning, Project Delivery, Project Evaluation, Pavement Technology and Bridge Technology. A comprehensive listing of Austroads publications is available from the Austroads web site www.onlinepublications.austroads.com.au.

2.2 Context of the Road Design Process

The philosophy and principles set out in the Manual supported by the suite of Austroads Guides underpin the creation of a successful, site-specific design solution.

Designers choose the features of the road and dimensions of its elements based on technical guides, calculations, and their own experience and judgement. However, a very important principle in choosing these dimensions is to avoid combinations of minimum or limiting values of different design elements as this has the potential to quickly reduce the inherent safety of the overall solution.

The practice of good road design, especially under constraints, involves judgement as well as calculation. It involves compromises between conflicting goals. Experience assists the designer to arrive at an appropriate balance that cannot be met by a system of mathematical rules alone. The Manual and the Austroads Guides give ranges of values within which the designer has reasonable flexibility to produce an appropriate design solution for a specific problem, whilst retaining a reasonable overall level of uniformity.

Some key areas that provide a context for the road design process are discussed in this section.

2.2.1 Road Planning

Projects involving road design may range from minor improvements to small sections of existing roads, to restoration projects that improve road cross-sections while retaining existing alignments, or to major greenfields design of arterial roads as part of significant regional or inter-regional development. At one extreme, the work may have no significant environmental or social impacts and involve minimal interaction with other agencies. At the other, the road agency may be but one player in a broad or inter-government activity. The inter-relationship between land use and transport planning is an important consideration in any planning scheme – they should be complementary. The upgrade of existing roads or design of new road infrastructure should therefore be in accordance with local planning objectives as well as with the transportation and traffic management strategies relevant to the particular road corridor or link. There should be consideration of national, provincial and local road safety strategies and the interests of all road user groups.

The location and function of a road within the built and natural environment will affect the objectives and strategies to be adopted and will influence all aspects of the design process. Information on these aspects can be found in the Austroads *Guide to Traffic Management* and the *Guide to Transport Planning*.

Familiarity with road design principles is important in road planning activities, especially during concept development, for the purposes of assessing options in terms of traffic service, road safety, environmental impact and other important considerations. Consideration should be given to undertaking road safety audits at various points throughout the design and implementation processes for a project (Commentary 1).

2.2.2 Project Purpose

The design of roads may also be influenced by the investment strategy for the road network or particular project, as well as the costs and issues associated with options or parts of options. The design process is often iterative as the effects, costs and benefits of various options are explored. For example, the geotechnical properties of soil, the nature of a river crossing or the level of interaction between road user groups may all influence the design. It is therefore essential that effective communication take place between persons responsible for delivering a project (e.g. project manager, project team members and client) and the road designer. A road designer should be clear on the project objectives, for example is the primary focus about pedestrian safety, traffic amenity for heavy vehicles or seeking to remove conflicting manoeuvres at an intersection?

Final approval of a project may rest with a person or persons removed from the design process. The rationale for the preferred design should be clearly documented, including the scope, cost and consequences of viable alternative solutions. This could include the degree of take-up or adoption of Safe System elements incorporated into the design, and the manner of addressing public concerns which may have been the basis for the project conception.

2.2.3 Road Safety and Road Design

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 has been reiterated in the current strategy documents for each country (prepared by the Australian Transport Council 2011 and Ministry of Transport 2010).

The Safe System approach in Australia and New Zealand has four pillars that underpin the above principles.

Safe roads – that are predictable and forgiving of mistakes. They are self-explaining in that their design encourages safe travel speeds.

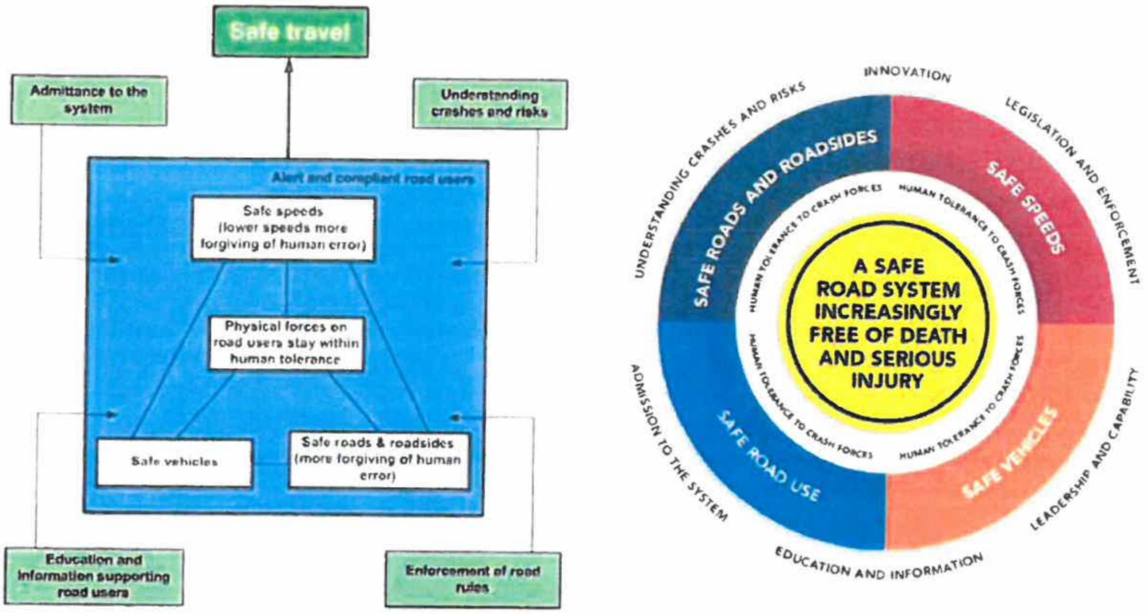
Safe speeds – travel speeds suit the function and level of safety of the road. People understand and comply with the speed limits and drive to the conditions.

Safe vehicles – that prevent crashes and protect road users, including pedestrians and cyclists, in the event of a crash.

Safe road use – road users that are skilled and competent, alert and unimpaired. They comply with road rules, take steps to improve safety, and demand and expect safety improvements (Ministry of Transport 2010).

There are conceptual representations of the Safe System approach, as illustrated in Figure 2.2.

Figure 2.2: Conceptual representations of the Safe System framework (Australia and New Zealand)



Source: Australian Transport Council (2009) and Ministry of Transport (2010).

Research and guidance about the Safe System principles is available in the Austroads *Guide to Road Safety*, from the Austroads website (www.austroads.com.au) and local jurisdictions.

2.3 Road Design Philosophy and Principles

2.3.1 Introduction

Design is the process of originating and developing a plan for an aesthetic and/or functional object, requiring research, thought, modelling, iterative adjustment and redesign.

In road design, the end result of the design process is presented on drawings and in specifications to allow the road to be constructed. The philosophy and principles set out in these documents underpin the creation of a successful design. Every road project is a unique undertaking, and can never be precisely repeated. There are no 'off the shelf' solutions that will fully address all situations encountered, and the rigid and unthinking application of charts, tables and figures is unlikely to lead to a successful design outcome. Good design requires creative input based on experience and a sound understanding of the principles.

The geometric design of a road is the selection of its features and dimensions (e.g. curvature, lane widths). The basic aim of geometric road design is to optimise the operational efficiency and safety within given constraints (e.g. financial, environmental, social), taking into account the volume, type and distribution of the traffic expected to use the road.

The main geometric elements that may impact on efficiency and safety are:

- cross-section (e.g. widths of lanes, shoulders, medians and verges)
- horizontal curves
- vertical curves and gradients
- intersections
- merge/diverge areas.

Designers choose the features of the road and dimensions of its elements based on technical guides, calculations, and their own experience and judgement. While these elements may be considered in sequence it is essential that designers understand the effects (particularly on safety) of combining limiting values of different design elements under different circumstances.

In situations where road designs are not constrained by topography, natural or man-made features, environmental considerations, or budgetary requirements, the most suitable detailing of a design should not be difficult. However, many situations arise in which constraints apply and, in such cases, the experience and judgement of the designer, together with relevant research and literature, play a significant role in developing the most appropriate outcomes.

2.3.2 Road Design Guidelines

Road design guidelines are developed with consideration of the need to achieve a balance between the sometimes competing demands of operational requirements, safety, cost, and social and environmental impacts.

Design texts have historically used the concepts of *absolute* and *desirable* limiting values for each of the different design elements. The desirable limits identified where good practice should lie when allowed by the prevailing constraints, while the absolute limits defined design values that were outside of the desirable but were permissible subject to the professional judgement of the designer. Selection of design values outside the absolute limits was not considered an option.

This Manual (and the Austroads *Guide to Road Design)* is intended to provide designers with a framework that promotes efficiency in design and construction, economy, and both consistency and safety for road users. However, the Manual moves away from rigid design limits as the basis for achieving these goals, and promotes the concept of 'context-sensitive design'.

The intention is to allow designers the flexibility to exercise their critical, engineering judgement, for example, by choosing design values outside of normally accepted limits when prevailing constraints require, provided that they recognise their responsibility to be able to produce strong, defensible evidence in support of that judgement (Commentary 2).

2.3.2.1 Legal Liability and Guidelines

Legal claims against road agencies have steadily risen in recent years, and court decisions have cast doubts on general immunities previously enjoyed by road agencies. Adherence to manuals and guidelines is not, of itself, necessarily a sufficient defence against claims of negligence that may arise. Likewise, deviation from established manuals and guidelines does not necessarily justify a claim for negligence. It is essential that the rationale for all decisions be suitably documented so that any claims that might arise may be suitably defended (Commentary 3).

2.3.2.2 Application of Guidelines

Design guidelines usually provide a range of acceptable values for each parameter (the 'design domain' discussed in 2.3.2.3), from which designers choose the most appropriate value. Construction cost considerations sometimes lead to designers selecting recommended minimum values that may or may not be appropriate for the particular circumstances. The use of a minimum value for a single parameter may be acceptable, but the use of minimum values for several inter-related parameters is generally not recommended, as the resulting design might be hazardous. Experience and judgement must be used in selecting the correct balance of values (**Error! Reference source not found.**).

This Section of the Manual provides information and background material to help the designer choose appropriate characteristics for the elements of the design. Information presented in the Manual is supplemented by additional material contained in the Commentary and References sections. However, the number of combinations of elements is large and can apply to a range of circumstances from local rural roads to major urban motorways. Consequently, this Manual cannot take account of all design situations and specific site circumstances. However, it does provide guidance to the designer in reaching appropriate decisions for each set of circumstances.

Design values that are not within the limits recommended by the relevant sections of the Manual do not necessarily result in unacceptable designs, and values that are within those limits do not necessarily guarantee an acceptable or safe design. In assessing the quality of a design, it is not appropriate simply to consider a checklist of recommended limits. The design has to be developed with sound, professional judgement, and guidelines assist the designer in making those judgements.

In considering the results of any design process, it is important to step back and apply a reality check. The designer should be satisfied that the finished product is likely to best meet the various objectives of the project. Despite the great advances in analytical methods, good design has a healthy dose of art mixed in with the science.

2.3.2.3 Context-sensitive Design

Context-sensitive design is a concept that emphasises the development of an appropriate and cost-effective design for the particular context that applies, rather than providing a design that simply meets specified limiting values. (Contrasting examples of 'context' in this sense are 'no significant constraints on design choices' and 'design tightly constrained by steep topography'.) Context-sensitive design can be implemented through the related 'design domain' concept, which requires designers to select a value for each design element from a recommended range of values, and to consider the extent to which the selected set of values satisfies the objectives defined for the design.

For each element of a design, the design domain is a range of suitable values, the acceptability of which can be justified in an engineering sense (based on test data, sound reasoning, etc.) and which therefore is defensible if the need arises (e.g. legal liability). The design domain approach formalises and clarifies the reasoning behind the choice of values for design parameters including the extent of trade-offs. It also highlights the inter-relationships between the various design elements and encourages a holistic approach to design. Practitioners should consider the Safe System approach outlined in Section 2.2.3, and in other Austroads Guides when applying the design domain concept.

The lower end of the design domain typically is a range of values that are considered undesirable selections under ideal conditions, but which could be justified and defended on engineering grounds in certain circumstances. The use of values within such a lower range may be limited to particular characteristics (e.g. road shoulder width) for which research has demonstrated that the adoption of those lower values will not result in death or serious injury to road users. While this may be the least preferred design solution, it may be necessary in certain circumstances, particularly for existing roads in constrained situations.

The design domain concept is described further in Section 3: *Design Considerations of this Manual.*

2.3.3 Geometric Consistency

2.3.3.1 General

Many characteristics of a road link are given (e.g. topography, traffic volume and composition), but the geometric form is largely under the control of the designer. The provision of consistent geometric design along roads, particularly roads in rural environments, is an important aspect of road safety. There should certainly be 'no surprises' for drivers, such as an isolated sharp curve in a section of road where all other curves have large radii.

Different road classifications are used to indicate the type of service provided. 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 classification, in each terrain type, regardless of location (Transport Association of Canada 1999).

This approach leads to the concept of the 'self-explaining road' (Fuller & Santos 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 nature of the road.

Design consistency can be addressed in three areas:

- cross-section
- operating speed
- driver workload.

It is also important that consistency be achieved in the type of intersections selected and their layout along a route so that driver expectations are met. For example, all other things being equal, the lack of a right-turn lane at one particular intersection may not be anticipated by some drivers, resulting in rear-end crashes.

2.3.3.2 *Cross-section*

Roads of the same classification, in similar terrain, should have similar cross-sections. It is particularly important that the cross-section be consistent along any one route, so that drivers are not faced with unexpected changes. Also, the operating speed of the road can be affected by cross-section elements, and differential speeds are known to be the cause of many crashes.

Where terrain on a route changes and it is considered necessary to reduce cross-section dimensions for financial or environmental reasons, the safety implications should be assessed.

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 of an existing road without a corresponding improvement in the alignment can result in drivers incorrectly assuming that the road has been reconstructed to provide for higher speeds. Speeds might then be excessive for the alignment conditions, with potentially hazardous results.

There will be cases where changes in cross-section dimensions along a route are unavoidable (e.g. where a four-lane divided road becomes a two-lane, two-way road). In these cases, the designer should manage the situation by providing a well-designed transition between the two cross-sections with appropriate tapers and signing.

2.3.3.3 *Design Speed*

The design of a road must be appropriate for the operating speeds of vehicles using the road, and the desired or expected speed should be determined in the early stages of the project. The design speed selected for the road environment should consider the principles of the Safe System approach. It should match the road environment to ensure the safety of all road users.

The selected design speed will affect virtually every aspect of the design – horizontal and vertical curvature, lane width, superelevation, roadside clearances and barriers. Every effort should be made to design the road to facilitate, and implicitly encourage, a consistent operating speed (Commentary 5).

Designers can therefore enhance the safety of a road by producing a design that encourages a consistent speed of operation. There are some situations, however, where a change in topography requires substantial reduction in the design speed. In these circumstances it is preferable for the horizontal curve radii to be gradually reduced through a series of curves with appropriate warning signs in place.

Road networks that do not provide an appropriate road hierarchy may lead to inconsistent speeds of operation. 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.

2.3.3.4 *Driver Workload*

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 alertness) 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 driver's brain activity level is too high (e.g. stress, information overload, emotional situations) they 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 higher collision rates. These increases can be caused by:

- the nature of the feature (e.g. an intersection or lane drop is more critical than a change in shoulder width)
- 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
- 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).

Situations where most or all of these factors are encountered simultaneously should be avoided (Transport Association of Canada 1999). Designers' awareness of such factors will enable them to provide the driver with a consistent level of concentration that is neither too low nor too high, but with adequate variation to maintain alertness levels.

2.4 Design Considerations

Design considerations include all the things that are important from an engineering and community perspective that impact on the outcome of the design. They also include consideration of economic, social, environmental and safety matters and issues with respect to the development of a road project.

At the highest level, the inputs will relate to project objectives that may be influenced by planning schemes, budgets, and government policies concerning transportation, sustainable development and the environment. At a project level the inputs may relate to detailed engineering requirements such as geotechnical information, availability of materials or the occupational health and safety of road workers. Section 3 of this Manual provides information on the range of considerations that should be taken into account in road design and includes a detailed list of factors that influence design.

Each part of the Manual and the supporting Austroads *Guide to Road Design* plays an important role in enabling a holistic and integrated approach to the design of road projects. A successful road design results from the coordination of all inputs that affect a project and all elements that combine to form the road. Designers should therefore have a sound understanding of all parts of the Manual and the supporting Austroads *Guide to Road Design* and how they relate to each other.

2.5 Design Process

2.5.1 General

Planning and design are each iterative processes, requiring assumptions to be made using the available data. As the project proceeds and more data become available, the validity of the assumptions needs to be checked and necessary modifications made. Essential to the planning process are road designs that are accurate enough to demonstrate the feasibility of various options and to confidently define right-of-way requirements.

Scoping, including the road planning process, is the first step in project planning and occurs within the context of road network or corridor strategies.

Figure 2.3 illustrates a typical road planning and design process. It shows the desirable flow of activities throughout the process but at any given time, any activity may be in some stage of review.

A risk assessment approach should be taken to ensure that appropriate cost estimates are made, with proper allowance for unknowns identified in the risk analysis. Guidance on risk assessment methods can be found in the Austroads *Guide to Project Evaluation* and in ISO 31000: 2009 *Risk Management: Principles and Guidelines* (Standards Australia 2009).

2.5.2 Process Elements

Following from the road network strategy (Figure 2.3) and various investment strategies, specific implementation plans must be developed. The complexity of the plans will depend on the location and scale of projects that can range from simple rural road developments to complex urban motorway projects. The level of complexity will determine the detail of the processes required.

The essential elements of the process are (refer to Figure 2.3):

- land use/transport planning, including environmental impact assessment
- public consultation
- scoping and option development
- project planning and preliminary design
- detailed design.

For restoration projects, in which cross-section improvements are made on an existing road without altering its horizontal or vertical alignment, considerably less effort is likely to be involved in the first two of these elements than would be the case for a greenfields project.

2.6 Land Use / Transport / Environmental Planning

A comprehensive treatment of the land use/transport planning processes and assessment of environmental impact is beyond the scope of this section and Manual.

Designers should be aware of the planning process that preceded the design, and ensure that relevant information is taken into account in the preparation of the design. Further guidance is available in the Austroads *Guide to Transport Planning*.

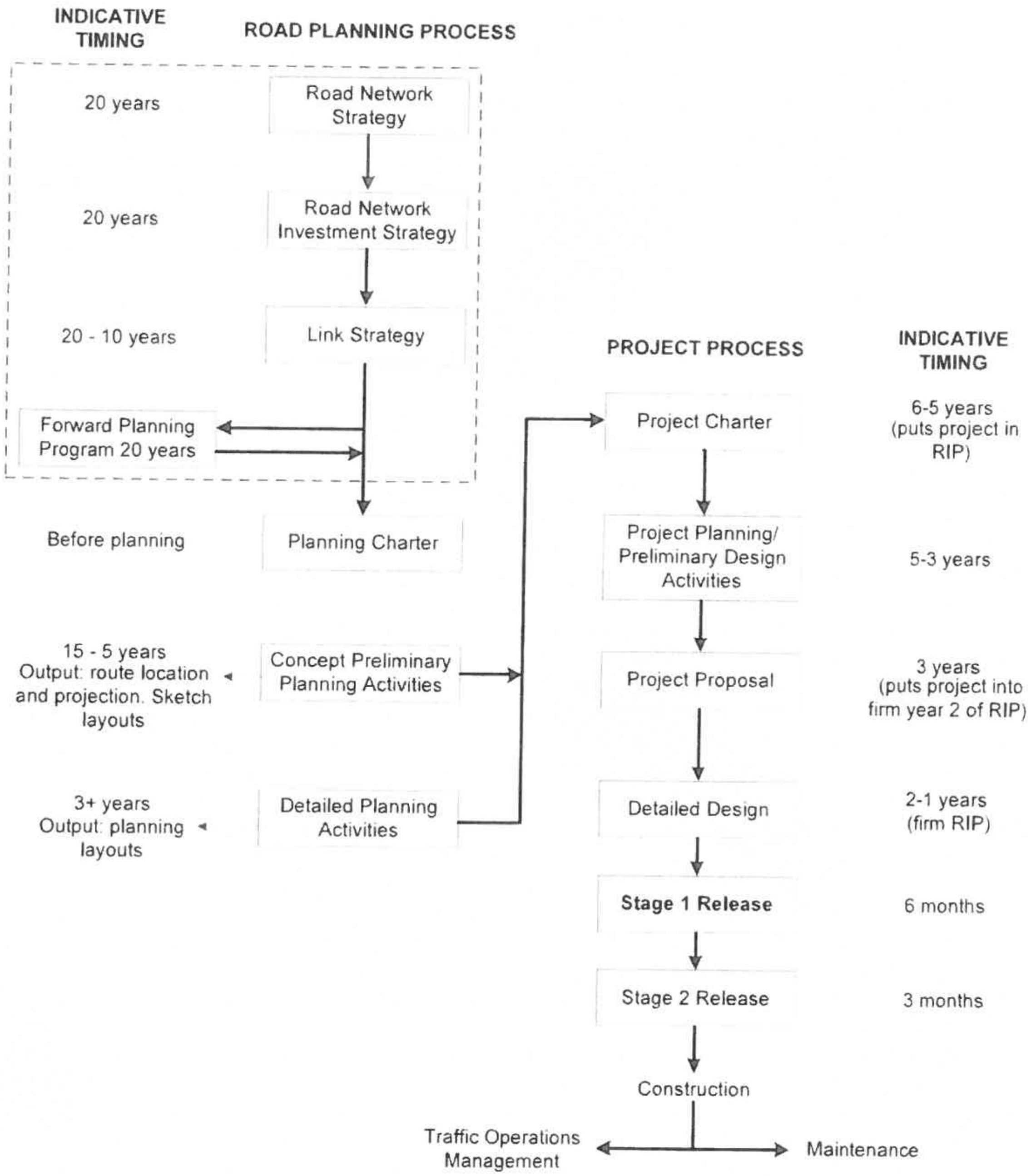
2.7 Public Consultation

The planning process is community driven and consultation with stakeholders is important at every stage. Stakeholders include:

- affected and adjoining landowners
- relevant statutory authorities (e.g. environmental agencies, provincial government, national government departments, utility companies)
- industry bodies
- public transport operators
- road users.

The involvement of stakeholders will ensure that all issues and needs are considered and should lead to outcomes that have a high degree of support and ownership. Initially it is important to start with a 'clean sheet' and develop proposals for the project as the consultation process unfolds. This is particularly applicable to route location proposals and greenfield sites. The consultation must be recognised and accepted by stakeholders as an open process where they can influence outcomes. Following initial public consultation, alternative proposals can be developed and assessed as the process continues. Further guidance can be found in the Austroads *Guide to Road Transport Planning*.

Figure 2.3: Typical road planning and design process



Source: Department of Main Roads (2005)

Refer to Commentary 6.

Commentary 1

First developed in the United Kingdom, Australia and New Zealand, this process has a proven potential to improve the safety of both proposed and existing facilities.

A road safety audit has been defined as 'a formal examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project's crash potential and safety performance (Austroads 2009).

The objectives of a road safety audit are to identify potential safety problems for road users and others affected by a road project, and to ensure that measures to eliminate or reduce the problems are considered. It can work in two ways – by removing elements with high collision potential at the planning or design stages, or by mitigating the effects of remaining or existing problems by the inclusion of collision reduction features, such as traffic control devices.

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 the safety of a design can be identified early and can more easily be incorporated into the work.

Guidelines on the conduct of road safety audits are available in Austroads (2009).

Commentary 2

The change in approach is well explained in Transport Association of Canada (1999). It has occurred in part because of the difficulty of applying the concept of 'standards', as they are thought of in other fields, to a process that necessarily required the designer to exercise professional judgement and expertise in addressing road design. The transition has also come about because of the contribution of road safety research, which is bringing new data to bear on the road design task. The impact of the Safe System approach to road safety must be considered during the road design process. Practitioners should acknowledge the importance of the Safe System approach and should incorporate it in all aspects of road design.

This Manual provides designers with advice about the use of new data, where these are available. This is intended to enhance the designer's ability to explicitly assess the safety impacts of design alternatives in the context of the impacts that such changes may have on other aspects of road performance including operations, the environment, and the economics of construction.

The guidelines and design domains provided in the Manual are based on prevailing and predicted vehicle dimensions and performance, driver behaviour and performance, and current technologies. As knowledge in these fields evolves, it is expected that the resulting guidelines will be revised and updated. Changes in the design domains, or differences between these and previous standards, do not imply that roads designed on the basis of former standards are necessarily inadequate. Rather, the new design framework and approach can be expected to generate designs for new facilities and rehabilitation and reconstruction of existing facilities that more appropriately reflect evolving knowledge.

It should be noted that gradual adoption of design dimensions based, for example, on collision experience, may not have the same margins of safety under most operating conditions as traditional standards based on laws of physics. However, they should be more realistic, and may result in road designs that are less costly to construct.

The Manual places a greater emphasis on the role of the designer in the design process. It requires more explicit analysis of alternatives, and where possible suggests a basis on which to carry out such analysis. It provides guidance to road designers about the paradigm shift associated with adopting Safe System principles, how road designs need to take into account error by road users and reduce the risk of death and serious injury that can result. It places greater demands on the designer in terms of exercising skills, knowledge and professional judgement and emphasises the responsibility of the designer to properly and fully inform those responsible for policies, which affect all aspects of cost-effective road design, of the potential consequences of their decisions.

Commentary 3

Tort claims against road agencies have steadily risen in recent years. (Tort is a legal term that refers to a civil wrong that has been committed. Negligence is a term used to refer to a classification of tort in which the injury is not intentional, but where there was a failure to use due care in the treatment of others compared to what a 'reasonable man' would have done. Liability is the responsibility to make restitution to the damaged party through an action or payment determined by a court.)

Although these claims have been substantially relating to physical activities or road conditions, tort liability is potentially an issue for road designers.

Austroads or road agency Manuals or guidelines, regulations, Australian Standards, and research reports may be used in tort cases to educate the jury about the accepted level of practice for design. Expert witnesses may also be used, who in turn rely on written text to explain the accepted design practices to the court or a jury.

This does not mean that adherence to accepted practices, Manuals and guidelines automatically establishes that reasonable care was exercised. Conversely, deviation from the Manual or guidelines does not automatically establish negligence. The best defence for a designer is to present persuasive evidence that the guidelines were not applicable to the circumstances of the project, or that the guidelines could not reasonably be met. It is highly recommended that designers document the rationale for their decisions.

If the justification documented by a designer completely describes the physical and environmental factors that make the variance from guidelines necessary, it is likely that this will be legally persuasive that the correct procedures were followed and ultimately the appropriate decision was made. It is also helpful to have statements by other design experts who concur with the decision in the documentation.

As a result of concerns about litigation, designers may be tempted to be very conservative in their approaches to highway design, and avoid innovative and creative approaches to design problems. While it is important for designers to do their jobs thoroughly and carefully, avoiding unique solutions is not an answer. This may undermine design practice and limit growth in the profession. Designers need to remember that their skills, experience and judgement are valuable tools to be applied to solving design problems and that, with reliance on complete and sound documentation, tort liability concerns need not be an impediment to achieving good road design.

Commentary 4

The traditional approach to design techniques is described in Transport Association of Canada (1999). Traditionally, road design standards have provided the basic dimensions for road design practice. These 'standards' were not intended to be rigid, or applied uniformly in all cases. Different road agencies placed different emphases on quality of service, cost, environmental issues and road safety. Such differences were considered matters of policy, but it has been generally assumed that design merely had to meet standards and the results would be satisfactory. In most cases that has been a valid assumption, since traditional design standards based on laws of physics offer substantial margins of safety under most operating conditions.

As road agencies have come under increased fiscal pressure, designers have in turn come under increasing pressure to minimise capital costs by designing to 'minimum standards', with little regard for maintenance or user costs. In addition, increased awareness of environmental issues has led to pressure to use minimum values for geometric parameters to reduce impacts. Furthermore, designers have not usually been required to examine road safety issues related to geometric design, on the assumption that a road designed to meet minimum standards would be 'safe'. For a while this assumption was not unreasonable, in the absence of knowledge or data that would enable the designer to evaluate the road safety consequences of changing geometric design parameters.

However, this situation has been changing. More than ever, society is demanding value for money spent, and emerging knowledge in the field of road safety has raised awareness of the relationships between geometric design parameters and crash risk. These demands have been at odds with a design process based on the use of minimum standards and have resulted in the increasing use of processes aimed at providing checks and balances on design.

Central to this checks and balances approach has been the road safety audit. A road safety audit is a specialised activity that reviews the safety (or the crash potential) of a road design. Importantly, a road safety audit is not a design check confirming the application of accepted standards and guidelines, and it is not intended to question the capability of the road design team. Road designers should understand that a road safety audit seeks to highlight vulnerabilities in a design that may contribute to an increased risk to all road user groups and under a Safe System approach the focus of this is the risk of death and serious injury. The findings of a road safety audit are presented as a means to improve the safety of a road design, and this may be achieved in any number of ways, or indeed, it may be deemed the identified risk is acceptable given the constraints on the road designer.

Commentary 5

Multiple-vehicle crash rates and rates of fatal and serious injuries (FSI) are closely related to the differences in speed between vehicles. These differences can be caused by drivers travelling substantially slower or faster than the average speed of the traffic, or by individual drivers adjusting their speed to negotiate intersections, property entrances and changes in geometry. The greater and more frequent the speed differences, the greater the probability of a higher crash rate and fatal or serious injuries.

Single-vehicle crashes are also affected by speed. Larger reductions in design speed between successive geometric elements of a road produce higher single-vehicle crash and FSI rates. The same outcome results from increased absolute operating speeds on a given road.

Every effort should be made to obtain local traffic crash data.

Commentary 6

The diagram is sourced from Queensland's Department of Transport and Main Roads, which uses a 'roads implementation program' with a five-to-six-year lead-time. The diagram is indicative of the processes followed by most Australian jurisdictions, though details and terminology will vary. The designer should determine the practices in use by the relevant PNG agency or agencies in their own area.