YOUR NATIONAL TRANSPORT RESEARCH ORGANISATION

BRIDGE MANAGEMENT BEST PRACTICE GUIDE

4

PRODUCED BY

arrb YOUR NATIONAL TRANSPORT RESEARCH ORGANISATION

FUNDED BY

Australian Government

Department of Infrastructure, Transport, Regional Development and Communications

SUPPORTED BY

Australian Local Government Association

AUS SPEC

NATSPEC// Construction Information

IPWEA

INSTITUTE OF PUBLIC WORKS ENGINEERING AUSTRALASIA

The Hon Michael McCormack MP

Deputy Prime Minister and Minister for Infrastructure, Transport and Regional Development

Foreword

I am pleased to support the Australian Road Research Board's suite of Best Practice Guides for Local Governments, which seek to expand Local Governments' understanding and capacity to manage road infrastructure.

Australia's Local Governments manage a majority of the road network, meaning capacity building for our Local Government road managers is vitally important. These Best Practice Guides will support national and international best practice in procurement, design and management of materials for road construction and for essential structures such as bridges.

As our nation's National Transport Research Organisation, the Australian Road Research Board has an important role in road management research and advice.

Road safety is a key priority of mine as the Federal Member for Riverina in regional New South Wales and as Minister for Infrastructure, Transport and Regional Development, especially as rural and regional roads currently account for a disproportionate level of road casualties.

With a user-friendly focus, these Guides aim to provide technical information in a simple-to-understand format that will be readily available and accessible for all road managers.

The Australian Government provided the Australian Road Research Board with $2.6 million as part of the 2019-20 Federal Budget, in recognition of the importance of road management.

This funding enabled ARRB to deliver these Best Practice Guides and a Portable Assessment Device project to assess in-situ road infrastructure conditions across a variety of national Local Government and council infrastructure networks.

I applaud the collaboration between ARRB and Local Government in the development of these Best Practice Guides, which will be an important road management resource.

Australian Government
Department of Infrastructure, Transport, Cities and Regional Development

Acknowledgements

The authors greatly appreciate the contributions of the Local Government and other industry representatives who attended the Best Practice Guides workshops and provided initial feedback.

Acknowledgement is also given to the work of those involved in the development of this guide, including the following people:

Project Director

Nigel Powers

Project Coordinator

Lydia Thomas

Stakeholder Coordinator

Jaimi Harrison

Guide Authors

Darby Johannessen
Dr Neal Lake
Dr Tim Heldt
Robert Meiklejohn
Joshua Seskis

Technical Review

Kevin Fenwick

Editorial Review

Peter Milne

Creative Direction Review

Kyle Murphy
Sophie van Egmond

Summary

Throughout Australia councils are facing significant challenges in the provision of effective infrastructure that satisfies the demands of stakeholders at a cost affordable to their ratepayers. These challenges extend across all organisations responsible for the provision and management of infrastructure, each with their own unique challenges. At the core of this challenge is to provide effective levels of service that meet the needs of the community and industries reliant on this infrastructure, while managing the performance, costs and risks associated with the provision of this infrastructure. Bridges and other similar infrastructure are critical to the connectivity of the country and pose special risks to their owners and users.

Traditionally bridge management has been seen as an activity that is undertaken after a bridge has been designed and constructed with a focus on maintenance management. Often funding of maintenance activities has been dictated by historical funding levels without adequate consideration of the residual risk and/or maintenance debt associated with adopting a certain fixed funding level. In more recent times this approach has come under scrutiny as organisations try to optimise their sustaining capital and operating spend whilst meeting the required level of service.

Asset management is about building a better business not a better asset, it therefore takes a holistic approach to ensure the asset continues to support the business goals over the life of the asset ‘from cradle to grave’. Maintenance management is a critical component of asset management and is generally focused on what is needed to maintain or restore the asset to enable it to perform its intended function. Taking an asset management approach to bridge management has gained significant traction over the last 15 years to address the issues raised above. Taking this approach changes the focus from a maintenance management approach to a more holistic approach where:

- the cost, risk, performance trade-off comes to the forefront of decision making
- the management of the asset is focused on the whole-of-life where critical management factors necessary to optimise the whole-of-life spend are considered at the start of the process before design and construction
- an organisation understands and declares their appetite for risk and has appropriate policies and procedures in place to ensure that staff can make decisions in the context of their organisation, managing the cost, risk, performance trade-off. These are all dynamic factors. Procedures need to acknowledge this fact and accommodate provision for changes in operating context associated with ongoing decision-making.

Many documents exist that describe asset management and bridge maintenance management however there are few that consider the specifics of bridge asset management. This document is aimed at addressing this deficiency in the Local Government context. The document focuses on:

- explaining the basics of asset management in the context of bridges and other related infrastructure focusing on a whole-of-life management approach
- describing the bridge asset management process in the context of meeting legal obligations
- describing the basics and critical factors in the operation and maintenance of bridges including inspections, maintenance, disposal/repurposing and assessing heavy vehicle access to structures
- providing some templates and proformas, focusing on the procurement of relevant services in the bridge management context.

Much of the guide is structured to introduce the basics, examine critical issues, direct the reader to specialised references and provide guidance on procuring relevant services. It is focused on Local Government where most specialised services would be outsourced. The design and construction of bridges is discussed in the context of asset acquisition and general bridge management. Chapter placeholders have been allocated to maintain consistency among the various Local Government guides but detailed examination of these topics is not part of the scope.

Contents

Tables

Figures

1 Introduction

1.1 Background

Local Governments fulfil a vital role in the provision and management of Australia's road assets and are responsible for over 80% of the road network. The acquisition and management of these road assets is challenging, considering the significant and diverse assets Local Governments are responsible for while often being under pressure to obtain better value from their budgets.

The *Best Practice Guide for Bridge Management* is one of a suite of guides developed for Local Government with the aim of expanding the understanding and capacity to manage road infrastructure. The guides will assist Local Government and other organisations that manage lower volume roads across Australia to manage their road assets effectively and fulfil their obligations to the community while also improving mobility and safety.

Each guide reflects current global best practice and information and has been tailored to Local Government requirements.

1.2 Bridge Management – Current State

Increasingly, organisations including Local Governments are being asked to optimise the spend on their asset base while still meeting an ever-increasing service demand on their assets. This is particularly relevant to bridges where there is an ever-present push to increase loadings to drive efficiencies needed to meet the Australian freight task. Asset management has come to the forefront in an attempt to meet this challenge and as a result, the industry has seen significant development over the last 15 years moving from a maintenance management approach to a more holistic, whole-of-life, asset management approach to managing bridge assets. Asset management in infrastructure sectors such as water and electricity have progressed significantly, and these sectors have two key attributes:

1. Performance targets can be concisely defined ($/kWh at % availability)
2. The span of typical organisational control includes all three key asset management parameters of performance, risk and cost.

Despite this push towards asset management, bridge asset management is still developing, and many organisations need assistance to help move away from a pure maintenance management approach to a more holistic asset management approach. While there are many resources focused on bridge maintenance management and more general asset management, there are few that address bridge asset management specifically. This guide addresses this gap. Key challenges for bridge management as it transitions to asset management are:

3. Typical bridge management business processes were developed in the latter part of the 20th century before the maturation of contemporary concepts of risk management and asset management. Thus, current bridge management business processes need to be transformed to benefit from these concepts.
4. Performance metrics for road infrastructure (of which bridges are a key asset class) are relatively difficult to quantify, which is exacerbated by the industry structure which sees responsibility for risk and cost

parameters reside with the road agency, and somewhat disconnected from key benefits of performance, which resides with other parties, notably in the private sector.

1.3 Use of this Guideline

The purpose of this guideline is to provide:

- an overview of the basics of Bridge Management including:
  - management, decision making, governance, risk frameworks and legal considerations
  - operations and maintenance
  - procurement of relevant services related to bridge management
  - asset disposal, re-purposing or replacement
- references that assist with the various processes associated with managing assets
- templates and proformas for the more common tasks such as procurement of specific services
- an understanding of heavy vehicle permit access requests.

1.4 Scope of Guideline

1.4.1 In Scope

The scope will be generally consistent with the purpose of the guide highlighted in Section 1.3 with the following clarifications:

Structure types

This guideline is focused on bridges and culverts and will not comprehensively cover all structure types, but the general principles outlined throughout can be applied to the management of practically all transport-related structures. A typical concrete bridge is shown in Figure 1.1, and a typical corrugated steel culvert is shown in

Figure 1.2.

The following structure types may be considered to be in scope of the management methods and processes outlined in this guide:

- bridges
- culverts
- causeways
- boardwalks
- tunnels
- jetties
- retaining walls
- signs and gantries
- high mast lighting
- architectural features.

This list is not definitive however a simple rule can be applied to identify if the structure fits within the structures management system: *If an unanticipated failure of the structure/item were to occur, would the result of this failure significantly impact the safety of users or impact the function or effectiveness of the network's level of service?*

Figure 1.1: Concrete bridge

Figure 1.2: Pipe culvert

1.4.2 Scope Limitations

Since focus for the guideline is management of bridge and culvert assets, technical aspects of bridges and culverts are therefore not emphasised. These aspects are generally well covered by a range of other publications referenced throughout the guide. In particular, the following notes are pertinent:

- Design and Construction
  - This guide does not focus on detailed elements of design and construction. Elements of design and construction as they relate to the asset management of the structure life cycle are considered.

- Detailed risk management methodologies
  - The basics of developing and implementing risk management frameworks have been introduced and some of the pitfalls highlighted, however these frameworks and methods have not been developed in detail. The use of risk management methodologies to manage bridge assets is still undergoing significant change within the industry. Many of the approaches have not yet been well tested in practice. Over the coming years it is expected that this field and appropriate methodologies will mature and converge, and aspects associated with risk management can be revisited in future revisions of the guide.
- The guide is intended to be an overview of the processes of bridge management and provide, where relevant and convenient, more detailed information such as proformas where they can be generically helpful to organisations. Bridge management is very context specific and therefore it is difficult to develop a guide that goes into specific context detail. This guide has therefore focused on explaining the basics, referencing relevant material rather than reinventing the wheel. The focus has been on connecting it all together into a cohesive document that will be useful to personnel responsible for bridge management and will hopefully stimulate conversations within organisations that will lead to an improvement in policies, systems, processes and communication.

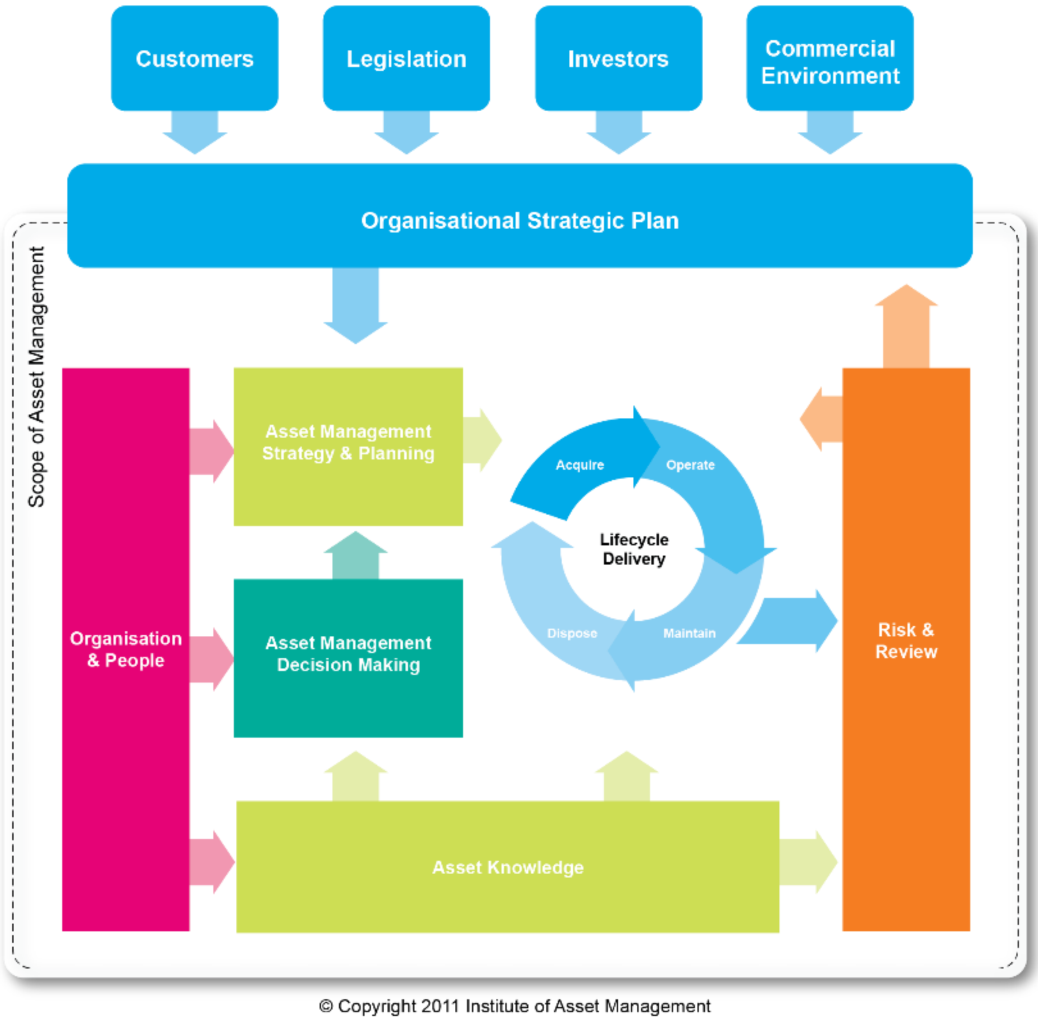
2 Asset Management

2.1 Ownership and Agency Context

The primary responsibility of Council with respect to bridges and culverts is to provide services to the community. Therefore, the functional requirement for the service provided by bridge assets must be defined, along with their associated performance standards. Effective use entails balanced investment and extracting maximum value from the asset at a reasonable cost to the community over the asset's life. Asset management is a key framework that guides the cost-effective planning, acquisition, operation, maintenance and replacement and/or disposal of an asset (Victorian Auditor-General's Office 2019). This framework provides a mechanism to meet the community needs efficiently, while managing risks related to safety, functionality, economic and (legal) compliance obligations.

Figure 2.1 is the Institute of Asset Management's (AIM) conceptual model. As an example of a suitable asset management framework, the model identifies core elements within the asset management scope and how they relate with the key outcome being to support the organisational strategic plan.

Figure 2.1: Typical asset management framework



Source: The Institute of Asset Management (2015b).

Underpinning the conceptual model above is the further breakdown of the IAM conceptual asset management model outlining the subject groups and 39 subjects as shown in Figure 2.2.

Figure 2.2: Asset management subject groups

Source: The Institute of Asset Management (2015a).

Mature asset management organisation will be focused across all of the 39 subjects set out above. Clearly depending on the organisation different levels of maturity will be required across different subjects to meet the business goals. IAM maturity assessment ranks the subject on a scale of 0–5 with 0 being Innocent and 5 being Excellent.

Expanding on the subject groups shown in Figure 2.2, Strategy and Planning is intended to align an organisation's asset management activities and asset outputs with overall organisational objectives. Asset Management Decision-Making is concerned with the possible approaches to decision-making over the life cycle of an asset (refer to Section 2.3) in addition to the challenges faced. Life Cycle Delivery covers the implementation of asset management plans developed in accordance with the Strategy and Planning subject group. Asset Information is concerned with the identification and management of asset data requirements, which is discussed in Section 2.4.1. Organisation and People covers the process of integrating an asset management approach into an organisation, including change management and the introduction of asset management thinking. Finally, Risk and Review covers risk management in relation to asset management including the creation of feedback and review mechanisms, which is discussed in Section 2.6 (The Institute of Asset Management 2015a).

This Bridge Management Guide does not provide comprehensive coverage of all 6 groups in Figure 2.2, based on the following rationale:

1. Strategy and planning – This group is focused on network service delivery, and bridges are a key asset class, but need to fit within the broader organisational context, so coverage has been limited to bridge specific issues.
2. Asset management decision making – current business processes associated with bridge and culvert management have their roots in maintenance management. The guide focuses on advancing key

elements of decision making towards an asset management framing while retaining operational effectiveness.

3. Life cycle delivery – similar to (2) above
4. Asset information – similar to (2) above
5. Organisation and people – While there is little explicit coverage of this group, it is key to progress, but like (1) needs to transcend asset class, and is very organisation specific.
6. Risk and review – Understanding risk differently, and provision of appropriate governance are considered key elements to advance bridge and culvert management, so are addressed in some detail.

To achieve best practice in the management of assets across their life cycle a clear asset management framework and supporting elements needs to be developed and/or implemented throughout the organisation as part of normal business.

2.1.1 Legal Obligations/Responsibilities

Responsibilities of Local Government bridge asset owners are generally defined by various pieces of Statute law or Acts of parliament however they are generally state based and not uniform throughout Australia. These pieces of legislation also do not refer specifically to the responsibilities associated with an asset class such as bridges. However, it is important that all bridge managers and staff are familiar with the interpretation of relevant legislation for bridge assets in their state.

Historically the responsibilities of Council have also been shaped by common law cases. Pre-2001, Local Governments were protected by the non-feasance rule. This meant that councils had to provide a duty of care in the design and construction of a road, but not the subsequent maintenance of the road assets (Institute of Public Works Engineering Australia 2015b). In 2001, the High Court of Australia decided that the non-feasance rule no longer applied to Australian common law and councils now have to show due diligence in all aspects of maintenance as well as design and construction (Institute of Public Works Engineering Australia 2015b).

Due diligence is a legal concept regarding moral philosophy of how humanity should behave (Robinson & Francis 2019). Typically, it is used in common law to mount a defence against negligence. In engineering terms showing due diligence is about ensuring adequate function of infrastructure primarily in terms of being safe (causing no harm) and being useful (does what it is intended to do) (Robinson & Francis 2019). If a duty of care exists, then for a council to be found negligent, all of the tests summarised in Table 2.1 need to be answered in the affirmative.

Table 2.1: Tests for due diligence/negligence

Question	Description
Foreseeability	Did you know or ought to have known? Could this have been foreseen? (e.g. through prior incidents, complaints, wide or common knowledge, or expert advice)
Causation	Did the injury or damage occur because of the ‘unsafe’ matter on which the claim of negligence is based? This is sometimes known as the ‘but for’ test. This includes existing precautions and mitigations
Preventability	Is there a practical way or alternative to how things were done? (This follows the hierarchy of controls: elimination, substitution, engineering, administration and personal protection equipment). That is, what else could be done in addition to what is already in place?
Reasonableness	Are any of the possible further precautions or mitigations reasonable in the circumstances? That is, is the balance of the significance of the risk vs the effort required to reduce it reasonable?

Source: Robinson and Francis (2019), p24.

Due to constraints in funding it is not possible to maintain every asset in perfect working order and often there are significant backlogs in maintenance which in the worst-case create an unacceptable safety risk. Despite this, councils still need to show a duty of care to all stakeholders and users of their infrastructure, ensuring the function of the asset is maintained, and operated within the defined function. The law recognises this conflict and the fact that there is not infinite funding available to curb every possible maintenance and operational issue (Robinson & Francis 2019). However, to show due diligence a council needs to be able to demonstrate that:

- There is a framework or system in place to manage the bridge stock which focuses on:
  - establishing processes and accountabilities for policy decisions and setting appropriate performance standards
  - monitoring performance outcomes
  - incorporation of processes of continuous improvement.
- There are criteria for asset management decision making and prioritisation of limited public funding.
- Decisions to undertake, defer or not undertake work are linked to a careful consideration of the risks involved and that all actions that are ‘reasonably practicable’ have been undertaken.
- Decisions are recorded with reasoning and linkage to the organisational framework for managing the assets.
- Risk is dynamic and needs to be reviewed should there be a change in the operating context.

With respect to the above points it is important to realise that ‘we did not know’ or ‘our budget is limited’ or ‘we didn’t have the resources’ will not be an adequate defence. While some of these points may have merit, without the appropriate decision-making process and appropriate documentation, they will not likely form an adequate basis for a defence against a negligence claim. Quite the opposite is true in that, documenting the processes and decisions provides an excellent basis for defending against claims of negligence and ensures that staff are afforded some personal protection against negligence claims as they have a framework of decision making that they are operating within.

In light of the acknowledgement that councils have to operate in a budget constrained environment the term ‘so far as is reasonably practicable’ (SFAIRP) becomes important in legal terms. In the past, courts have found that there is no limit to risk and the focus is on precautions rather than hazard risk level (Robinson & Francis 2019). Critically the objective is to demonstrate that all reasonable practical precautions are in place, not that a targeted level of risk or safety has been achieved (Robinson & Francis 2019). Typical engineering risk frameworks (e.g. AS ISO 31000:2018) are based on the concept of ‘as low as is reasonably practical’ (ALARP). There are two key differences between SFAIRP and ALARP, namely:

1. differences in reasoning and documentation of reasoning
2. differences in treatment of high consequence low probability risks.

Thus, while the AS ISO 31000:2018 based business processes are useful, they are not sufficient to demonstrate application of the SFAIRP philosophy (Robinson & Francis 2019). Essentially if a mitigation involves minimal difficulty then it is difficult to reason why it was not done which may lead to organisations or individuals being identified as negligent. The ALARP philosophy does not systematically address this circumstance.

The above discussion is aimed at providing a basic but rational basis for meeting a council’s legal obligations but is by no means fully comprehensive. It is also framed negatively, defining negligence. Due diligence should be considered the antithesis of negligence and has many practical benefits over and above avoidance of negligence claims. Council business processes should be subject to periodic compliance reviews to validate and confirm council’s legal responsibility, and also to demonstrate due diligence.

2.2 Governance

The objective of governance is to ensure that organisational policies are converted into actions. Governance includes several different areas such as business performance, ethics, risk management, compliance and administration. Keys to converting policies into action are:

- having well thought out policies and procedures to realise organisational goals while managing and controlling risks. This requires the articulation of effective goals, strategies, tactical and operational plans, systems, documentation, feedback loops etc.
- determining what measures are needed to ensure the various strategies are executed as intended (assurance)
- determining and formally documenting the delegation of authority, who is responsible to ensure systems and processes are executed as intended and what are their responsibilities in terms of documenting their oversight. This delegation must extend from elected councillor (board) level all the way through to workers on the ground
- ensuring communication is fluid through the organisation so that the performance of the policies, systems and procedures can be monitored, and an effective feedback loop maintained to ensure the continual improvement of both the systems and processes themselves, as well as the governance framework.

Execution of governance typically only goes wrong if:

- there are gaps in the governance structure; or
- there is deliberate obstruction of governance.

Both are equally concerning, but gaps in governance can be regularly reviewed as part of a governance audit process which is essential to demonstrating due diligence. It is also important that an organisation is up to date and acting in accordance with rules and regulations (compliant) and ensuring the safe and effective operation of the asset stock.

Governance can be carried out at many levels depending on the size and organisational structure. Typical levels may include:

- board governance
- corporate governance
- investment governance
- program governance
- project governance.

Regardless of the level at which governance is required to be applied it is important governance within the organisation is tiered to ensure rigorous review and avoid 'group think'. As a minimum there would be three tiers:

1. **Self**; tools are made available to allow self-audit.
2. **Corporate**; an independent group within the organisation that ensures consistency of interpretation and application of governance.
3. **Independent**; an independent third party/consulting group with subject matter expertise.

Practical asset management governance concepts are still emerging, as the discipline matures. No matter how many levels there are, it is key that each level effectively feeds into one another as appropriate, supporting communication and documentation throughout the organisational structure.

2.2.1 Risk Assurance

Risk assurance is a ***key element of governance*** and due diligence and is performed with the goal of making sure that the risk management framework is working as intended. It can be used to ensure that feedback loops are effective and that the risk framework employed is supporting the achievement of organisational objectives and regulatory requirements but still maintaining an adequate consideration for safety and financial performance. A key part of risk assurance is ensuring that there is a program of periodic review/audit of the risk management process and that resulting recommendations are implemented. Audits should be planned and undertaken, with responsibilities clearly defined (AS31000:2018).

2.2.2 Outsourcing

Outsourcing of services can be an attractive proposition for councils, and it can be argued that this provides the most cost-effective provision of service (as a result of the commercially competitive nature of outsourcing). However, care needs to be taken when outsourcing as it is not possible to outsource all responsibilities and obligations, and ultimately the asset owner 'owns' any associated risks. Effective governance needs to be in place to ensure obligations are met.

AS ISO 55001:2014 indicates that an organisation needs to determine and document how outsourcing activities are to be controlled and integrated into the asset management process. Governance forms a key part of this process.

2.2.3 Record Keeping

Record keeping underpins governance and is critical in demonstrating due diligence. It is the mechanism by which transparent assurance is provided within the organisation that the policies and processes are being fairly and appropriately executed. Record keeping shows that decision makers have acted appropriately in accordance with their obligations and operational context. Of course, it is important that there is an appropriate framework of policy, procedures, organisational objectives, asset management strategies, plans and capabilities required to execute them so that the decision maker can reference the appropriate context of the decisions that they make.

Common root causes of decision making not being recorded within organisations are:

- policy, procedures, organisational objectives, asset management strategies and plans being poorly documented and not focused on assisting decision makers and staff to make decisions i.e. often the documentation associated with these aspects are too generic or non-specific to be practical
- the risk appetite of the organisation and how this translates through the organisation is not well articulated, communicated and documented and staff are afraid their decision may not line up with the organisation's view
- the documentation systems are not well developed and/or may not consider the specific needs of sub-sections of the organisation
- a view that non-documented decisions are easier to defend in a court of law. i.e. the 'I did not know defence', which is actually the antithesis of due diligence
- non-existent or poorly implemented management of change process.

Record keeping is also a key component of supporting good structure asset management practice. The keeping of comprehensive records supports the long-term management of structures by allowing the manager to view structure history and make informed data-based decisions. Data kept for bridges should be in an easily accessible format and should be kept consistently organised. Data governance is essential. It is important to 'gate' data going into the record system to ensure that it is valid, and similarly 'gate' data being removed from the record system. Failure to do this means that invalid or incomplete data may reside in the record system, leading to a lack of confidence in the whole data set, and a preference for decision makers to revert to empirical rather than data driven decision making.

It is recommended that the following data is kept for each bridge managed by a council:

- basis of design/functional requirement
- asset strategy (whole-of-life model) & maintenance strategy
- asset criticality consistent with the basis of assessment that determined criticality ranking (failure mode, frequency, mean time to repair and consequence)
- bridge inventory information – number of spans, materials, dimensions etc.
- inspection records for all levels of inspection
- documentation of individual bridge servicing and maintenance strategy (including compliance)
- both proactive and reactive maintenance and repair records
- capacity assessment records
- asset management decisions including risk assessments associated with the design, commissioning, operation and maintenance of the asset
- management plans that reflect asset management decisions
- design/as built records and drawings.

When developing or adopting a record (information) system for the management of data, it is important to be focused on how the system will support overall asset management goals. Overly large and complex systems are prone to becoming a drain on time and resources which results in less time spent on actual analysis and decision making. Ultimately, the system needs to allow the user to keep track of all relevant data for a bridge. File management services with a cloud storage component can be beneficial as this allows staff to access files from any internet enabled device, such as from a tablet in the field. This also supports the use of computer application-based inspection forms. There are numerous third-party systems available however selection should be based on a solid functional requirements document, built and/or signed off by key asset management stakeholders.

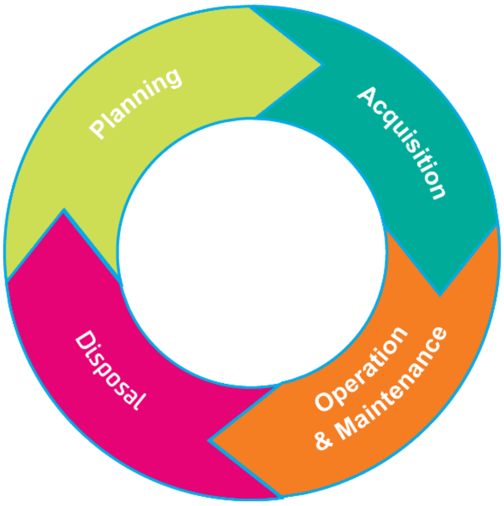
2.3 Life Cycle of a Structure

There are a number of different descriptions of the life cycle of an asset, with three versions included in this discussion for comparison purposes, namely:

1. Assetworks: The asset lifecycle (Figure 2.3)
2. Institute of Asset Management (Figure 2.4)
3. Institute of Public Works Engineers Australia (Figure 2.5).

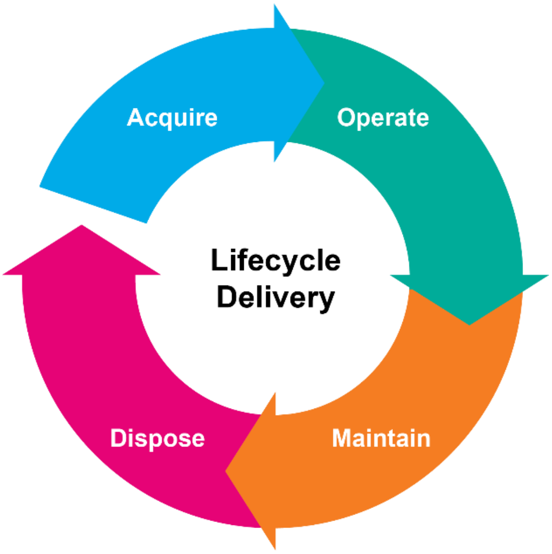
An overview reveals that the differences between them are centred around the level of detail included and the categorisation of activities. A brief summary of the process is provided in this section, followed by a brief discussion of lifecycle costing. One of the key practice transitions (Section 1.2) is for structures managers to consider more comprehensively the asset life cycle and associated costs.

Figure 2.3: Assetworks: The asset lifecycle



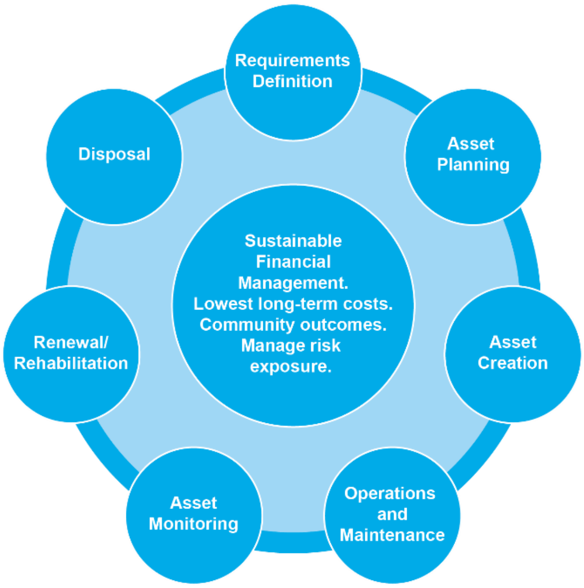
Source: AssetWorks (2017).

Figure 2.4: Institute of Asset Management: The asset lifecycle



Source: The Institute of Asset Management (IAM) (2015b).

Figure 2.5: Institute of Public Works Engineering Australia: Asset lifecycle



Source: Institute of Public Works Engineering Australia (2015b).

There are several definitions of asset life including:

1. Physical life – the time period over which the asset maintains its inherent integrity
2. Functional life – the period over which the asset performs the functions required by the organisation
3. Economic life – the period over which the cost associated with ongoing asset utilisation exceeds the cost of an alternative.

From the perspective of the owner, when an asset exceeds any of these life definitions, consideration should be given as to whether it has exceeded its useful life – i.e. the period through which the asset performance fulfils all or part of the performance (level of service) outcomes desired of it. Structures typically have a nominal design life to guide the design process. While this can form a starting point for estimates of remaining life as per the definition above, it is important to consider this as a nominal value and estimates of asset life need to be continually assessed during the life of a structure to ensure asset management processes are optimised.

The asset acquisition phase can be divided into planning and delivery sub-phases. Planning is the first phase of the structure life cycle during which a need for a new structure or major upgrade is identified. This will often be linked to the end-of-life of an existing structure or a change in the level of service requirement for an existing road or structure. During planning the functional level of service that the proposed structure will provide needs to be evaluated in the context of future needs as well as the present-day requirement. Other considerations at the planning stage include solution concept (bridge, culvert, tunnel), expected maintenance requirements and whole of life costs. Once planning activities have defined the operational requirements for the asset (or group of assets), structural and delivery options should be defined and developed into a business case to facilitate funding. Essential elements include clear scope, schedule and budget definition, contract and resource plan, and risk and stakeholder management plans. It should be noted at the end of this phase 85% – 95% of the asset life cycle cost is determined and locked in.

The second acquisition sub-phase is delivery of the (now defined) project, which is the main resource commitment – normally about 80% of the total asset capital (up-front) cost. It is in this sub-phase that project risk is most likely to materialise. In large measure, the delivery sub-phase 'tests' the effectiveness of the planning phase. While very few projects are delivered precisely to plan, the planning sub-phase should provide the platform for successful project delivery, particularly facilitating timely contingency plan implementation as the project plan is adjusted during delivery. The key aim of the acquisition stage is to obtain a structure which closely aligns with the expectations outlined in the planning stage.

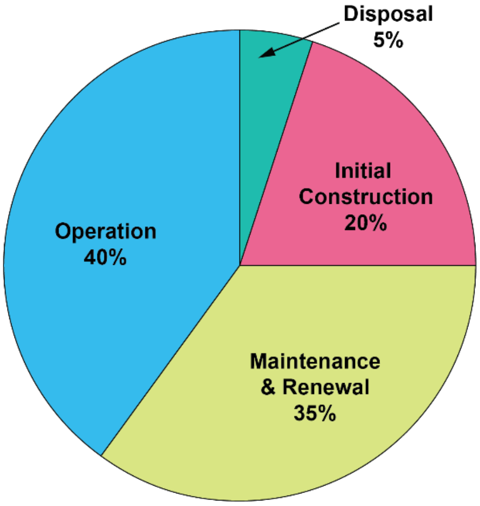
Once a structure has been commissioned and opened for use, the operational phase of the life cycle begins. During this phase the structure should undergo programmed inspection and maintenance. The ongoing condition and performance of the structure should be tracked with identified risks addressed as required. Life cycle costs should be recorded in line with financial management requirements. Operation is the longest phase of the structure life cycle (service lives will typically range from 20–100 years depending on the structure) and generally requires the greatest level of on-going management effort.

The disposal stage is initiated once it is recognised that a structure is no longer fit for purpose or if operational/maintenance costs are unreasonably high and capital funding is available. During this stage the safety and performance of the structure must be managed until a preferred option for remediation or removal is identified and carried out. Thus, disposal is closely linked to planning and network needs.

2.3.1 Life cycle costing

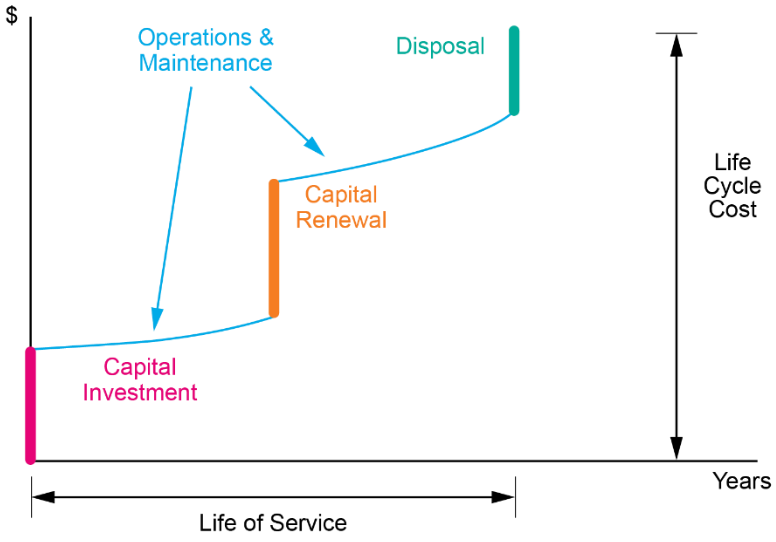
Life cycle costing is defined by AS/NZS 4536:1999 as the practice of determining the total cost associated with a structure asset over each stage of its life cycle. This includes costs associated with planning, design, installation/construction, operation, maintenance, rehabilitation, decommissioning and disposal. The cost profile of an asset is a key consideration in asset selection. Typically, the acquisition cost is not the most significant (Figure 2.6), but it is the cost that gets disproportionate consideration because it occurs within the timeframe of the decision to acquire (Figure 2.3). The discounted cashflow concept (Austroads 2013) also means that it is preferentially weighted in decision making.

Figure 2.6: Typical relative costs of the various life cycle phases



Source: Institute of Public Works Engineering Australia (2015b).

Figure 2.7: Life cycle costs of an asset-based service



Source: Institute of Public Works Engineering Australia (2015a).

Life cycle costing should generally be undertaken in accordance with the requirements of AS/NZS 4356:1999 R2014 and should include (Institute of Public Works Engineering Australia 2015a):

- capital costs associated with construction
- costs associated with ongoing maintenance over the structure life cycle
- costs associated with ongoing inspection over the structure life cycle
- costs associated with expected future rehabilitation or upgrade (new structures should be designed to minimise this requirement).

Ignoring costs over the whole life cycle can result in decisions being made based on capital cost only, which is usually lower than the cost that will be incurred over the operational life of the structure. Life cycle costing should be undertaken in the planning stage for new structures, and throughout the lifecycle as required to assist with decision-making when the structures manager faces a choice between various options for inspection, maintenance, upgrade, repair etc. While the majority of life cycle costs are defined at the planning and acquisition stages, actions taken during the operational stage will impact on ongoing levels of operational expenditure.

Future maintenance requirements and costs associated with maintaining the structure will be dependent on the structure type chosen and the materials used in construction. The complexity and frequency of maintenance required will also be influenced by the expected usage of the structure and the environmental conditions to which the structure is subjected. Following is an example structure type comparison which is intended to stimulate the kind of thinking that is required when considering different options for bridge construction.

A timber structure would be likely to require a greater volume of maintenance over an operational lifetime when compared to a concrete structure built in the same location which provides a similar functional level of service. However, if a council has a readily available skill base for maintenance of timber structures, a timber structure which is cheaper to construct up front could prove to be a better choice in the situation described since the council will be able to effectively maintain the structure and reduce life cycle costs. The need to retain or externally procure this skill base over the lifetime of the structure should also be considered.

2.4 Structures Management Transition

Section 2.3 provided an overview of the life cycle of a structure and demonstrated the need to manage the structure through that life cycle. Councils own a portfolio of structures for the purpose of providing services to the community. Structures management is the collection of business processes that manage that portfolio (with different assets all at different stages of their life cycle) to meet the community need. As highlighted in Section 1.2, structures management (as a practice discipline) is in transition.

Many Local Governments are faced with the task of managing a network of road structures which continue to age and deteriorate while the requirements of stakeholders and users increase in tune with a growing population and the demands of industry for bigger, heavier trucks on the road. In the past there has been a focus on providing new bridge infrastructure, which in some cases has come at the cost of effectively managing existing structures. Local Governments are forced to operate in a resource-constrained environment where a large network of structure assets must be managed with limited funding from council rates and other more sporadic sources including state and federal government grants.

Traditionally, Local Government structures management has had a maintenance management focus (e.g. Figure 2.8), which is quite different to the emerging asset management focus (e.g. Figure 2.1 in Section 2.1). Maintenance management is an element of asset management, but the basis for decisions is much broader with an asset management approach and focused on organisational outcomes rather than the asset (or asset class). In order to realise the best possible value from existing assets and provide an acceptable level of service to users, it is becoming increasingly recognised that a structure asset management approach is needed that is proactive and network focused, rather than individual bridge focused.

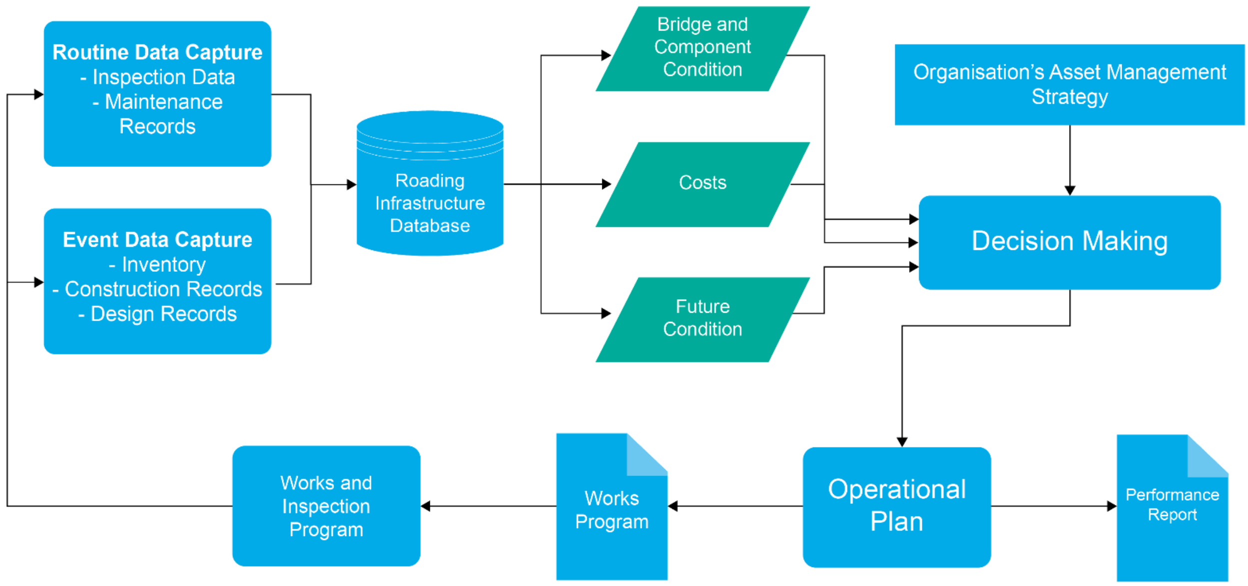
Institute of Public Works Engineering Australia (2015b) defines asset management as follows:

> The goal of infrastructure asset management is to meet a required level of service, in the most cost-effective manner, through the management of assets for present and future customers.

A more straightforward way of thinking about asset management is:

> Asset management is the process that helps answer the question: 'If I had one more dollar to spend on my network, where would I spend it for maximum value?'

Figure 2.8: Typical maintenance management framework



Source: Adapted from Seskis and Lake (2012).

2.4.1 Transitioning Asset Management and Information Systems

A simplification of the asset management subject groups introduced in Section 2.1, Figure 2.2, is to consider the emerging structures management systems as a combination of:

1. people
2. (business) processes
3. technology (facilitating people and business processes).

These three elements are required to effectively and efficiently deliver asset management objectives and support the organisational needs. Their requirements are identified and applied to the asset base via data-based decisions. Clearly one of the key challenges over the foreseeable future is to transition people, processes and technology from current state to a better state, while minimising business disruption, and retaining the value of existing capability and data. Many Local Government agencies will have some form of asset information system. The data structure for most systems will have been based on a maintenance management framework (Figure 2.8). While this is a useful starting point, the data structure for a forward-looking asset information system (based on Figure 2.1 from Section 2.1) will be significantly different.

AS ISO 55001:2014 is an international standard that specifies the requirements for the establishment, implementation, maintenance and improvement of a management system for asset management. This standard is not specific to structures, but AS ISO 55001:2014 discusses aspects critical to the successful implementation of an asset management system which include:

- understanding the context of the organisation
- understanding the needs and expectations of stakeholders
- determining the scope of the system.

One of the fundamental problems that exist in many organisations is the failure to understand the needs and expectations of the different stakeholders and ensuring that systems can meet the varying needs. From the perspective of structures management, the needs and scope of a system are very different to other disciplines and organisational functions.

Critical to structural asset management systems is:

- ensuring that all asset management policies, objectives, plans align with the management system architecture so that performance over time can be tracked and used to feedback into the system. These need to focus on the specifics of structures
- suitable to support criteria developed to control processes, keep documented information that shows that the criteria and processes have been upheld and needs to be capable of framing the treatment and monitoring of risks
- identifying critical financial and non-financial information relevant to bridges and how this information is reported both internally and externally.

Ideally, asset information systems (technology) allow an organisation to order their asset data such that it can support asset decision-making. Importantly, an asset information system is just a tool to support an organisation, an asset management system does not tell you what to do. However, if correctly developed and implemented an asset information system can create a valuable framework for governance and decision making in a council. Collecting and collating data is expensive and asset information systems need to be focused on supporting long term decision making using the minimum data required. The power in the data once converted to information, is the ability to have a risk-based discussion based around multiple criteria focused on delivering the best outcome for the organisation, rather than a purely financial discussion.

Many organisations fall into the trap of buying off the shelf asset information solutions without adequate consideration as to whether it will truly support their organisational asset management objectives. This is particularly true when it comes to managing structural assets as most off-the-shelf systems do not adequately support this asset class. Increasingly, asset information systems have taken a more organisational enterprise view, focusing on corporate functions and financial reporting. This has led to many issues in organisations including asset information systems not being suitable for recording data including objectives, risk, condition, assessment, maintenance, renewal, service level, decision making etc. that supports the structural asset management process. Ultimately the technology (asset information system) needs to support the people and processes, rather than having the technology constrain the people and processes.

As a minimum the following information should be recorded in an asset information system focused on structural assets:

- bridge management objectives and monitoring
- basic inventory
- current and historical condition
- current and historic design and evaluation information
- servicing and maintenance plans
- historical maintenance including costs
- risk management strategies and/or individual structure management plans that link to the cost/risk/performance setpoint nominated by the organisation
- service level history
- business cases for maintenance/renewal activities over and above the servicing plans
- log of all decisions made and how they tie to asset management objectives.

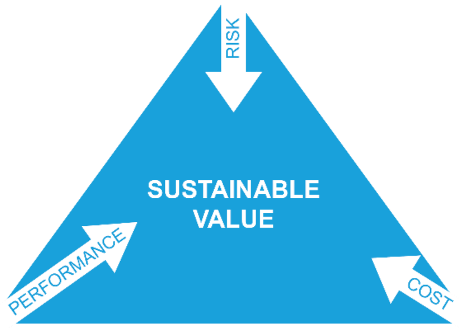
Failure to adequately cater for structures management information needs within an organisation can lead to:

- structural management functions being reduced to engineering spreadsheets scattered across the organisation
- structural management becoming focused on individuals rather than on an organisational team and organisational objectives
- structural management becoming about what the organisation has historically done (typically empirical based decision making) rather than aligning with organisational objectives
- loss of information, confidentiality and/or data integrity
- an inability to be able to show due diligence in legal matters should they arise.

2.4.2 Decision Making Fundamentals

A key purpose of structures management and information systems is to facilitate decisions that optimise the asset, focusing on the achievement of the organisational objectives and goals using appropriately developed asset management strategies. The focus of this decision-making process is the trade-off between performance, risk and cost as illustrated in Figure 2.9 which also includes an extract from AS ISO 55002.

Figure 2.9: Decision making parameters: Cost, risk and performance



Asset management decisions are made across all levels within an organisation, i.e. at strategic, tactical and operational levels. It is important for the organisation to establish a decision-making framework that comprises decision-making processes and decision criteria, to ensure consistency and alignment between its decisions.

The purpose of a decision-making framework is to facilitate decision making by:

a. *incorporating a risk-based approach;*
b. *ensuring alignment with asset management objectives, organisational objectives and the value assets provide to the organisation and its stakeholders;*
c. *ensuring the organisation's resources and efforts are targeted at achieving organisational objectives and realising value;*
d. *taking into account cost-effectiveness of decisions.*

Text Source: AS ISO 55002:2019.

A consistent decision process provides a solid foundation for asset managers and associated staff to make decisions in the context of the organisation. Decision-making processes and decision criteria allow consistency across all levels of an organisation including strategic, tactical and operational levels and facilitate effective alignment between each of these. Developing decision-making frameworks based on strategic, tactical and operational plans is essentially setting the cost/risk/performance 'setpoint' for the organisation.

There are many models for decision making but they all follow the same basic philosophy with minor variations. The following decision-making framework is suggested (Figure 2.10).

Figure 2.10: Decision making framework

RDFCAP

Review Context

Define Objectives

Factors Affecting Outcomes

Courses of Action

Alignment of Stakeholders

Plan

Review context – involves reviewing all contextual factors which may include (but not limited to):

- what is the current problem/issue?
- who are the stakeholders?
- social, political and legal context
- organisational context
- strategic, tactical and operational context (including performance, risk and cost parameters).

Define objectives – involves determining what needs to be achieved to address the problem/issue.

Factors affecting outcomes – In light of the context and objectives, determine factors that may affect the outcome. For example:

- understanding how stakeholders may be affected
- technical considerations
- asset strategy/plan considerations
- financial and budget constraints.

It is particularly important to identify the factors that dominate decision making.

Courses of action – Identify various courses of action (options, both capital and non-capital) and understand their implications including the effect of performance adjustments, how funding constraints (over time) constrain the feasible options and understand and document risks and possible mitigations, for example

- due diligence check ensuring duty of care has been satisfied
- has SFAIRP has been satisfied?

This process characterises the identified options and provides the basis to select the preferred option, and importantly provides definition of why alternative options were not selected – which can be very important in subsequently establishing due diligence in the decision process.

Alignment of stakeholders – Provide the opportunity for stakeholder engagement in the option selection process. This can provide enhanced assurance that the preferred option is the most appropriate option and can provide a valuable reference point to facilitate engagement once the plan is being implemented. Depending on the organisation communication policy this may or may not be a formal process.

Plan – Having selected and validated the preferred option to address the issue, details of how it needs to be implemented must be defined and documented.

The decision process is simple, yet the key to expedient, good decision making is clear definition of context and objectives. If these two elements of the process can be readily defined, then the balance of the process is relatively straight forward. A good asset information system can provide fast, accurate and consistent articulation of context and objectives. With appropriate data architecture, decision capture can also be incorporated, facilitating the practice and demonstration of due diligence.

2.4.3 Continual Improvement

As identified in Section 2.4.1, the key elements of the structures management system are people, business processes and technology, and all require structured improvement based on emerging feedback. The continual improvement process provides both the mechanism and governance to ensure that all stakeholders have the opportunity to contribute to improving organisational outcomes.

In addition, governance and other management processes can provide input to the continual improvement system when they review, for example:

- alignment of decision making to organisational policy and processes
- effectiveness of policy in informing decision making
- outcomes of decision making in terms of cost, risk and performance
- review of the adequacy of any decision-making criteria set at the various levels
- review of communication and documentation procedures
- review of the cost, risk, performance setpoints including a review of:

- current level of service and the expectations of stakeholders
- risk exposure levels against risk appetite
- budget targets and actuals.

2.5 Defining Levels of Service

One of the key inputs into the structures management system is the required performance (level of service) of the structures. Levels of service need to be determined at the network level, then articulated in a form meaningful to structures management. This section provides an overview of level of service considerations. Consistent articulation of road asset levels of service is still emerging and varies significantly between asset owners.

In order to meet the expectations of the community and other stakeholders, maintain user safety and show due diligence, the desired and essential level of service attributes for each structure managed by a Local Government organisation need to be well understood. Establishment of road network levels of service by an organisation is based on the goals and objectives that guide their asset management strategy. These goals and objectives fundamentally need to be definable, specific and measurable. Functional levels of service are the critical element that transforms goals and objectives into outcomes and establishes the cost, risk, performance setpoint.

It is therefore critical that the functional level of service is defined for each structure. The functional level of service that a structure asset provides is related to the degree to which it meets specific functional requirements. These can include:

- load capacity/heavy vehicle carrying capability
- alignment/speed environment
- trafficable width
- number of lanes
- overhead clearance
- adequacy of barriers and delineation
- structure waterway area and/or height affecting frequency of road and bridge closures and flooding of upstream properties (flood immunity)
- waterway area for passage of water traffic
- fish passage
- provision for pedestrians and cyclists
- changes in traffic usage
- lighting
- requirement/ability to carry ancillary services.

Resulting costs of the deficiency in level of service (value minimisation) to the community may include increased travelling times, an increase in accidents, and increased commercial vehicle operating costs due to a need to take detours to avoid the bridge.

As structures managers, Local Governments are responsible for providing a safe level of service for all structure users who might be expected to lawfully use a structure within reason. Levels of service can be defined by several mechanisms including:

- community and stakeholder consultation
- legislative requirements

- codes of practice such as the Australian Standards
- internal policies.

Desired, or ideal functional levels of service may be established through consultation with community structure users and other related stakeholders such as commercial vehicle operators, utility companies etc. Where possible, a proactive approach should be taken to avoid the situation where an inadequate level of service is realised unexpectedly due to user complaints or the occurrence of an unwanted event.

Levels of service can also be defined by legislative requirements. The adequacy of a structure for key community services such as fire trucks, school buses and garbage trucks must also be considered. If a structure is not suitable for these vehicles, community quality of life will be reduced.

Levels of service need to be defined on an individual bridge basis however these requirements often need to be rolled up into route and sometimes network levels of service to promote strategic and efficient use of agency funding. For example, a single lane timber bridge on a no through road which experiences a traffic volume of 20 vehicles per day may provide an adequate level of service, while the same bridge located on a regional link road which experiences 1000 vehicles per day including commercial vehicles may not. If the latter bridge was in a poor condition and required major rehabilitation work to achieve a minimum safe level of service, replacing the bridge with a structure which provides a higher level of service (greater functionality) regarding load capacity and/or trafficable width, may be a preferable option. The viability of this will depend on available funding however, and in some cases, commercial stakeholders with a vested interest in an increased level of service may be approached to support/provide investment. This example illustrated the inter-dependency between the individual asset and network levels of service.

Load capacity is a primary concern of the structures manager, as providing an insufficient level of service in this regard has the potential to result in catastrophic consequences such as bridge damage, collapse, injury or death to structure users and loss of structure function. Many bridges in Australia were built prior to the introduction of current design load standards and heavy vehicles designed to current standards often produce load effects which are beyond the design capability of these bridges. Despite this, older bridges can often be observed to be performing relatively well, and in some cases proven capability may be well beyond what is assumed by the structures manager. However, this **should not** be taken as assurance that any given bridge will be able to withstand loadings greater than what is indicated by its design capacity or build era unless suitably investigated by an engineer with specific experience in such matters. Heavy vehicle access requests and bridge load capability are discussed in detail in Section 2.9.2.

When considering the load carrying capability of Local Government assets, due regard needs to be given to who funds level of service requirements. Levels of service that accommodate critical local function or support local business growth and development could be considered as responsibilities of the local council however if levels of service are more about state or national productivity then potentially other organisations should be contributing to providing a suitable level of service. This is particularly relevant when demands by stakeholders are being made and the current level of service is inadequate to meet these demands.

The transport needs of the community change over the service life of most bridges. For example: delays due to frequent flooding or provision for single lane traffic only on narrow bridges often become more costly and less tolerable to the community as usage increases. Safety issues, where, for example there is no provision for separation of vehicles and pedestrians, become more acute as residential areas are extended. These factors should be considered as a part of ongoing lifecycle planning and management of the network and align with the organisation's goals. Thus, levels of service should be a dynamic consideration that is updated on a continual basis.

2.5.1 Structure Criticality

While the functional level of service defines what a structure needs to be capable of, it does not measure how critical this level of service is to meeting organisation objectives. Some structures are so important to the performance of the network that they should be defined in a specific category so that this class of asset can be managed in an appropriate way (vigilance and assurance) commensurate to the potential risk of losing the performance of the asset. These structures are defined as 'critical structures'.

Broadly, there are two risk scenarios that significantly highlight structure criticality:

1. Functional (network) performance risk – structures where the consequence of functional failure is so severe, that enhanced risk assurance is considered appropriate regardless of likelihood.
2. Risks associated with known technical deficiencies – regardless of network performance issues, known asset limitations or deficiencies generate severe risk through the prospect of fatalities associated with structural collapse.

Drivers of the former may include:

- economic impact of failure
- post emergency function
- traffic volume capacity of adjoining roads
- heavy vehicle usage of bridge
- length of detours and suitability for required vehicle types.

Examples of functional performance risk could include a:

- structure which provides the only road access to a location that is economically significant
- structure located on a link road between two towns where alternative routes would add significant time and cost and/or may not have the required level of service
- structure which provides access for heavy vehicles related to economically significant local industry
- heritage structure with high cultural value to the community.

Known technical risks by definition have a reasonable probability of occurrence, albeit under specific circumstances. Risk severity in these cases is driven by the fatal consequence potential, so the exercise of due diligence promotes enhanced risk assurance. Examples can include:

- structures with halving joints that are difficult to inspect
- structures with limited ductility
- older bridges with limited capability (design capacity)
- bridges with chronic deterioration
- structures that have primary structure details with limited redundancy etc.

The safety risk associated with these structures may motivate specialised management, inspection and care to ensure that unwanted events are not realised.

Generally, structures which have been identified as critical should receive higher priority when programming maintenance and allocating funding in order to reduce risk of failure and/or reduction in functional performance.

2.6 Risk Management

Robinson and Francis (2019) provide good coverage of relevant risk management for bridges and structures. From a historical perspective, the international hierarchy of most significant bridge failures is (McCarten 2018):

1. Waterway failures – scour, log rafts etc. (by far the most common)
2. Bridge strikes – vehicles, trains or ships colliding with the bridge
3. Structure/maintenance failures.

Conventional maintenance management practices usually provide an effective control for (1) provided that they are adequately resourced. The combination of design solutions and conventional maintenance management practices often provide effective controls for (2). There are significant opportunities to improve outcomes for (3) through better risk management processes.

Structural engineering is a key input into risk assessment and control for bridges, and three asset attributes of particular interest when considering bridge capability (load carrying capacity) are redundancy, inspectability and ductility as summarised below (Heywood et al. 2017):

- **Redundancy** refers to the ability of a structure to continue to carry loads after the failure and loss of load carrying ability of one member. The inclusion of redundancy in design has the effect of preventing the catastrophic failure of a bridge after the failure of one member. As an example, for a girder bridge, this would typically involve the inclusion of four or more girders per span.
- **Inspectability** refers to the level of ease with which all key structural members can be inspected. Key structural elements should be able to be safely accessed by inspectors with provision made for close visual inspection. Where access will require the use of equipment such as a UBIU or EWP provisions should be made for the safe setup and use of the equipment. Critically, defects in structural members should be detectable and surfaces on which defects may appear should not be hidden from view.
- **Ductility** refers to the likely failure mode of the bridge. A ductile failure will occur gradually once capacity is exceeded and will provide an indication that failure has occurred before catastrophic failure occurs, for example sagging/loss of stiffness of a girder. In contrast, a brittle failure will occur suddenly once capacity is exceeded and may lead to catastrophic consequences. Shear failures are typically brittle in nature, and designs for which shear strength controls capacity should be avoided.

Where structure risks are noted, but any structural failure would be ductile with multiple redundant load paths and readily checked, then it is quite conceivable to establish reliable risk controls, thus significantly reducing the residual risk. To the extent that structural failure does not materialise with these attributes, it can become difficult if not impossible to identify reliable risk controls, meaning that the residual risk following implementation of a risk control may remain essentially unchanged.

Contemporary risk management practice typically involves:

- identifying hazards and associated risks
- categorising risks by rating the likelihood and consequence
- identifying options to mitigate the risks using the hierarchy of controls: elimination, substitution, design, administration
- managing the residual risk
- reviewing risk in light of changes to operating conditions.

This process is defined in *Risk management – Guidelines* (AS ISO 31000 2018) and is used by many organisations as the basis for their risk management framework. Critical to a risk-based approach is the incorporation of a feedback loop that allows an organisation to review the effectiveness of their risk management procedures and what effect the level of funding is having on the cost, risk performance setpoint. Understanding the effectiveness of the risk framework is critical to demonstrating due diligence and ensuring that the business systems and process are achieving intended outcomes.

A common approach to risk management is to go through the risk management process and then allocate limited funding to address the worst risks first. One of the challenges of this approach is defining what level of risk is acceptable, how is one investment opportunity chosen over another and what is considered a reasonable limitation of funding. While using traditional risk management processes such as those identified in AS ISO 31000:2018 is useful to identify risks, it is not generally defendable to start at the top and work down the list until the available budget is expended. As discussed in Section 2.1.1, in order to demonstrate due diligence, it is important that an organisation is able to demonstrate that they have undertaken activities that are 'as far as reasonably practicable' to ensure a safe and suitable operating environment. Importantly, even business processes that are compliant with AS ISO 31000:2018 do not necessarily achieve this outcome. Risks most likely to be poorly addressed in this regard are those with high consequence, but low likelihood – the trap being 'it would be really bad if it did happen, but the chances of it happening are low, so we can't justify doing anything'. This position is very difficult to defend if the mitigations are not expensive and are relatively easy to implement.

An example could be something that is well down the risk list but there are things that are reasonably practicable to do (i.e. they are generally straightforward and not overly expensive) in which case the onus is on the organisation to ensure these measures are implemented. Extending this example: if a bridge has a condition state 4 girder but funding does not allow for repairs (funding has been allocated elsewhere) then simple and practicable measures may include closing the bridge or using traffic lights to close one lane of the bridge, directing traffic away from the location of the damaged girder, etc. These mechanisms are simple, straightforward and not overly expensive to ensure the safety and continued functionality of the bridge. If no action was taken and an incident was to occur, it would be very difficult to argue that measures 'as far as reasonably practical' were taken.

Current typical practice is influenced by current bridge information systems (Section 2.4.1) which do not incorporate processes consistent with the above approach since they (and importantly, their data structure) were developed prior to the maturation of the above process. Consequently, there is often a significant disconnect between modern corporate risk frameworks and bridge and culvert risk as described by contemporary business systems. Instead, the experience of the asset management staff is often relied upon to make decisions about what maintenance or upgrade projects are undertaken. While this approach will typically ensure the most important projects are undertaken, the residual risk associated with the approach is not quantified or documented so there is no mechanism to communicate the residual risk up through the organisation. This communication channel is essential for an organisation to demonstrate that they are carefully considering the funding allocation to their operation and maintenance activities.

Many organisations use a pseudo aggregated risk score, taking a 'bottom-up' approach in an attempt to identify and quantify technical risks. In this process, aspects associated with different risks related to a particular asset are aggregated to develop a single score or rating. This rating can then be used to rank and prioritise limited funding allocations. While this approach can be used to help prioritise maintenance, caution should be used if relying on it solely to allocate funding. Depending on the methods used, this approach can mask actual risk, as weighting factors can overemphasise aspects such as importance of the structure. This can result in situations where structures that require intervention to address significant safety issues are overlooked because they are, for example, not on a critical route. Experience is that this approach facilitates a disconnect between corporate and bridge risk framing.

2.7 Financial (Cost) Management

2.7.1 Basics

As part of modern governance best practice, Local Governments have an obligation to be transparent and accountable to the community at large (CPA Australia 2016). The community provides funds in the form of rates and taxes, and it is the responsibility of the council to demonstrate that these funds are being used to provide services with the best interests of the community in mind. Key to achieving this is financial reporting, including annual budgets, operational plans and long-term financial plans which provide the basis for annual planning.

Sound financial management practices complement best practice with regard to structures management. The structures manager should understand key financial practices related to asset accounting and how these relate to relevant structures management goals. There should also be close collaboration between structures management staff and financial staff in organisations so that there is not a disconnect between processes managed by the respective sections (ISO/TS 55010:2019).

The fundamentals of financial management as it relates to the management of bridges and road structures are discussed in the following sections, and the reader is encouraged to refer to the *Australian Infrastructure Financial Management Manual* (AIFMM) (Institute of Public Works Engineering Australia 2015a), *International Infrastructure Management Manual* (IIMM) (Institute of Public Works Engineering Australia 2015b) and relevant accounting standards for more detailed financial management guidance.

Asset accounting

According to legislative requirements, Local Governments must report the written down current cost of assets (also known as the carrying amount), accumulated depreciation, and asset values in each financial period. The valuation of road structures and related Local Government assets is chiefly legislated by the Australian Accounting Standard AASB 116 *Property Plant and Equipment*, which also covers depreciation of assets and revaluation. Certain requirements are covered by other accounting standards which are detailed below.

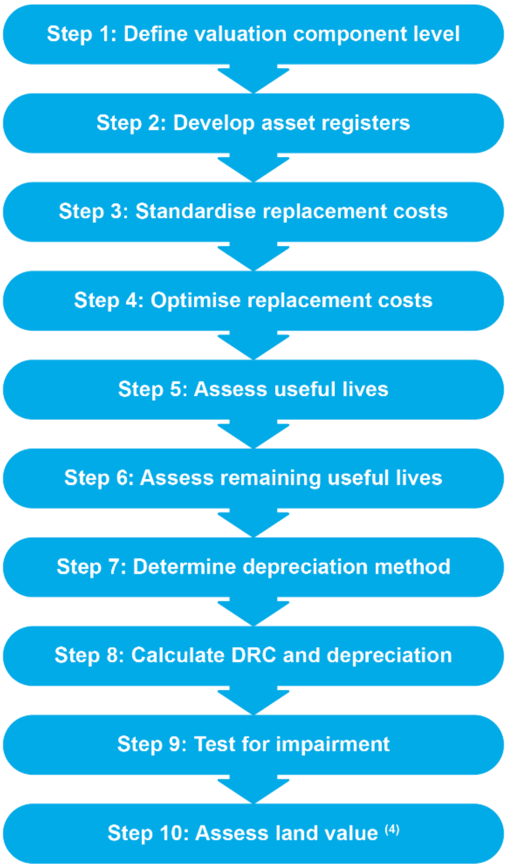
The current accounting requirements concerning assets held by Local Governments are primarily dealt with by:

- Local Government accounting regulations and guidelines issued by state and territory governments
- AASB 13 – *Fair Value Measurement*, which covers definition of fair value and sets out a framework for its measurement
- AASB 108 – *Accounting Policies, Changes in Accounting Estimates and Errors*, which covers accounting for changes to accounting estimates which may include asset values, remaining useful lives and depreciation methods
- AASB 116 – *Property, Plant and Equipment*, which covers accounting practices for most physical assets including recognition, determination of carrying amounts, depreciation and impairment
- AASB 136 – *Impairment of Assets,* which covers accounting for sudden losses in structure service potential.

Bridges effectively generate no direct income and are very rarely, if ever sold on the open market. New bridges should be valued at their initial cost to Council (acquisition/construction cost), or at fair value if the structure was donated or acquired at a nominal cost. Fair value will generally refer to the written down replacement cost of the structure (also known as the carrying amount) which is defined as the replacement value less allowance for depreciation (Institute of Public Works Engineering Australia 2015a). The written-down value must reflect operational realities and it is usually based on an estimate of the remaining life of a structure with due consideration of the maintenance or repair operations adopted by the particular council.

Figure 2.11 outlines the recommended process for developing an estimate of written down replacement cost as recommended by the IIMM and AIFMM (Institute of Public Works Engineering Australia 2015b; Institute of Public Works Engineering Australia 2015a). A brief outline of the processes associated with each of the steps is provided following the figure. Assessment of land value is generally not applicable for road structure assets and has not been discussed.

Figure 2.11: Process for calculating depreciated replacement cost



Source: Institute of Public Works Engineering Australia (2015b).

The definition of the valuation component level refers to the level of componentisation that an asset will undergo before each of the parts are valued. Appropriate componentisation will vary depending on the type of bridge or structure which is being valued, but the general aim should be to divide the structure into groups or individual components with similar expected life spans. Bridges may commonly be split into superstructure and substructure, but further componentisation can result in improved estimates, for example bearings, joints and decking are likely to have a design life different to the remainder of the structure (Kleywegt 2010). If certain components are replaced or upgraded together it will often be desirable to separate these out. Certain small bridges, culverts, causeways or other small structures may be most appropriately valued as a single component if all parts are expected to have a similar lifespan.

An asset register provides the data to support the valuation process. Data collection for use in addressing AASB 116 reporting requirements includes but is not limited to:

- structure inventory details
- year constructed
- costs of replacement
- remaining effective life

- maintenance and rehabilitation records
- condition assessment and ratings.

Further discussion relating to the use of asset management systems for road structures can be found in Section 2.4.1.

The current replacement cost is the cost of replacing the existing structure with a new structure providing the same level of service as the existing structure. An order of magnitude estimate of the replacement cost may be calculated from the deck area and current unit construction costs. A more detailed approach is to consider the unit costs of materials, services and labour required to construct the new structure. The reality is that the actual cost of any replacement is dependent on how it is packaged, market conditions and perceived risk at the time of replacement, so any such estimates should be considered indicative for accounting purposes.

Reliable sources of information for determining current replacement cost are (City of Gold Coast 2018):

- suitably qualified and experienced expert valuers
- reference to industry standards such as *Rawlinsons Australian Construction Handbook* (Rawlinsons Group 2019)
- costs incurred by the organisation in the acquisition/construction of similar structures
- estimated costs of materials, services and labour sourced from appropriate providers and aggregated by an experienced structures manager.

Optimisation of replacement cost refers to the process of determining the cost of a modern equivalent asset that will most efficiently provide the required level of service. Optimisation only applies in situations where a new asset will have a replacement value lower than for a like-for-like replacement of the existing asset, as the replacement value cannot be higher than the value of the existing asset (Institute of Public Works Engineering Australia 2015b). An example of optimisation in the context of bridges could be a deteriorated steel truss bridge being replaced by a cheaper concrete structure which provides the same level of service.

The remaining useful life of a structure is dependent on its functional adequacy and context as well as on its condition. The physical life of a bridge often exceeds its functional life, because functional requirements often change. Bridge life can be extended almost indefinitely by appropriate rehabilitation and repair but may also be shortened if the level of service is reduced by functional inadequacies or excessive load demands. From an accounting perspective, remaining useful life should be reassessed on a yearly basis and updated if changes are required.

The estimation of remaining useful life should include consideration of:

- observed condition (degree of deterioration)
- effects of age on remaining service life
- maintenance history
- functional adequacy of the structure relative to required levels of service.

Depreciation is the financial representation of asset stock consumed or the rate of asset consumption. It is intended to represent the consumption of future service potential, or future economic benefit in financial terms. All non-current assets with limited useful lives (including all road infrastructure assets) must be depreciated in accordance with the requirements of AASB 116. Preservation of the asset stock will require expenditure that is at least the equivalent of the depreciation amount. Expenditure below this level will see a decline in asset stock and/or the levels of service available to the public.

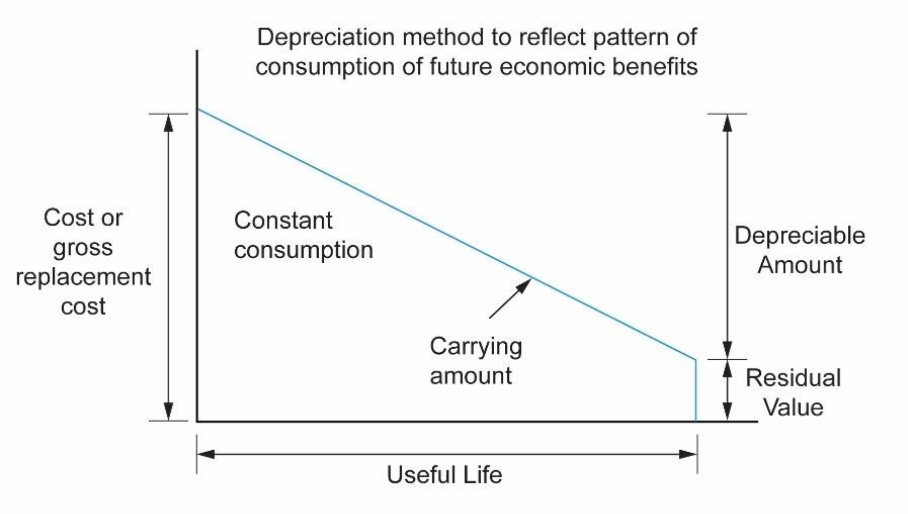
The four main depreciation methods complying with AASB 116 can be summarised as follows:

- **Straight line** – depreciation is charged uniformly in each accounting period over an asset's lifecycle if residual value does not change

- **Diminishing balance** – depreciation charged for an asset progressively reduces in each accounting period over its life cycle
- **Output/service based –** depreciation is charged at a significantly increasing or decreasing rate over the asset life cycle
- **Units of production –** depreciation charged in each accounting period can vary and is dependent on an asset's actual or deemed usage.

Straight line depreciation is most often used for bridge assets due to its ease of application and the fact that other recommended depreciation methods are less suitable for bridges and structures under typical conditions (Figure 2.12). Depreciation rates are to be reviewed annually, and, if necessary, adjusted so that they reflect the most recent assessments of the useful lives of the respective structures, having regard to such factors as structure usage, structure condition, the rate of technical and commercial obsolescence, and also the most recent assessment of the net amounts expected to be recovered on their disposal, if any (residual value). Any assessed changes to remaining useful life or residual value must be accounted for in accordance with AASB 108.

Figure 2.12: Straight line depreciation



Source: Institute of Public Works Engineering Australia (2015a).

Condition-based depreciation methods have been proposed in the past as an alternative approach for quantifying the depreciation of assets with long life spans, including road structures. These methods were developed on the basis that traditional depreciation methods could not adequately account for the depreciation of complex assets which undergo cyclical maintenance and rehabilitation that regularly extends the life of the asset (Institute of Public Works Engineering Australia 2015a). Typical aspects of these methods include periodic assessment of condition, estimation of costs required to restore assets to a certain service level, recognition of increases in restoration cost as depreciation and recognition of all expenditure (including maintenance and capital expenses) on the asset in the accounting period in which it was spent (Institute of Public Works Engineering Australia 2015b).

It was decided by the AASB Urgent Issues Group that condition-based depreciation methods do not comply with the requirements of AASB 116 and are therefore not to be adopted (AASB Interpretation 1030). Some reasons cited for this included that the depreciation expense is not determined based on the depreciable amount of the asset and that maintenance expenditure related to maintaining certain service levels is not recognised as an expense in the reporting period it was incurred. While condition-based deprecation is not an accepted depreciation method, consideration of the condition and performance of a structure is key to accurately determining remaining useful life and re-investment.

The normal starting point for assessing the remaining life of an asset would be the nominal design life minus the time elapsed since commissioning. Remaining life is what is left unless there is a reason to expect something different. However, it is important to understand that design life is a construct to facilitate the design process and is nominal. Adjusting residual life based on historical performance is important to ensure that financials are commensurate with actual in-service performance. Critically this is important to ensure:

- financial accounting is accurate i.e. residual = actual value
- the forward investment profile reflects the actual state of the network.

Sudden reductions in service life of a structure asset over and above the effect of depreciation are referred to as impairment (Institute of Public Works Engineering Australia 2015a). In real terms, impairment of a structure may occur due to damage caused by natural disaster (flood, fire, etc.), accident, overloading or vandalism. The impairment estimate in this case will be the cost of restoring the structure to its previous operational state (taking into account depreciation which had occurred prior to the impairment). The written down cost will then be equal to the carrying amount less the impairment estimate. Impairment is covered in legislation by the accounting standard *AASB 136 Impairment of Assets* and further details can be found in Section 12 of the AIFMM (Institute of Public Works Engineering Australia 2015a).

If an asset was destroyed or otherwise irreparably damaged this would not be counted as impairment, rather as a disposal and subsequent derecognition of the asset. Furthermore, if an asset was restored to its pre-damage level of service before the end of financial year, an impairment test would not be required, although the maintenance or capital expenses incurred would need to be recognised (City of Gold Coast 2018).

Financial planning

Long term financial planning regarding structure assets is undertaken with the aim of establishing comprehensive future financial needs relating to structure acquisition, inspection, maintenance, renewal and disposal as well as how these financial needs will be addressed (Institute of Public Works Engineering Australia 2015a). Long term financial plans (LTFPs) should be developed based on the best available information regarding the current state of the network, predicted future level of service requirements and structure depreciation. Long term financial planning should generally be undertaken with consideration of all asset types and operational areas to prevent siloing and allow for funding to be allocated based on the needs of each area. For example, if there was predicted to be a surplus in regard to roads expenditure in one year, more funding could potentially be made available for bridge works and vice versa.

LTFPs should cover a period of a least 4 years or longer and should illustrate the financial consequences of the organisation's planned activities (Institute of Public Works Engineering Australia 2015a). Arguably for long life structures such as bridges the horizon for LTFPs should extend beyond 30 years, in part to adequately address sustaining capital requirements. LTFPs should generally be updated annually or more often as required. It should be noted that the accuracy of financial projections generally reduces as timescales increase, but this does not decrease the value of long-term financial planning which is regularly reviewed.

LTFPs need to be underpinned by a clear financial strategy which includes practically quantifiable financial goals. A key objective of long-term financial planning is to identify the financial viability and sustainability of the level of service targets set by structures management planning. In some cases, long term financial planning may indicate that the level of service targets or projected maintenance/renewal requirements outlined by structures management planning are not financially viable based on the current financial position of the organisation, which represents a funding gap.

Long term financial planning has been in some cases neglected by organisations in the past as structures management was reasonably new and only required limited maintenance or rehabilitation input (Institute of Public Works Engineering Australia 2015a). As structures age and begin to require higher levels of maintenance, rehabilitation and renewal, it becomes crucial to undertake financial planning that considers set operating income targets in comparison to expected costs. Without appropriate long-term financial planning, significant funding shortfalls are likely which may result in reductions in structure safety and/or performance is likely to reduce.

Templates for long-term financial planning are provided in the appendices of the AIFMM (Institute of Public Works Engineering Australia 2015a). Additionally, IPWEA have developed a spreadsheet-based model for the preparation of LTFPs. This can be accessed along with the related *Long-Term Financial Planning: Practice Note 6* (Institute of Public Works Engineering Australia 2012) at the following link: https://www.ipwea.org/publications/ipweabookshop/practicenotes/pn6.

While LTFPs provide an indication of long-term resource requirements, allocation of funding is based on the inner years of the LTFP as part of capital investment planning. Capital investment planning is focused on planning for investment to acquire new structures, or the renewal of existing structures through upgrade or replacement with new structures. The overall aim of this planning task is to effectively plan for the allocation of funding to meet current and projected level of service requirements. In the Local Government context, the renewal of existing structures will generally command the most attention as the road network is likely to be fixed in most circumstances aside from the development of new subdivisions or similar.

Capital investment planning should provide time for the organisation to make well-considered decisions and provide key stakeholders with information which will allow them to undertake coordinated planning. Capital investment planning should include both new capital and sustained capital requirements. Sustaining capital is a sub-category of capital planning and provides for major periodic (and predictable) change out of components with a life shorter than that of the asset – in the case of bridges examples include, bearing and joint replacement, and repainting of structural steel. These investments are significantly larger than annual maintenance spending and should be capitalised from an accounting perspective and represented in the LTFP.

Key aspects of capital investment planning include (Institute of Public Works Engineering Australia 2015b):

- estimation of future expenditure requirements
- identifying potential projects
- developing options for each project
- evaluating options and prioritising each project
- project scoping and development of business cases
- predictive modelling of future renewal requirements based on available condition and remaining life data
- identification of need through information from inspection and maintenance of existing structures.

Some aspects relevant to capital investment planning are discussed in the Structure Lifecycle Section 2.3, and the planning and development of projects is discussed further in Section 2.8.

Short-term planning tasks include the development of yearly budgets and operational plans. In general, financial planning needs to result in outputs which are clear and easy to understand including any changes in operating context. Key indicators which demonstrate the financial performance of the organisation should be clearly visible to enable informed structures management planning. Annual budgets should generally reflect the outcomes of the long-term financial and capital planning process. Budgets must recognise the effects of depreciation and allocate funding to address the consumption of service potential. Capital expenditure and operational expenditure should be clearly distinguished within the budget.

Life cycle costing undertaken at the planning stage should be compared to expected available funding over the structure life cycle in order to identify funding gaps and enable early planning to identify suitable funding sources or adjust the proposed option (Institute of Public Works Engineering Australia 2015a). To this end, life cycle costing should be undertaken in coordination with long term financial planning. Where funding gaps are identified, potential options could include alterations to the chosen structure option, planning for borrowing or other funding options, or reduction in service potential elsewhere to address the projected shortfall.

A funding gap exists where an organisation is unable to fund the operational expenditure, maintenance or capital expenditure required to provide a satisfactory level of service across the structure network (Institute of Public Works Engineering Australia 2015a). Infrastructure studies conducted in Australia have recognised that most Local Government organisations will need to increase expenditure on maintenance, renewal and replacement into the future as structure networks continue to age and level of service demands increase, which is likely to lead to funding gaps if income does not increase (Institute of Public Works Engineering Australia 2015a). When a shortfall arises, a proactive approach is required in order to optimally determine realistic service levels which are achievable with the funding available from current income and sustainable use of borrowing and other sources of finance. This may result in a need for reduced levels of service, and a consideration of cost, benefit and risk is needed when deciding what level of reduction is acceptable in varying situations. What is critical is that a funding shortfall does not translate into uncontrolled additional risk. It is important to carefully and purposefully control the cost, risk, performance setpoint rather than just arriving at one by accident or worse still not even knowing where one sits, particularly in relation to risk.

Borrowing should not be seen as a substitute for income, and organisations must be able to generate sufficient operating income to cover operational expenses. With this said, sustainable borrowing can be an appropriate means of acquiring funds for some capital expenditure needs if a clear plan for future repayment can be developed, i.e. future operating income will exceed requirements for asset maintenance and other operational costs. Potential use of borrowings should be explored when undertaking long term financial planning. This should identify years where there may be an increased need for capital expenditure and how this compares to maintenance and operational expense projections. Local Governments have been historically wary of incurring debt, but this can lead to under-investment in new infrastructure and subsequent reductions in the level of service provided to the community. Further guidance on the appropriate use of debt can be found in the joint ACELG/IPWEA publication *Debt is not a Dirty Word* (Comrie 2014), as well as in the AIFMM (Institute of Public Works Engineering Australia 2015a).

Alignment of financial and asset management

The need for alignment of financial and non-financial practices in relation to asset and structures management is becoming increasingly recognised, and the recently released ISO /TS 55010:2019 seeks to provide guidance to organisations which wish to implement best practice. There is often a disconnect between the activities of financial and asset management staff which can lead to poor outcomes regarding allocation of funding and capital expenditure. Structures management staff should seek to gain insight into financial processes and drive better outcomes for structure renewal and operational needs by coordinating with financial management staff in capital investment planning and long-term financial planning.

Some key enablers for alignment include (ISO/TS 55010:2019):

- alignment of cross-functional processes in order to allow structure attributes to be captured in a consistent fashion in financial and non-financial structure registers
- commitment to alignment by top management through promotion of collaboration, sharing information, common understanding of terminology and ensuring that all functional areas have influence in decision-making
- adjustment of the governance framework to facilitate alignment
- strategic asset management planning to support alignment
- collaboration between financial and non-financial functions to ensure that key data is shared and accessible when required to support improved decision-making processes.

2.7.2 Relevant Standards and Manuals

There are a range of resources available which provide further guidance on financial management for asset-intensive organisations, although these resources are generally not road structure-specific. Notwithstanding this, these resources provide highly valuable guidance on the integration and execution of financial management and infrastructure asset management. These resources include:

- *Australian Infrastructure Financial Management Manual* (AIFMM) (Institute of Public Works Engineering Australia 2015a)
- *International Infrastructure Management Manual* (IIMM) (Institute of Public Works Engineering Australia 2015b)
- *Guide to Valuation and Depreciation for Public and Not-for-Profit Sectors Under AASB Accounting Standards* (CPA Australia 2016)
- Relevant accounting standards issued by state and territory governments and the Australian Accounting Standards Board
- ISO/TS 55010:2019 *Asset management — Guidance on the alignment of financial and non-financial functions in asset management*
- AS/NZS 4536:1999 R2014 *Life Cycle Costing – An Application Guide*.

2.8 Acquisition

Section 2.3 provides an overview of the life cycle of an asset and identifies the first phase as Acquisition. This section provides an overview of the acquisition phase, noting that Design (Section 3) and Construction (Section 4) both form part of the acquisition phase, and many elements of the acquisition phase are addressed elsewhere (e.g. IIMM (Institute of Public Works Engineering Australia 2015b)). For the purposes of this discussion, the IAM (The Institute of Asset Management 2015b) definition of asset life cycle has been assumed, so planning forms part of the acquisition phase. The following acquisition discussion is divided into asset planning and asset delivery.

2.8.1 Asset Planning

Overview

Sitting above the planning process for a single bridge project is the need to assess the structure network and identify which capital investment projects should be prioritised. Capital investment planning connects both financial and asset management and should be coordinated across the organisation. Planning may be conducted at the network level, and at road/link level if there are key roads that would benefit from a coordinated approach to works planning. Planning conducted at the road level may be coordinated to provide a certain level of service based on stakeholder requirements. Network-level capital investment planning should consider the cost, risk and performance implications associated with the completion or non-completion of each potential capital investment project over a certain timeframe. Whether or not certain projects fit the strategic objectives of the organisation should also be considered.

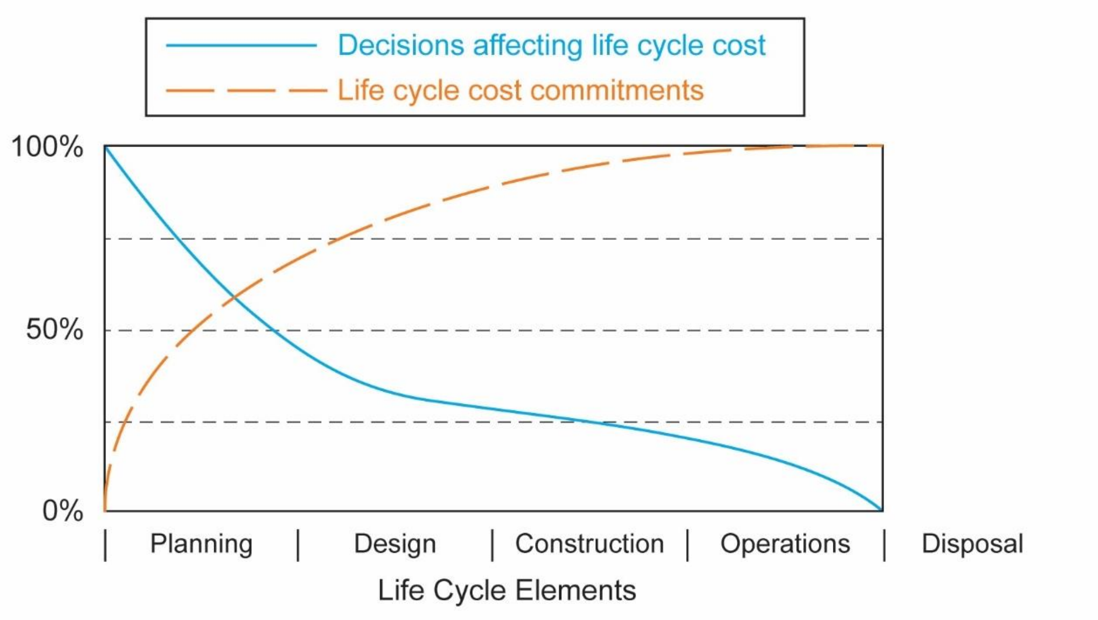
The question of whether a new structure is required at all (demand management) should be explored at the planning stage if an existing structure is proposed to be replaced. In some cases, it may be more beneficial to upgrade or rehabilitate the existing structure in order to provide the required level of service. Options to retrofit, rehabilitate or re-purpose existing structures should be considered and compared against options for a new structure in terms of associated cost, performance and risk. The current capacity and condition of the structure should be considered when examining the feasibility of rehabilitation or upgrade. Life cycle costing should be undertaken to compare options for rehabilitation against options for a new structure. Ongoing operational (inspection, maintenance, repair etc.) costs associated with a retrofitted/rehabilitated structure vs. a new structure must be considered as part of life cycle costing. The expected service life of the rehabilitated structure should also be considered in comparison to what would be possible for a new structure.

The planning stage of the structure life cycle is initiated when a potential need for a new structure or major upgrade/rehabilitation of an existing structure is identified. This will often be linked to:

- network expansion, growth or augmentation
- a change in level of service requirements for an existing structure
- deterioration to an unacceptable level of service provided by an existing structure.

The benefits (performance targets defined by level of service), costs and risks associated with the construction, operation and maintenance of the future structure should be considered when choosing a structure type and construction material. Life cycle costs are heavily influenced by decisions made at the planning stage (Figure 2.13). Almost three quarters of the decisions that will impact on life cycle cost are made during the planning stage, with the majority of factors decided by the end of the construction stage. This makes life cycle costing at the planning stage a task of utmost importance.

Figure 2.13: Life cycle cost



Source: Institute of Public Works Engineering Australia (2015a).

Capital investment planning should ideally identify time-phased capital expenditure requirements over a certain period, providing an indication of when projects are to be initiated. A need for capital expenditure may also arise from events such as accidents, vandalism or natural disasters. Project development needs to align with this capital investment planning and will also occur over extended time periods, with scoping studies and feasibility studies in particular, subject to review and update (not necessarily a single pass process). Context can change significantly over the project development period (changed demand, new technologies etc.), so it is important that business governance processes ensure the relevance of proposed capital investments, regardless of what has been reported in preceding studies.

Planning should be framed by scoping, analysis and decision-making processes through which specific requirements are scoped, potential solutions are identified and analysed, and a preferred concept selected for progressing through the acquisition phase. It has been recognised that poor concept selection is an issue that impacts on many councils across Australia, leading to unexpected project cost overruns and ongoing financial ramifications. This is not limited to bridge projects, but such projects should have comprehensive planning processes in place to ensure capital expenditure and ongoing life cycle cost forecasts are accurate and achievable.

Activities which typically form part of asset planning include:

1. project nomination – identify which bridge-related projects are a priority
2. scoping study – scope the requirements of the project and suggest preliminary options. Focus must be on scoping service requirements, identifying high-level preliminary options and establishing whether there is likely to be a business case. Business governance processes should pay particular attention to scoping studies – with the objective of 'killing' proposals early if they are unlikely to provide a business case aligned to organisational needs
3. pre-feasibility study – identify and investigate the viability of a shortlist of options, select the preferred option via options analysis, and define what will be required to establish the business case. The study should also re-confirm that a business case still appears probable
4. feasibility study – defines the business case and the request for funding allocation of the defined project. Business processes should focus on minimising expenditure on potential projects until the business case has been defined. However, in some cases activities beyond those normally required at the feasibility study stage might be advisable to de-risk the proposed project and associated business case.

The above activities (sometimes referred to as project development) are normally undertaken as part of normal business operations, although in some cases (large projects), the feasibility study may be 'capitalised' from an accounting perspective as part of the project because of the magnitude of funding required to undertake it. Similarly, for larger projects, additional funding may be required to support scoping or pre-feasibility studies because of the demand placed on business resources, however these are not usually 'capitalised' from an accounting perspective. Planning activities may in some cases be coordinated between local and state and territory government agencies and external consultants.

Performance planning

Each stage of the planning process is underpinned by a range of activities through which the needs of the project solution are defined, and performance (level of service) requirements are identified. Regarding levels of service, planning should consider:

- what happens if the service is not provided?
- currently provided level of service (for upgrades/replacements of existing structures)
- required level of service (considering the level of service provided by the road on which the bridge will be situated and other requirements)
- predicted future level of service requirements:
  - an increase in required level of service may be estimated by considering expected population growth in an area serviced by a structure or freight task growth for structures located on freight routes
  - decline in required level of service could occur due to changes in road alignment, construction of new roads or reduction/closure of industry operations (e.g. a concluding forestry operation or quarry).

Level of service requirements are determined by the current and future expected usage of the structure. Defining the level of service requirements of the potential new or rehabilitated structure should involve consultation with stakeholders including but not limited to the community, local industry and freight users as well as other affected parties such as managing agencies for waterways, rail or other services which may rely on the structure such as for telecommunication cabling.

Key contributors to the functional level of service requirement can include:

- current and expected future traffic volume on the road (or proposed road) that the structure will be located on
- heavy vehicle usage of the structure
  - service vehicles such as fire trucks, garbage trucks, school buses, local delivery trucks (typically rigid vehicles)
  - vehicles associated with local industry or through-freight (truck & dogs, semi-trailers, B-doubles)

  - permit vehicles (may have abnormal width/height/mass)
- expected pedestrian/cyclist usage
- legislative requirements and minimum standards.

Ideally the asset criticality should be identified (noting it may need review at the various stages) as this will likely also have an impact on downstream options.

Early planning should involve the identification of a range of preliminary options for further analysis. At this stage, a wide range of potential solutions may be considered, which for example could include various new bridge options, culvert options, options for upgrade or rehabilitation of the existing structure if applicable, or management solutions such as planned reduction of service provision. Key at this stage is seeking innovative and creative solutions which could for example include a new type of structure solution. In some cases, there may be an established solution which has been used by an organisation in the past (such as a proprietary bridging or an established rehabilitation method), but there should always be some consideration made of other potential options as every situation is different and there is no guarantee that a similar solution will provide the best outcome for more than one project.

Risk, cost and value

Potential risks should be identified, and high-level estimates of cost should be made for the various options. The general objective of early planning is to identify a shortlist of options for further analysis which are most likely to achieve the desired outcomes and avoid those that are unlikely to provide cost-effective performance, or otherwise introduce increased risk into the asset base. Unfortunately, this latter consideration (risk) inherently discriminates against innovative solutions, because they almost always have an elevated risk profile. It is important under these circumstances that focus is placed on risk management rather than risk avoidance, and this will require the support of the business governance process. While an option may present with an elevated risk profile, the key issue is whether effective risk controls are available to reduce the residual risk, and if so, business governance processes should provide oversight to ensure that the risk controls are effective.

Cost planning should consider all likely asset life cycle costs from initial conception, design, construction, usage, maintenance, rehabilitation through to disposal. Bridge assets may go through many cycles of decline and rehabilitation and costs associated with disposal can include those incurred by management of the asset until an option for rehabilitation or renewal is actioned. The business case needs to consider the above cost in the context of the value proposition of the proposed investment which may include:

- value to local community and industry users (where it can be defined)
- value in addressing the local freight task
- funding available for capital expenditure and ongoing operational expenditure including sources for capital expenditure and ongoing operational expenditure
- depreciation of structure asset value over the life cycle.

Funding sources for Local Government capital expenditure may include:

- rates
- grants from state, territory or federal government
- borrowing
- funding from industry sources with a vested interest in a certain bridge/route.

In some cases, industry stakeholders may have a vested interest in the level of service provided by an existing or proposed structure. The economic benefit provided by the presence of the industry should be weighed against the cost of building a structure to the level of service desired by the industry operation. In some cases, it may be viable for construction and/or operational expenditure to be partially or fully funded by industry stakeholders who will receive a direct benefit, or by state/Local Government.

Structure type considerations

Depending on the site-specific conditions, stream or gulley crossing may be achieved by a causeway, culvert (steel, pipe, box) or some form of bridge structure. The level of service provided by each of these structure types varies, with causeways and culverts potentially more prone to flooding depending on stream width. There are a wide range of options available for bridge construction, and it is likely that an investigation and choice between several options will be required.

When selecting a structure type and construction material, the following questions may be relevant:

- Will the structure type chosen meet level of service requirements? (refer to Section 2.5)
- Does the concept offer general robustness including redundancy, inspectability, and ductility? (Heywood et al. 2017).
- What waterway area (if any) is required?
- How durable is the material when considered against the environmental conditions that it will be subject to?
- Does the Local Government organisation have an in-house skill base which will support continued maintenance of the structure, or is the agency confident in their ability to procure contractors with relevant skills over the life cycle of the structure?
- Is there a local skill base for construction?

The skills required to inspect, maintain and rehabilitate a structure over its life cycle need to be considered in the process of identifying the best structure option. Skills required for design and construction must also be considered. As the complexity of structure options increases, so may the cost and difficulty of procuring personnel capable of delivering the required services. This does not necessarily mean that councils should avoid adopting emerging or uncommon technologies for structure delivery, but the benefits, costs and risks associated with such systems should be carefully considered along with any proof of past performance. Consideration should also be given to whether inspection and maintenance will be able to be undertaken using in-house resources, or if these tasks will be undertaken by external providers.

When planning for a new structure, future level of service requirements must be considered carefully. It is relatively inexpensive to add additional capability or capacity to a structure at the design stage, but it can prove to be a very costly exercise to add additional capacity to a structure which has already been constructed. A typical example of this is the inclusion of substructures that are significantly wider than the installed superstructure, allowing rapid widening with minimal works in the future should the demand exist.

There is just as much a need to undertake in-depth life cycle planning when receiving contributed infrastructure (such as from an industry operator, subdivision developer, state road agency etc.) as there is when constructing a new bridge or renewal from scratch. There is limited (or no) initial capital expenditure for contributed assets, but life cycle costs can often be high, especially if council has had no input into the design and construction process as it is possible that whole-of-life costing has not been comprehensively considered by the agency which has managed acquisition and operation prior to handover.

The availability of personnel skilled in the construction of the preferred structure option must be a consideration when identifying a design option to proceed with. If there is not a local skill base available who can deliver the preferred structure option construction costs will increase as there will be a requirement to procure a temporary workforce from outside the region. For regional and remote areas, use of pre-engineered bridge solutions which enable rapid construction can be an attractive solution if site conditions allow (Pathirage & Mahagamage 2018). These options are typically subject to some limitations related to configuration and level of service functionality.

2.8.2 Asset Delivery

Overview

Delivery of a structure asset or major upgrade/rehabilitation works is initiated once planning has advanced to a stage where it is agreed that a new structure is required, the organisation has identified a preferred course of action, the business case has been approved, and funding secured. At the delivery stage, the organisation should be confident in the preferred concept design of the structure. Changes, either in project or structure configuration following approval of the business case, are problematic, and result in increased risk. If concerns are raised early in the delivery process, it may be advisable to consider re-evaluation of the business case to ensure that all issues are appropriately considered. In any case, a thorough risk assessment should be undertaken at the business governance level if substantial changes to delivery are proposed post business case approval.

Delivery includes design and construction of the asset. Whether these stages should be considered as separate or combined will depend on the project configuration, particularly the commercial structure of the delivery solution approved in the business case. Delivery will typically involve the following phases:

- development, pre-construction (implementation strategy, detailed design, costing, contract development)
- procurement of design, construction and materials
- implementation, involving construction and related project management tasks including coordination of contractors
- finalisation, involving commissioning, handover, review of lessons learnt and project closure.

Since design and construction and to a certain degree planning will generally be performed by external parties, it is of the utmost importance for council to maintain steering influence over the process to ensure that the end result represents what was envisioned and meets the requirements of the expected users.

Procurement

There are a range of contract options which may be used for road structure procurement (Austroads 2018a) including:

1. self-perform – council undertakes delivery using internal resources, augmented as required by specific external skills
2. conventional delivery – council organises external parties to undertake the various delivery phases under its own direction
3. design and construct – council essentially outsources delivery to an external party.

Other options are also available, and if adopted, should be described in detail in the business case.

Design and construction

Design and construction are not the focus of this guide as discussed in Sections 3 and 4, however it is important to address some key issues associated with design associated with Local Government delivery.

Detailed design may be undertaken in-house or by external consultants, with external design procurement being the most common method used by Local Government. If design is completed externally, the council organisation should be involved in review to ensure that the design meets their requirements but should also avoid being too prescriptive as this may hinder the development of a best-case solution. Review processes must be in place to ensure that the design is consistent with requirements identified during planning as well as with legislative requirements such as the AS 5100:2017 suite of bridge design standards. Critically the council must be involved in specifying the required level of service.

Costs associated with design will vary depending on the complexity of the solution required, the site conditions and level of service requirements. Design may be a relatively straightforward process in cases where the bridge type is relatively common and site conditions are favourable. More complicated designs may be required for sites with complex hydraulic or geotechnical conditions or where there are special performance requirements. These should be identified during the planning stages and included in the development of preliminary design estimates.

Regardless of the procurement process used, it is essential that the asset owner has oversight of the construction process. As a minimum, this should include review and approval of construction plans, and review and/or witnessing at defined hold points identified in the plan. Where council skill sets are limited, it is recommended that the council engage third party advisors to support oversight of the construction process. Execution of construction substantially sets up the on-going cost and risk profile of each asset. Due diligence over this process should be undertaken, and at the very least, there is no substitute for being an informed client.

Asset hand over

Regardless of the delivery process used, a critical interface exists when the asset is handed over from the acquisition to operational life cycle phases. The structures management team should have been involved at least in an oversight role in the scoping, planning, and delivery process, however it is prudent for this team to undertake a pre-hand over (internal) review of major assets, or asset packages to ensure that key requirements (particularly those defined in the business case) have formed part of the delivered solution.

One of the long-term deficiencies of the infrastructure hand over process is the appropriate transfer and storage of data associated with the new asset. Operational readiness processes should have defined (among other things), what data is required, what form it should be in, and how it should be structured to be compatible with the council asset information system. Good data governance requires that the data delivered is assessed against these criteria. It is often difficult to obtain this data from the delivery team when required as they are usually under substantial delivery pressure. Historically data transfer has been compromised, resulting in long term liabilities for Council. A key tool to mitigate this risk is to clearly define data requirements at handover in the contract and attach a substantial payment milestone at the end of the delivery phase based on delivery of a valid data set.

Due diligence is also facilitated when the structures management team specify a Level 2 inspection as part of the asset acceptance process (independent of that required as part of the delivery process). Not only does this benchmark asset condition, it provides a useful tool to ensure that appropriate issues can be identified within the defect liability period of the delivery team. It is important that such inspections are done by suitably qualified personnel either from the council or through an independent party. To ensure appropriate impartiality, handover inspections should not be engaged by the contractor.

2.9 Operation of Bridges and Culverts

Once a structure is commissioned, handed over and opened for use, the operational phase of the life cycle begins. The general objective of the structures manager during this phase is to continue providing an acceptable level of service while safeguarding the user and minimising operational costs. In structures management terms, the goal is to achieve a balance between performance, risk and cost as described in Section 2.4. Rather than considering structures in isolation, a management strategy should be developed that considers the operation of the structure network as an interconnected entity. There are a range of operational processes that relate to the road network (e.g. whether a road is open or closed or how traffic is managed) that are not discussed further in this Section. From a bridge and culvert management perspective, the two most significant operational activities are:

1. structural inspections
2. structural assessments.

Both are discussed in some detail in Section 2.9.1 and Section 2.9.2 respectively.

2.9.1 Inspection of Bridges and Culverts

Current bridge inspection regimes were established with a maintenance management framing, rather than an asset management framing. While there are opportunities for better outcomes as a result of re-framing the inspection regime, the current approach is reasonably robust when effectively implemented, so discussion in this section is focused on generally accepted Australian practice. Inspections facilitate monitoring of the performance of structures by structures managers to ensure they are operating at the intended level of service with risks commensurate with the risk appetite, policies and procedure put in place by the organisation to manage identified risks. In order to monitor the performance of structures, inspections are carried out on a regular periodic basis, and as required in special situations to:

- check the condition of structures
- understand the potential exposure to (and facilitate control of) risk
- provide the basis for further maintenance, repair and renewal treatment decisions.

The frequency of inspections is set according to organisational policies which need to be developed to manage potential risks that can develop over time. Inspection frequencies vary from organisation to organisation and depend on many operational factors. In general, the inspection data together with design and construction records (hand over) are used to:

- understand and record structure condition and significant defects
- identify developing issues and manage risks according to the policy and asset management strategies put in place
- provide relevant inputs to facilitate financial management of the portfolio (Section 2.7)
- maintain a current structure inventory
- establish structure performance history
- prepare maintenance and replacement programs
- ensure condition is considered when assessing heavy vehicle access requests
- provide feedback to design, construction and maintenance engineers
- identify design weaknesses.

Reframing the inspection regime based on asset management principles will provide increased emphasis on identification of functional failure modes, causes and effects along with the mean time between these failures. This will become increasingly important as asset management systems of organisations become more mature.

Basics

Bridges and culverts deteriorate over time due to natural processes. Several factors including use of unsound or incompatible materials within the structure, incompatibility between the materials and exposure environment, overloading, and poor workmanship at any stage of planning, design, construction and operation may exacerbate deterioration. Bridges may also be damaged due to accidents and natural disasters. Timber bridges deteriorate as a result of the decomposition of wood, even in the absence of aggressive environmental conditions, and the process is accelerated when the environment is aggressive. Other materials have similar deterioration mechanisms, that for accounting purposes (Section 2.7) could be considered as environmental consumption of the asset. Under a maintenance management regime, both operational issues (e.g. accumulation of debris) and condition deterioration are key inputs into subsequent servicing and maintenance activities and are detected via asset inspections.

Generally, in Australia, three levels of structure inspection are conducted which vary according to inspection purpose and frequency. These can be summarised as:

- Level 1: Routine maintenance inspection

- Level 2: Condition inspection
- Level 3: Detailed engineering inspection.

These are defined in more detail in the following subsections:

Level 1 inspection

The purpose of a Level 1 inspection is to check the general fitness for purpose and serviceability of a structure, particularly for the safety of road users, and identify any emerging problems that can be identified by an on-foot inspection. These inspections are generally carried out regularly on a 6-monthly or yearly basis and should also be conducted immediately after floods and other natural disasters (e.g. cyclone, fire, earthquake, landslide), bridge strikes or suspected overload events. Level 1 inspections may be conducted in conjunction with routine road and structure maintenance where practical.

Inspection should be carried out systematically and include all visible elements related to the bridge including adjoining roadway, footpaths, signs, embankment and waterway in addition to structural components. Visible problems, maintenance needed and requirements for higher levels of inspection should be logged by the inspector on an inspection form. A list of elements in scope of Level 1 inspections is included as part of the sample inspection form provided in Appendix B of this guide.

Any readily correctable maintenance tasks identified during Level 1 inspection such as loose non-structural bolts or blocked scuppers should be addressed when detected if access is safely available. All detected issues should be logged in the inspection report with notification of the corrective actions taken if applicable. This allows the structures manager to keep track of what maintenance has been carried out and what maintenance is required which in turn supports higher level maintenance planning and prioritisation.

Level 1 inspections are often undertaken in-house by Local Government, while Level 2 and Level 3 inspections are most typically delivered through external contractors. Where this is the case, there should be robust data sharing practices in place which allow the findings and recorded data of Level 1 inspections to be accessed by Level 2 inspectors and vice versa. Level 1 inspections should be carried out by personnel who have extensive practical experience in road and bridge routine maintenance and are able to assess by visual inspection the condition of structures and the road approaches.

Figure 2.14: Level 1 inspector

Level 2 inspection

Level 2 inspections are visual inspections which are focused on rating the condition of all accessible structure components above ground and water level, detecting defects in components and identifying maintenance issues. The scope of Level 2 inspection will generally include (Lake, Kotze & Ngo 2012):

- compilation of an inspection inventory in accordance with a predefined bridge component identification system
- visually inspecting all bridge components in close proximity to the individual elements to assess their condition using a standard condition rating system
- reporting the condition and extent over which it applies, of each bridge component
- providing a general condition rating for the structure as a whole
- identifying bridges and/or components which need further investigation, e.g. because of a rapid change in structural condition or deterioration of critical structural components
- identifying components which require closer condition monitoring and observation at the next inspection, for example, components which have deteriorated to condition state 3 or 4 or show rapid deterioration
- identifying supplementary testing as appropriate
- identifying the exposure classification in the immediate proximity of each bridge component
- providing a photographic record of the bridge and identifying any deficient or non-standard components
- identifying, and quantifying components for bridge inventory records
- identifying maintenance requirements and/or deficient maintenance practices
- verification of any 'design inventory' if required
- identifying if any Level 3 engineering investigations are required.

A system of four condition states is typically adopted for Level 2 condition inspection in Australia. Condition states 1 to 4 correspond to decreasing levels of overall structure or component condition. An additional condition state 5 (CS5) is applied to a structure when immediate closure is required due to a serious structural integrity issue which impacts on user safety. A situation which requires an overall CS5 bridge rating should immediately be communicated to the structures manager to be actioned upon. Table 2.2 has been adapted from the TMR *Structures Inspection Manual* which provides an example of subjective condition ratings 1 to 4 for a component (Queensland Department of Transport and Main Roads 2016).

Table 2.2: Condition states

Condition state	Subjective rating	Description	Action
1	Good ('as new')	Free of defects with little or no deterioration evident	No action required in foreseeable future
2	Fair	Free of defects affecting structural performance, integrity and durability Deterioration of a minor nature in the protective coating and/or parent material is evident	No action required until at least next programmed inspection
3	Poor	Defects affecting the durability/serviceability which may require monitoring and/or remedial action or inspection by a structural engineer Component or element shows marked and advancing deterioration including loss of protective coating and minor loss of section from the parent material is evident Intervention is normally required	Action required prior to next programmed inspection

Condition state	Subjective rating	Description	Action
4	Very poor	Defects affecting the performance and structural integrity which require immediate intervention including an inspection by a structural engineer, if principal components are affected Component or element shows advanced deterioration, loss of section from the parent material, signs of overstressing or evidence that it is acting differently to its intended design mode or function	Action required as soon as possible
5	Unsafe	This state is only intended to apply to the overall structure rating Structural integrity is severely compromised, and the structure must be taken out of service until a structural engineer has inspected the structure and recommended the required remedial action	Action required before bridge can be returned to service

Source: Queensland Department of Transport and Main Roads (2016).

The structure inspection manuals developed by state and territory road agencies contain condition rating guidelines tailored to specific structural components. Also provided in these manuals are details of defects common to specific components and structure materials. Most manuals contain photographic examples of common defects and condition ratings. Refer to Section 2.10.3 for further details on these inspection manuals. As a local road authority, there is no need to develop an inhouse Level 2 inspection manual and it is perfectly reasonable to adopt one of the state/territory manuals for this purpose. While it is not necessary to adopt the manual adopted by your state/territory, it may be prudent to do so as this may assist with consistency of information when transferring structure ownership between entities and may be a requirement of state or territory funding initiatives.

Inspection reports are the major output of Level 2 inspection, and it is important that the reports are of high quality and can be easily integrated into the organisation’s data management system. The report generated for each structure is usually broken into several sections which cover different aspects of the inspection. A suggested report layout is as follows:

- structure condition: inventory information, general comments, overall structure condition rating
- component condition: condition ratings for each component, comments
- defective components: components which have specific defects, recommended actions
- exceptions: components which were unable to be inspected
- photo and sketches record: high quality photos of approaches, overall structure, key components
- scour survey (if applicable): check of scour depth for applicable components
- timber drilling record (if applicable): details of timber drilling carried out.

A Level 2 report template has not been provided in this guide because each state/territory has a proforma incorporated into their Level 2 inspection manual. What is critical is that the flow of information from Level 2 inspections is consistent from year to year, contractor to contractor. Care needs to be taken when tendering Level 2 inspections in terms of the format of inspection forms and data capture. It is important to avoid falling into the trap of using data formats that are convenient to the contractor but difficult to incorporate into the organisation’s systems.

Quality review of Level 2 inspection reports is a key part of the asset management process which should be undertaken by people who have bridge engineering experience in order to confirm and validate findings. While appropriate inspector training and experience will reduce the likelihood of defects being missed, inspectors are only human, and mistakes can be made. It is important that the inspection processes in place consider this and account for potential errors. To this end, the capture of high-quality photos of all key components during inspections is very important as these photos may show defects which can be identified during review.

Level 2 inspection frequency varies between jurisdictions, with recommended intervals ranging from 1–7 years for different state/territory road agencies. Inspection frequency can be varied according to several factors including:

- structure type
- structure material
- environmental classification of structure site
- previously recorded structural condition
- frequency and extent of Level 1 inspections
- structure criticality.

For example, timber bridges or steel culverts may require shorter inspection intervals due to their increased potential for deterioration. Inspection frequency may also be increased for structures which are network critical, but the necessity and benefit of this should be determined by the overall structures management strategy adopted. Out-of-schedule Level 2 inspections may be triggered by the findings of Level 1 inspections if the Level 1 inspector or reviewer believes there is a need for a more detailed inspection.

Critically, budget constraints should not be allowed to impact on the development of an inspection schedule or the adherence to a schedule once it has been implemented. This is a critical element of asset management strategy that cannot be overlooked.

The following Level 2 inspection frequencies are recommended in the absence of any existing policy (Lake, Kotze & Ngo 2012):

- timber structures every 2 years (CS1-2), every year (CS3-4)
- steel and concrete bridge structures every 5 years (CS1-2), every 2 years (CS3), every year (CS4)
- steel culverts every 2 years (CS1-2), every year (CS3-4)
- underwater components every 8 years.

It should be noted that condition rating is a subjective process, and the rating applied to a component or structure can vary depending on the experience and preferences of the inspector. In certain circumstances, a change of inspector may result in a change of applied condition state without any change in the actual condition of the component in question. This can occur in situations where a rating has been applied based on inspector knowledge of a certain defect type, or when a condition rating has been reduced in consultation with the structures manager contrary to the guidelines of the inspection manual.

In order to most effectively apply the condition rating system, condition states 1 to 4 should be linked to actions which relate to the structures management process. These can be defined in simple terms as follows:

- CS 1: do nothing for a long time. The structure is in good condition. Annual Level 1 inspection is required as usual.
- CS 2: do little for a short period of time (until next inspection). Some maintenance may be carried out to maintain the structure within CS 2 rating. Annual Level 1 inspections should be carried out as usual.
- CS 3: do something soon. CS 3 requires intervention within the next year to prevent the onset of structural damage if deterioration is not mitigated. Depending on the nature and extent of the defects, the actions may include:
  - monitor (closer intervals than typical Level 2 inspections)
  - Level 3 inspection
  - maintenance
  - renewal.
- CS 4: do something now. Immediate intervention is required for structures having a CS 4. It may involve:

- – Level 3 inspection
- – traffic control and/or speed restrictions
- – load limit posting
- – maintenance
- – closing the bridge
- – renewal.

The addition of an action helps ensure that the ratings given are well founded and reduces the incidence of overly conservative poor ratings which overstate the severity of the existing defects. Actions linked to defects which attract a CS3 or CS4 rating should form the basis of maintenance and rehabilitation works planning.

An example of a situation where a conventional condition rating is overly conservative could be abutment cracking where crack widths >0.6 mm will result in a CS4 rating under most current Level 2 inspection manuals. In this case, despite the width of the crack, the abutment cracking may not have a serious impact on structure safety and an appropriate response may be to simply monitor the cracking for any impact on durability. A decision on the severity of a defect and priority of any required corrective measures should be made by a qualified structural engineer with bridge engineering experience when the defect exists in a structural component.

An alternative to the condition rating system of four condition states consists of a system of nine condition states. This system is specified by the United States Federal Highway Administration (FHWA) and has been used by the DPTI in South Australia to rank overall bridge condition for federal funding allocation (Lake, Kotze & Ngo 2012). The system is generically the same as the four CS system, with the addition of extra condition states including ‘excellent’ condition and further granularisation of poor condition. This system is not recommended as it not as easy to apply compared to the four CS system and cannot be easily linked to structures management actions as previously described. Also, most training courses in Australia focus on the 1-4 rating system.

Defect-based inspection is an alternative approach to condition rating which is focused on identifying major defects in components and tracking related deterioration. This approach is used in some circumstances to support deterioration modelling of specific defects. There is the potential for defect-based inspection to lead to an undue focus on certain major defects, while the rest of the structure is neglected. For this reason, defect-based inspection is not recommended in most circumstances. Basing Level 2 inspections around condition rating promotes a systematic approach to inspection practice where all components receive attention. This reduces the likelihood of defects being missed in inspection and allows the manager to understand the condition of the complete structure.

Level 3 inspection

Level 3 inspections are undertaken to investigate specific defects and issues where:

- structure condition cannot be adequately quantified by Level 2 inspection
- where the load carrying capacity needs to be understood
- when the structures manager wishes to determine requirements for rehabilitation or replacement.

Such inspections generally need to be carried out by engineers or technologists with specialist expertise relevant to the objectives of the inspection. Common inspection activities can include:

- coring of structural members
- laboratory testing
- underwater inspection
- desktop analysis of structural capacity or capability
- load testing.

Due to their complexity and skill requirements, Level 3 inspections are usually only conducted when required, with no recommended set schedule. In some cases, Level 3 inspections may be programmed if there is reason to conduct a specialised inspection on a regular basis. Sometimes these are referred to as a Level 2.5 inspection. Examples of this might include underwater inspections or inspection of the internal area of box girders. Appropriate inspection schedules will vary in this case and should be set based on the level of risk associated with the component(s) to be inspected and the overall criticality of the bridge asset. Level 3 inspections are often called up from a Level 2 inspection to investigate critical issues or defects that have been identified.

Level 3 inspections are expensive to undertake and clear goals and mechanisms for achieving them should be developed before undertaking the work. The scope should ideally not overlap with the scopes of Level 1 or Level 2 inspections but may if these inspections are out of date or have not been carried out appropriately. Clear aims and objectives must be defined before a Level 3 inspection is undertaken. The potential upside of any Level 3 work should also be carefully assessed to ensure that there is an opportunity for appropriate value to be realised from the work. For example, there is not much point undertaking material testing on a structure that was only designed to take half of the current service level requirements.

Critically, there must be a clear understanding of whether the chosen Level 3 inspection activities will achieve the intended aim of the inspection. For this, gaining the advice of a professional skilled in undertaking such inspections should be sought and a second opinion obtained when there is a conflict of interest in certain advice being provided. For example: dynamic load testing may be undertaken with the aim of establishing additional bridge capability through establishing the dynamic amplification factor for a bridge. Dynamic load testing is however unlikely to yield a less conservative dynamic amplification factor compared to standard assumptions as tests are done using service loads at low speeds. Once this information is gathered it cannot be disregarded but it does not help with making decisions when it can only be speculated that the dynamic amplification factor may be lower in situations of full overload and multiple presence of vehicles.

An incremental approach to Level 3 investigations is recommended to ensure the most cost-effective solutions and options are arrived at. To date, many organisations attempt to lump all possible options that may be required into a single tender. In most situations this is inappropriate because it can lead the investigation down paths that are unnecessary and unproductive. A common example of this is where Level 3 investigations are incorporated with strengthening designs. This approach leads the investigation to the enviable conclusion of strengthening or replacement is required as the consultant has already priced it and is the type of work they would prefer to do. Often this can lead to sub-optimal outcomes.

The critical challenge to agencies in the future is to address procurement issues to allow the award and management of appropriate contracts that support Level 3 investigation outcomes. To assist with effective decision making and to realise true value, procurement needs to support a progressive and incremental approach to engaging consultants so that incremental decision making can be considered.
Austroads (2018c) provides more information on undertaking higher order assessment and Level 3 investigations. It summarises the types of Level 3 investigations available, uses, pitfalls and order of magnitude costs.

Decision making based on inspection data

Data obtained from inspection is used as an input to inform strategic, tactical and operational decision-making for structural assets (Section 2.4). It is important to recognise particularly with Level 1 and Level 2 inspections (in most jurisdictions), that inspectors are required to propose servicing and maintenance actions. The context in which the inspector makes those recommendations is consideration of a single asset against a set of criteria and the inspector's experience as discussed above. The decisions (proposed recommendations) of the inspector are context specific and may not directly translate to appropriate decisions at the network level. Recommendations from inspections must be reviewed in the context of network and asset strategies and plans which the inspector is unlikely to be privy to. From a data consistency perspective, it is also important that the inspector does not include this broader context in their deliberations, since this broader context will be variable over time, whereas the inspector's context should be relatively fixed. Level 3 inspections are usually scoped following the network review process, and so usually form a directed and structured input into the organisational decision process (as recommended above), relatively independent of the inspection context.

Relevant standards and manuals

There are several road structure inspection manuals which have been compiled by state road agencies in Australia. Some of these include:

- TMR *Structures Inspection Manual* (SIM) – Queensland (Queensland Department of Transport and Main Roads 2016)
  - https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Structures-Inspection-Manual
- RMS *Bridge Inspection Procedure Manual* – NSW (Roads and Traffic Authority 2007)
  - https://www.rms.nsw.gov.au/business-industry/partners-suppliers/document-types/guides-manuals/bridge-inspection.html
- VicRoads *Road Structures Inspection Manual* (RSIM) – Victoria (VicRoads 2018b)
  - https://www.vicroads.vic.gov.au/business-and-industry/technical-publications/bridges-and-structures
- MRWA *Inspection Guidelines* – Western Australia (Main Roads Western Australia 2019)
  - https://www.mainroads.wa.gov.au/BuildingRoads/StandardsTechnical/StructuresEngineering/Pages/Asset_Management.aspx

These manuals have been developed according to the specific requirements of each agency. There are some variations in procedure and component terminology between manuals, but the founding principles of each are relatively consistent. Local Government agencies need to consider that road agency manuals have been prepared to meet road agency needs, not those of Local Government, which are generally more resource constrained, and may have region specific issues. Thus, while Local Government agencies in each state/territory might sensibly use the corresponding road agency documentation as the basis for their activities, careful consideration should be given to adjusting requirements to meet specific Local Government needs. For example, it may be in the interests of a remote regional council to adhere to the road agency Level 1 inspection regime (which can be done with local resources), and reduce the inspection frequency for Level 2 inspections (most likely undertaken by external resources) to more cost-effectively manage their assets. While such decisions may be prudent, ***care should be taken to accurately record the basis for such decisions*** (demonstrating due diligence – Section 2.4.1), ensuring that such adjustments are approved in the corporate governance and risk processes. While adopting the relevant state-based manual is not mandatory in the event of asset acquisition from state government, data consistency is more likely if the council already uses the state based manual and processes.

Adopting a consistent inspection manual and reporting format over time is very important to ensure that data remains relevant over time and useful to establish the historical performance of each structure component and monitor the progress of defects. Such consistency will ensure that structures are managed effectively and systematically, enable managers to identify current and future maintenance requirements, assess the effectiveness of treatments, establish patterns of deterioration modes, and identify rehabilitation and replacement budget needs (Lake, Kotze & Ngo 2012). In this regard, it is important to ensure that there is alignment between contractor inspection processes and those recognised by the council.

It is possible to develop an inspection manual from the ground up, but this is an expensive and time-consuming exercise which is not likely to result in greatly improved outcomes when compared to the formerly described approach. It is generally not advisable to adopt overseas manuals as inspection practices may differ from what is recognised by local contractors.

Procuring relevant service

Consultation has shown that most councils conduct Level 1 inspections internally, while Level 2 and Level 3 inspections are most often conducted by external consultants. Where this is the case, data captured from Level 1 inspection should be readily accessible to Level 2 and Level 3 inspectors. Data management practices adopted by the Local Government should be designed to facilitate this. Similar considerations apply if Level 1 inspection and Level 2 inspection are contracted out to different providers. In any case all raw data from inspections needs to be entered into the council's data systems with council maintaining full ownership regardless of the service provider.

It is ideal for periodic inspections to be carried out by the same personnel to allow consistent condition rating and for the inspector to develop an ongoing understanding of structure condition which can be communicated to the structures manager. When contracting for work this may not always be possible however, and in all cases, data from previous inspections should be available to the inspectors so that changes in condition and the development of new defects can be identified.

It is important that the format of the inspection outputs be defined in the procurement documents including the format of the data required for easy utilisation in the council's structures management system. Consistency with previous and future reports is usually desired and council may specify custom requirements if preferred. It is generally more cost-effective to base data requirements on typical formats such as the state/territory road agency manuals as contractors are likely to be familiar with these. The inspection manual adopted by the client should be specified in tender documentation and any manual amendments made by the client should be provided to the contractor prior to commencement.

The following is a summary of the key items that should be dealt with in contract documentation for Level 2 inspection and pre-award negotiations:

- inspection manual and any special formats to be used
- vegetation removal, roles and responsibilities
- how inaccessible bridges and bridge elements are to be dealt with
- clear access scope, methods and pricing (What level of access is expected of the supplier (on foot?, arm's length inspection?, specialist access equipment))
- safety and environmental requirements (requirements of safety management plan documentation, number of personnel required on site should be specified as a minimum of two both with first aid certification)
- traffic management process including both the contractor's and jurisdictional responsibilities.

An example scope of services template for Level 2 inspection is provided in Appendix A that may be modified to suit organisational requirements. The scope of services is intended to outline the responsibilities of the contractor and the client organisation in regard to the delivery of the inspection service.

Inspector training, qualifications and accreditation

It is important that inspectors are appropriately trained and experienced before undertaking inspections as a lead inspector. Typically, for Level 2 inspections, this would need to include some sort of recognised training course with a minimum number of inspections undertaken and reviewed by an experienced inspector/engineer, however currently there is no legislative prerequisite required for undertaking Level 2 bridge inspections.

Some local agencies insist on having engineers with national or state based chartered engineering status undertake Level 2 inspections. While the appropriateness of this approach can be rooted in the organisational approach and responsibility placed on a Level 2 inspector, an increased cost for undertaking such inspections should be expected. In most situations an inspector who has undergone a recognised training course along with a suitable duration of experience should be suitable for undertaking Level 2 inspections.

As the scope of Level 3 inspection varies greatly it is not possible to comprehensively summarise which qualifications may be required, but it is likely that experience and a higher-level qualification in structural engineering or other field relevant to the objectives of the inspection (e.g. hydraulic, geotechnical engineering etc.) will be required. Typically, Level 3 inspection should only by undertaken by chartered engineers or specialist technicians based on the specific job requirements.

Level 1 inspections can be carried out by anyone who has had exposure to bridge maintenance but again inspectors should have undergone suitable training through a recognised training program. While there is not a legislative requirement for Level 1 inspectors to be formally trained, having suitably trained routine maintenance staff undertake Level 1 inspections can improve inspection and maintenance outcomes.

The issue of experienced, qualified and accredited inspectors has plagued the bridge management industry and these terms are described below to provide clarity around these issues.

- Experienced Inspector: An inspector who has undertaken recognised short course training in the inspection level being undertaken and has a suitable level of experience gained by undertaking inspections in the field.
- Qualified Inspector: Currently there are no official Level 2 bridge inspection qualifications available in Australia and none are required by legislation. The following TAFE units are relevant, but their usefulness depends on the quality of the provider:
  - RIICSG405D: Carry out inspections of civil structures
  - RIIIMG301D: Maintain site records
  - RIIRIS301D: Apply risk management processes
- For Level 3 investigations the qualification of chartered engineering, or supervision under the direct supervision of a chartered engineer is recommended.
- Accredited inspector: An accreditation is handed down by an organisation to allow an inspector to undertake inspections of their structures. This can involve training courses, experience and a program of audited inspections. These accreditations are usually only relevant to the particular organisation with specific training and accreditation only being available to staff and contractors of that organisation. This accreditation is usually not available to the general engineering community and supply and training is limited to meet the organisation’s requirements only.

One of the challenges in recent times has been that, when specifying inspector requirements, local agencies have sometimes called up state-based accreditation requirements. The problem with this approach is that such accreditation is not typically available to the general engineering public and thus limits the potential pool of tenderers to ex-employees of the particular state agency. Even then, the reality is that their ‘accreditation’ would not be current unless they still worked for that agency. This can be seen as anti-competition and will likely result in sub-optimal outcomes. Instead it is recommended to focus on demonstrated experience and appropriate training requirements that are universally available.

2.9.2 Structural Evaluation and Heavy Vehicle Access Requests

Background

As an asset owner and road manager, local councils are often called upon to assess applications for heavy vehicle access to a particular route and confirm that the structures on the route are capable of carrying the specific vehicles. In most states/territories, applications to gain access/use of a bridge or major culvert will be made by an applicant through the NHVR (National Heavy Vehicle Regulator).

The NHVR will send through the proposed route, the nature of the application (single trip, duration permit) and the vehicle configuration including masses and spacings. It is the road agency's responsibility to provide or deny approval to the application. For illustrative purposes, an example of an Oversize Overmass permit vehicle is shown in Figure 2.15. This particular example is en route to a mining operation.

Applications for bridge access needs to be assessed on a rational basis. It is not sufficient to just say no. Equally, it is not acceptable to say yes without sufficient defendable consideration. Road agencies must show due diligence in all aspects of managing structural assets.

Figure 2.15: Oversize Overmass (OSOM) permit vehicle

Understanding bridge assessment and heavy vehicle access assessment context

This section focuses on making a clear distinction between bridge assessment and heavy vehicle access assessment. While the two use similar engineering fundamentals they are different, and it is important to understand these differences to ensure that any assessment is appropriately focused and undertaken by appropriate systems and/or suitably qualified people.

Bridge assessment is similar to bridge design and focuses on ensuring that:

- the estimate of load effects < an estimate of structural capacity.

The estimation of load effects and structural capacity happens at the element level and is an extensive and involved process requiring appropriately skilled structural engineers. Design loads are specified in relevant design codes such as AS5100 and are fictitious loads aimed at being representative of a loading that has a certain probability of occurring or 'return period'. Historically these loads have changed over time so older bridges generally have (but not always) a lower load carrying capacity than modern bridges.

The main difference between design and evaluation is that many of the assumptions in evaluation can be more finely tuned as the structure already exists and many of the assumptions can be refined based on the specific site and context, however this does come at an additional cost depending on the depth of the analysis undertaken into context-specific factors. While the differences in context and inputs may influence the detailed choice of process, ultimately the decision output is of a pass/fail nature. Either the assessor is:

1. confident that estimated structural capacity exceeds all estimated load effects (pass)
2. not confident that estimated structural capacity exceeds all estimated load effects (fail).

Decisions are based on professional engineering norms, and the parameters used by the structural engineer to make the above decision. The key decision drivers include the basis, validity, and cost associated with deriving the required estimates.

Heavy vehicle access assessment is different to bridge assessment and focuses on comparing an application vehicle to a vehicle that is representative of the capability of the bridge to carry heavy vehicle loads. Essentially the decision process requires an application vehicle to be assessed to establish whether:

1. the application vehicle exceeds network capability (fail), or
2. the application vehicle does not exceed network capability (pass).

Bridge capability is a component of network capability, and key decision drivers for heavy vehicle access assessment are the speed, certainty and repeatability of decisions.

While a bridge assessment approach can be used to establish the suitability of an application vehicle to access bridges on a particular route, it is rarely used due to the high cost associated with detailed bridge assessment. Instead an equivalence approach is used where the potential loading effects of the application vehicle are compared to the vehicle representing bridge capability using simple line models and basic structural mechanics.

Capacity-based bridge assessment

Structures are fundamentally designed and assessed using capacity assessment. This involves analysing a set of loads to determine 'load actions'. These load actions occur in all elements of the structure and can take the form of moments, shears, torsions, axial forces and reactions. The second part of the assessment process is to calculate the capacity of the individual elements to resist the applied load actions. This involves using structural mechanics and material properties to estimate structural capacity.

The basic bridge capacity assessment process consists of ensuring the load action effects are lower than the calculated member capacities. How this process is undertaken has changed over the years with assessment methodologies evolving from working stress design to the current day limit states design basis. The associated factors of safety, load factors, capacity reduction factors etc. also have changed over time to suit the assessment basis, and what is currently known about how a structure behaves, as well as how the loading characteristics vary.

Important points to note:

- Every bridge has had a capacity assessment done at least once (the original design).
- This type of assessment is not done very often, usually not more than a few times in the lifetime of the structure would be common on important routes. For many structures a capacity assessment is not undertaken again after design.

- This type of analysis is expensive depending on the extent and the rigour of the analysis. Costs are typically in the range of $5k to $20k per bridge.
- While heavy vehicle access can be assessed considering capacity-based bridge assessment, it is not typically done like this in Australia when considering normal Class 2 heavy vehicle loads (divisible loads) due to the high cost.

Considering the above, the structural engineer must make a series of decisions that idealise each structure into configurations that can be mathematically analysed. Structural engineering norms provide guidance on this process, but experience and judgment are also required.

Heavy vehicle access assessment (bridge capability)

The most common way heavy vehicle access is assessed in Australian is to compare the applicant's vehicle to a reference vehicle that has been determined to be the maximum vehicle that a particular bridge or route can take. This capability is usually expressed as a percentage of a reference vehicle and more than one reference vehicle can be used to define an envelope of 'bridge capability'. The reference vehicles are usually underpinned by some sort of 'underlying' capacity-based bridge assessment but not always.

The original design vehicle usually forms the basis for defining bridge capability and there is typically no reason to believe this is a conservative assumption or that additional bridge capacity assessments will yield additional bridge capability.

Due to the potential variability in axle spacing and masses, comparison between the reference vehicle/s and the applicant's vehicle is typically undertaken using basic structural engineering principles using a line model. It is important to understand that a line model itself does not define any actual measure of structural capacity, rather it is a comparison tool only to compare the potential effects of the application vehicle to the reference vehicle/s. Hence, this is why the term bridge capability is used rather than bridge capacity.

The configuration of the reference vehicle and the application vehicle can also influence this comparison and is the reason why some agencies have multiple reference vehicles. However, a single design vehicle is more than adequate to act as the reference vehicle.

The following should be considered in any line model comparison:

- structure articulation (simple support or continuous)
- span length
- maximum negative moment
- maximum positive moment
- maximum shear
- maximum pier reaction.

The work undertaken in past Austroads projects (Austroads 2014, 2018c and 2019) has shown that negative moment can be the critical loading action effect and therefore the full continuity of the superstructure should be considered in any comparative line model analysis.

A heavy vehicle is typically given access when the load action effects from the application vehicle are all lower than the reference vehicle/s. The process of assessing an application in this way is referred to as a Tier 1 assessment.

Access can be assessed in other ways and some road agencies (RAs) use bridge formula/e or axle spacing mass schedule/s (ASMS). However, a recent Austroads project has identified a number of issues with this approach thus the line model bridge capability approach is suggested for vehicle access assessments (Austroads 2020).

Much confusion exists around the terms of bridge capacity assessment and heavy vehicle access assessment with terms used interchangeably. The definitions in Table 2.3 should help clarify the terminology used in this document.

Table 2.3: Definitions related to bridge and heavy vehicle assessment

Term	Definition
Bridge capacity assessment	A bridge assessment process that considers load action effects in individual members and compares this to an estimate of capacity of the individual members. This is the process that is used in design of all bridges. The current day assessment approach is to use AS5100. This type of assessment must be performed by a qualified engineer.
Bridge capability	A measure of bridge performance that is defined in terms of the maximum unfactored load actions that the bridge can withstand as defined by a road authority. For the purposes of this guide it is defined in terms of maximum line model action effects caused by the unfactored application or reference vehicle only.
Bridge capability assessment	A process of defining the maximum unfactored line model action effects caused by the primary vehicle only. This process is undertaken by a suitable qualified engineer either from or on behalf of the RA. This may be informed by a capacity assessment, (but not necessarily) and should be consistent with the principles of AS5100. Outputs of this assessment could be maximum line model load actions, a percentage of a reference vehicle/s, or a percentage of a design vehicle/s.
Heavy vehicle access assessment	The comparison of a heavy vehicle seeking access to the network with the bridge capability. Can be undertaken with a suitably developed piece of software that analyses and compares the line model action effects of the bridge capability to the heavy vehicle requesting access.

Refining bridge capability

As defined in the last section the bridge capability is measured by the largest reference vehicles (or percentage of) that are deemed safe to cross a structure. Ultimately this capability is defined in terms of maximum line model load actions for the suite of reference vehicles defined by the RA. The original design vehicle forms the first definition of bridge capability by using the design vehicle as the reference vehicle.

Sometimes it is desirable to explore the capacity/capability of the structure further to gain greater confidence that the structure is being utilised to the greatest potential. To do this, higher tiers of assessment are undertaken, usually focusing on capacity assessment and investigation into site specific parameters (rather than using parameters associated with generic design approaches). Typically, assessment is broken into three tiers of assessment that progressively adopt more sophisticated and resource intensive approaches which are intended to better represent the structure’s actual behaviour and performance rather than its prescribed minimum.

The terminology regarding tiers of assessment varies among road agencies and associated stakeholders. The PBS tiers of assessment cause much confusion in this area and the remainder of this chapter aligns with definitions for bridge owner tiers of assessment as agreed by the Austroads Bridge Task Force, defined in Austroads (2019).

- Tier 1: using the reference vehicle technique based on a line model (bridge capability)
- Tier 2: using structural engineering principles, comparing capacity to vehicle load effect (capacity analysis)
- Tier 3: refined analysis using a wide range of activities, including advanced analysis methods, FEA, load testing, site-specific loading models, etc.

Presumably, as the detail and complexity of the assessment increases a greater level of confidence and certainty can be maintained around the accuracy of the predicted performance. However, it is important to understand that increasing the tier of assessment does not automatically make the results more or less conservative (a common misconception in bridge assessment practice). Failure of the application vehicle to pass a particular tier of assessment does not automatically mean the next tier of assessment is undertaken. It is perfectly reasonable to use a Tier 1 assessment methodology to assess all access requests as a Tier 1 assessment is not inherently a conservative approach (as previously discussed).

Careful consideration needs to be made as to whether higher tiers of assessment will potentially yield favourable results and who takes on the burden of these costs. Tier 2 and Tier 3 assessments are very specialised, expensive and not a sustainable practice for most local road agencies. These tiers of assessment need very skilled and experienced resources to both undertake and/or write procurement contracts. The latter is particularly important for local road agencies because the potential to waste large sums of money is high (as history has shown) without useful outcomes or adequate collection of outcomes to use in future assessments.

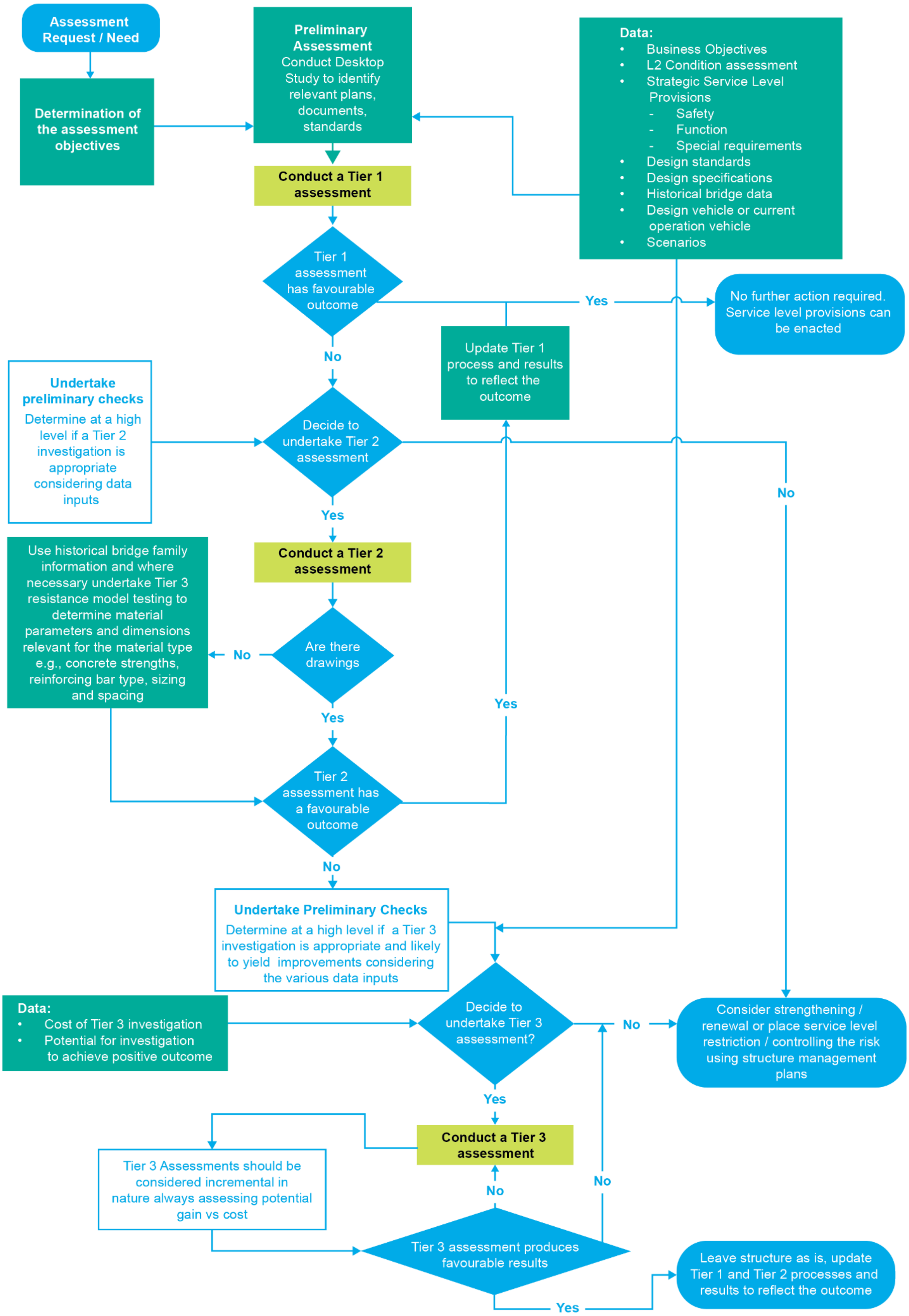
A strategic approach to higher tiers of assessment is generally suggested where accurate understanding of the bridge network capability is required to plan and align with strategic agency goals regarding bridge performance. The goals and level of service defined by the road agency to support the local community should drive expenditure in this area and if other departments or stakeholders require a high certainly/level of service, council should request appropriate funding from these stakeholders.

Some typical reasons why higher tiers of assessment would be undertaken may include:

- The condition of the structure has changed.
- The bridge was originally designed to an older code using an older basis or methodology and there is evidence that analysis using current approaches would yield more favourable results.
- An abnormal load that does not travel in normal lanes, requests access to the structure (Class 1 heavy vehicle loads) (but only if the structure was not originally designed for a heavy load platform, otherwise this could be used for comparison).
- The structure is showing signs of structural distress.
- The structure is limiting strategic access by a small margin and there is reasonable evidence that more detailed and site-specific considerations will yield higher load carrying capability.
- There is a plausibility gap of observed performance and theoretical estimates created by historic access higher than what the original design load would suggest.

Austroads (2018c) *Higher order bridge assessment in Australia,* has documented many aspects associated with tiers of assessment. The reader is referred to this document to gain further background information. Figure 2.16 presents a flowchart from this reference that defines the process of escalating to higher tiers of assessment. Suffice to say that local road agencies should not be looking to undertake higher tiers of assessment unless appropriately funded by stakeholders.

Figure 2.16: Tiers of assessment flowchart



Source: Austroads (2018c).

Considering change in conditions

The assessment process must recognise that the condition of infrastructure changes over time. Should any of the conditions that the assessment is based on change at any time following the assessment then the findings must be revisited. These include:

- any proposed increase in loading
- change of purpose
- change in condition of the structure.

As noted previously, the condition of the structure is fundamental to the assessment process. Consequentially it should be recognised that regular inspection of all structures as part of a prioritised program should be undertaken. Any change in condition of the structure must be investigated and the impact on any previous assessment reviewed. Processes to revisit previous approvals when structural condition changes, need to be considered to ensure the agency is operating their assets with adequate due diligence.

Information required for assessments

Critical information for a Tier 1 assessment includes:

- bridge configuration as defined by
  - number and length of all spans
  - continuity at each support including any pin locations (i.e. cantilevers with drop in spans)
- bridge geometry as defined by
  - vehicle envelope restrictions (both height and width)
  - number of lanes in each direction (need an agreed approach to define consistently relative to the GIS coordinates listed below)
- historic bridge information including
  - design year
  - construction year
  - design standard
  - design vehicle/loading – what design standard/vehicle was each structure designed to? Very often structures may have a loading panel installed identifying the age of construction and design loading
  - structural modification – whether there have been major structural rehabilitation/strengthening works conducted on the structure. What design standard/vehicle was used for the works?
- bridge location information including
  - GIS coordinates of each end of the bridge on the centreline
  - road identification number
  - road chainage
- information on bridge condition
  - date of last condition inspection
  - whether condition is restricting access
  - extent that condition is restricting access as a percentage of reference vehicle/s or line model loading actions
- current approved heavy vehicle gazettes.

Critical information for a Tier 2 assessment includes:

- all information requirements of a Tier 1 assessment
- design drawings fully defining all geometry and reinforcing
- any material specifications used that define required material performance
- as-built records – whether as-built drawings are available. This is not so critical for timber or steel superstructures or a Tier 1 assessment, however, it is essential for reinforced and prestressed concrete structures when structural capacity is assessed, as otherwise intrusive techniques may be required to determine the presence and location of reinforcement bars, strands or tendons
- if design information is not available, a Tier 3 assessment is required to investigate the makeup of the structure. This becomes very expensive and time consuming.

Critical information for a Tier 3 assessment is extremely variable depending on the nature of the investigation. Generally, the information defined for both Tiers 1 and 2 are relevant but not always.

Assessment documentation

For each structure assessed, a brief report should be prepared containing at least a record of:

- basis of assessment
- the purpose of the assessment
- any assumptions made
- assessment methodology
- assessment vehicles and related parameters
- copies or reference to drawings used for the assessment
- copy of the inspection report used to assess condition
- assessment findings.

A copy of the report should be kept in the structure file and relevant information extracted and added to the road manager's bridge information system. The above requirements need to be explicitly written into procurement contracts.

Relevant standards and documents

- AS 5100.7:2017, *Bridge design: part 7: bridge assessment*
- AS ISO 13822:2005 (R2016), *Basis for design of structures: assessment of existing structures*
- *Bridge Assessment: A comparison of approaches by bridge engineers and the Performance Based Standards Scheme,* AP-C103-19, (Austroads 2019)
- *Higher order bridge assessment in Australia*, AP-R582-18, (Austroads 2018c)

Decision making based on assessment data

Ultimately the Local Government agency has a duty of care to operate assets in the interests of the community by exercising due diligence (Section 2.1.1). Depending on operational context, this may need to be achieved with limited resources, and associated risk cannot be entirely outsourced (Section 2.6). Demands for access to increased performance are common (access requests for larger vehicles). In this context Local Government agencies are well advised to consider the following pro-active methodology:

1. clearly articulate via asset management strategy and planning documents, the level of service required by their constituents that they are able to support from their own resources
2. clearly link the risk profile associated with increased level of service requests to their corporate risk profiles and risk appetite statements
3. consider the cost implications of access requests for increased levels of service that exceed risk appetite statements accepted by their organisations, and at the very least request cost sharing (from industry and/or state government) to manage residual risk back to actionable levels
4. clearly document associated decision processes.

It is also important to acknowledge the limitations of bridge assessments. They are estimates based on imperfect models, and do not necessarily predict the accumulation of damage from repeated application of heavy loads. Where concerns of this nature arise, it is suggested that access request approvals should be conditional, with targeted (Level 2) inspection regimes used as risk assurance that the assessment process has adequately covered off on this type of risk.

2.10 Maintenance of Bridges and Culverts

Maintenance involves various cost-effective practices such as functional checks, servicing, and repair to keep assets operational; either before or after functional failure. For the purposes of this guide:

- Preventative maintenance – 'is the systematic servicing of a structure on a scheduled basis' which addresses possible issues *before* they occur, reducing the chances of unexpected functional failure.
- Reactive maintenance – occurs *after* a component or structure has functionally failed, often unexpectedly. Unexpected failures result in increased expenses such as more costly repairs, and unplanned structure closure and/or interruption to agreed levels of service. Reactive maintenance can be undertaken in a planned or unplanned manner depending on the severity and asset risk associated with the identified failure. A need for reactive maintenance is usually identified following inspection or in the course of undertaking preventative maintenance.

When developing a preventative maintenance strategy, the structures manager should take into account the resource needs of tasks from each category and balance against the performance needs and risk profile of the structure network.When tasks need to be performed reactively it is important to quickly gain a clear understanding of the resources required and service impact of the particular maintenance task. When a failure is identified, it is also important to understand the root cause of that failure to ensure appropriate actions are undertaken. Causes of failure may include:

1. lack of preventative maintenance task identified for the particular functional failure
2. poor quality execution or recording of the preventative maintenance task
3. structure or component is/has been operated outside of its design parameters (e.g. extreme event)
4. there is an inherent design or construction issue.

For the purposes of task planning and resource allocation, most state jurisdictions categorise maintenance activities as:

- Routine maintenance – tasks which are generally repeatable across many structures and can be completed with limited specialist knowledge or skills. Some guidance may be required depending on the nature of the particular task.

- Non-routine maintenance – tasks which are not intended to be repetitive and will generally require a council to consult with external service providers to either undertake work or provide guidance to in-house staff.
- Specialist maintenance – tasks which are complex in nature and may require structural/other engineering input or specialist equipment.

Tasks from each of these categories may be performed either preventatively or reactively.

Rehabilitation and upgrade are usually considered as planned activities beyond the scope of maintenance. The need for specific engineering input and/or the need for more rigorous project management are the two factors that typically determine whether rehabilitation and upgrade are part of maintenance activities. While such distinctions are acknowledged, the following discussion is a more general discussion of maintenance and does not systematically distinguish between them.

2.10.1 Maintenance Basics

The execution of maintenance activities by definition involves the development of a works program. This should ideally be undertaken in accordance with the work management process as follows:

1. identification
2. planning
3. scheduling
4. execution
5. follow up
6. analysis.

While these elements are partially embedded in current practice, associated business processes were typically developed before work management concepts matured to their current state. In addition, efficient work management is facilitated by advanced information systems, and as discussed in Section 2.4.1, the asset information systems in most organisations provide limited support to the above process. The balance of this section discusses the basics of maintenance cognisant of the above work management process but based on typical in-house capability.

Without appropriate maintenance, road structures will prematurely deteriorate throughout their service life, which will lead to reductions in the level of service provided, increased operating costs (cost ratio of unplanned to planned work is ~3:1) and premature replacement. Material damage and defects have the potential to accelerate this deterioration if the durability of the structure is compromised. Examples of this include corrosion of concrete reinforcement due to cracking providing an entry point for contaminants or corrosion of steel members due to paint system failure.

If left without intervention for a long enough period, defects which compromise durability will typically result in the development of more serious defects which compromise the integrity of the affected component and potentially the structure as a whole. The period for which a defect that impacts on durability can be left without intervention without leading to impacts on structure performance will vary depending on a range of factors such as defect severity, material, environmental conditions and structure usage.

In some cases, defects may not be detected until the structural integrity of the impacted component is compromised, or a defect may represent an immediate threat to structure performance or safety. For example, structural concrete cracking may be indicative of more serious issues such as structure overloading which could lead to further damage. Depending on location and size, a structural crack may indicate an increased risk of structural collapse. Structure damage caused by natural disasters, vehicle impacts, or overload events may pose a threat to structural integrity and, depending on the severity of damage, an immediate response may be required such as emergency reactive maintenance, bridge closure, or traffic restrictions.

The operational context of an organisation is a key consideration which will influence the determination of the cost, risk and performance setpoint linked to the assessment of individual maintenance tasks and the development of a wider maintenance strategy. Operational context will be defined by factors such as the composition of the structure network, maturity of the organisation's asset management process, availability of funding and skilled personnel for maintenance and upgrade, and the stakeholders which rely on services provided by the organisation. The organisational context will shape the business goals of the organisation. The maintenance strategy will generally be linked to the provision of a certain level of service while managing associated risks to an acceptable level. While Local Governments are often considered resource-constrained, this should not be allowed to define the approach taken to determine an acceptable level of maintenance. In order to develop an effective maintenance strategy, structures management must be able to clearly identify and communicate how each maintenance task impacts on cost, risk and performance, and what the consequences of performing or delaying a task or group of tasks will be in regard to organisational goals. Potential options and consequences could include:

- increased or decreased structure performance – requires management of stakeholder expectations
- increased or decreased maintenance spend – may drive change in funding allocation
- increased or decreased structure risk – change in organisational risk appetite, which requires clear articulation.

It is necessary for a structures manager to develop and implement a structures maintenance strategy that will:

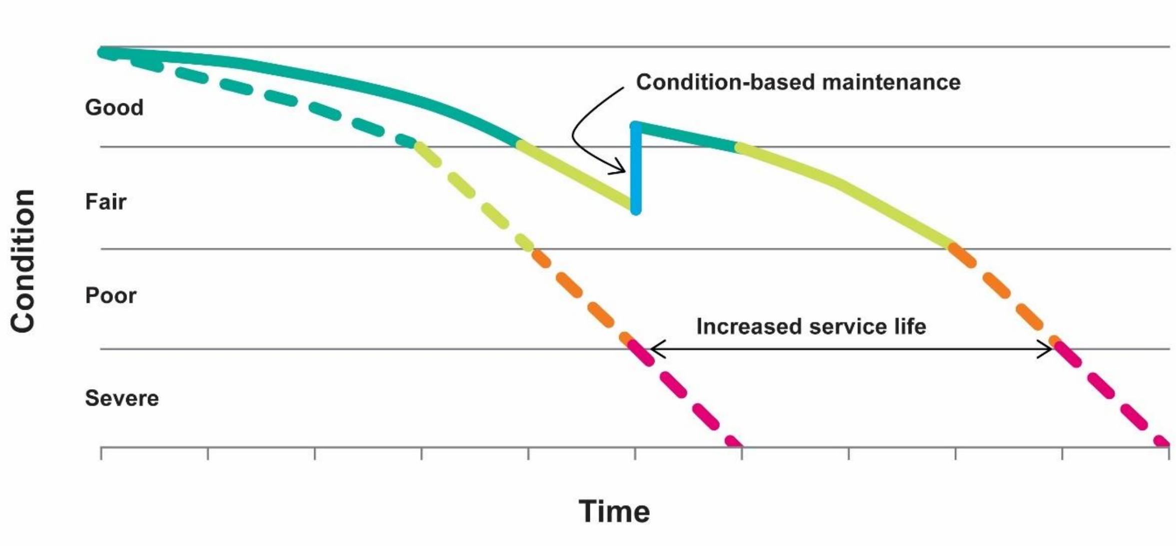
- ensure the safety of structure users and provide a satisfactory duty of care
- maintain structures in satisfactory condition (from both short- and long-term perspectives) and achieve required asset lives
- optimise the overall functional performance of the structure network in line with the expectations of the community (which change) and the life cycle management goals set by the organisation
- minimise significant unplanned interventions, which typically are associated with high cost, reputation damage, and reduced performance.

Each asset's environmental context can provide a threat to operational performance and integrity. Examples include:

- development of scour, particularly adjacent to foundations
- accumulation of debris in and around the structure, potentially allowing fires, or increased hydraulic loading
- blocked scuppers potentially increasing the likelihood of traffic aquaplaning and increasing the potential for long term water damage to bridge components
- growth of plants in the structure, trapping moisture and accelerating material deterioration mechanisms.

Proactive maintenance is necessary to maintain the required structure health over the life of the structure at the lowest possible cost, by understanding failure modes and their effects and ensuring appropriate maintenance strategies are in place to minimise deterioration of structures and limit the need for reactive responses to damage and defects. Reactive maintenance activities by their nature will usually take priority (the prevalence of urgent work over important work) but working towards a robust program of routine and preventative maintenance will reduce the occurrence of unforeseen defects which require reactive maintenance. Programmed inspections and maintenance are valuable in the detection and treatment of defects and serviceability problems at an early stage, for example, blockage of scuppers and loosened holding down bolts on deck joints, so as to minimise repair costs and avoid major safety problems.

Figure 2.17: Comparison of bridge condition over time with and without maintenance



Source: Federal Highway Administration (2018).

The benefits of (proactive) condition-based maintenance are illustrated in Figure 2.17, where the leftmost line represents the lifespan of a structure which does not undergo maintenance. In this situation, defects which impact on structure durability lead to increased structure deterioration and a shortened service life which in turn results in a much earlier need for costly renewal or major rehabilitation. The rightmost line shows the lifespan of the same structure if proactive and condition-based maintenance activities are undertaken. It can be seen that routine preventative maintenance undertaken when the structure is rated in good/fair (CS1/CS2) condition extends the period of time until condition-based maintenance is required. Furthermore, undertaking condition-based maintenance (blue line) before the condition of the structure dips to poor or severe (CS3/CS4) will typically be significantly more cost-effective. An archetypal bridge may undergo several condition-based maintenance cycles over its lifespan, but once maintenance requirements begin to become cost or resource prohibitive, renewal should be considered.

Expanding on the concepts introduced above, the period of time in between when an asset defect is detected (a defect that could potentially cause a failure) and when an asset experiences a functional failure is known in other industry sectors including manufacturing and aeronautics as the Potential-to-Functional failure interval, shortened to P-F interval (Jennions 2018). The P-F interval is generally calculated as the average time to failure once a certain defect has been detected based on past experience, and it will vary depending on both the type of defect and the type of asset being assessed. Knowledge of P-F intervals can be used to inform selective inspection and maintenance scheduling and contribute to risk analysis. The P-F interval is a core concept of reliability centred maintenance (RCM), and it is recognised that RCM is not yet matured in the field of bridge and structure management. Such concepts will begin to see greater adoption in structures asset management as asset management systems mature, and this is likely to drive a change in the inspection regime as discussed in Section 2.9.1.

When prioritising maintenance, the structures manager must strike a balance between routine and non-routine tasks across the structure network based on operating context (Institute of Public Works Engineering Australia 2015b). Critical structures for which a reduction in level of service would be highly undesirable may require a higher level of proactive routine maintenance to safeguard against premature deterioration or failures. In contrast, a lower level of proactive routine maintenance may be sufficient for structures with less stringent performance requirements. For these structures, it may be acceptable for certain condition issues to be dealt with reactively as required if user safety is not unduly affected. In all cases, the level of risk associated with maintenance decisions should be well understood and used to inform prioritisation decisions. Critically, the risk impact of resourcing shortfalls and associated maintenance debt needs to be communicable to higher levels of the organisation, since this is where ultimate accountability for risk resides.

The nature and extent of maintenance required, in general, will largely be dependent on the condition of a structure which is often linked to the age of the structure. A forward view of maintenance requirements and associated costs over the life cycle of a structure should ideally be established as a part of the structure planning process but can also be developed retrospectively based on structure condition and expected remaining life. Deterioration of well-designed and constructed newer structures is generally much less than for older structures, but routine preventative maintenance is cost-effective for all structures. Unless resources are severely constrained, routine preventative maintenance and inspection should be carried out as required across the structure network in tandem with non-routine maintenance, repair and upgrade tasks.

It is recognised that the operating context of most organisations is such that immediately addressing all of the existing maintenance requirements of their structure network is unrealistic and potentially unnecessary. However, they must be in a position to show that they understand the condition of their network and have a considered approach and plan for addressing maintenance issues. Many organisations may be unaware of the scope and volume of maintenance required on their network until a comprehensive program of inspection is carried out, thus inspection is a critical activity that must not be compromised by funding issues. In some cases, organisations may not be aware of serious defects on bridges until the public report an issue or an accident occurs. In these cases, an immediate response is usually required, and can usually be traced to a failure in the organisation’s management systems, which should be subsequently addressed.

In some circumstances, the use of a structure may need to be temporarily restricted in some fashion until maintenance or repair works can be completed. This could amount to:

- posting the structure with a load mass limit
- closure of lanes or reduction in trafficable width
- closure of the structure to:
  - heavy vehicles
  - all vehicles other than emergency vehicles
  - all vehicles.

Figure 2.18 shows a timber bridge which has been posted with a load limit. This is an example of a planned reduction in level of service, intended to prolong the service life of the bridge and reduce the risk of bridge failure due to excessive loading. While posting has been identified as a temporary measure above, it can also be used as a longer-term option where a reduced level of service (load limit) is accepted by stakeholders.

Figure 2.18: Structure with posted load limit

These restrictions will reduce the level of service provided by the affected structure and the level of restriction required will depend on the nature of the existing defects or damage and other site-specific conditions. When prioritising maintenance, the individual tolerance of each structure to reductions in performance should be considered. For critical structures, any reduction in the level of service is highly undesirable. Impacts of a level of service reduction may include economic losses, reduction in community quality of life and reputational damage for the managing organisation.

When programming works to address safety-critical issues, the structures manager should also consider the potential for other works to be conducted on the structure in tandem. If a structure was to be put under traffic control to address high-priority defects, it will usually be cost-effective to address other defects and maintenance tasks at the same time. To support this, it is important for the structures manager to be able to easily access details of all required maintenance tasks for a structure.

There is a need for the structures manager to engage engineering judgement to take account of the many complex factors involved in developing a maintenance strategy for the structure network, which is inclusive of asset and maintenance strategies for each individual bridge.

Section 2.10.2 discusses the categorisation and prioritisation of maintenance based on associated risks. Maintenance categorisation for resourcing and procurement is also discussed. This must take into account the skills required for each task and the time that each task will take to complete among other factors.

Routine maintenance

Routine maintenance involves tasks which can typically be completed without specialist knowledge or skills, although some external guidance may be required. These tasks will generally be repeatable across many different structures with minimal change to procedure or scope, although tasks may be unique to certain structure types or construction materials. Routine maintenance may be programmed for completion on a regular, repetitive basis with the aim of maintaining structure performance and preventing the development of serious defects. Depending on the nature of the task, routine maintenance may also be reactive in response to emerging issues. The need for routine maintenance may be identified by any level of structure inspection or by other observation of a structure.

There are a range of bridge maintenance manuals available which provide details of common routine maintenance tasks. In most cases, routine maintenance outlined in these manuals will be feasible for council staff to undertake without the involvement of external contractors. Some common tasks that fit into this category include:

- clearing blocked scuppers
- cleaning debris from joints and resealing
- tightening non-structural bolts
- spot repair of paint systems on steel members
- painting timber members
- clearing of vegetation
- removal of debris from waterway.

This list is not exhaustive, and the maintenance manuals detailed in Section 2.10.3 can be consulted for further details of typical proactive routine maintenance tasks. Some recommended intervals for programmed proactive routine maintenance and servicing are provided in TMR's *Bridge/Culvert Servicing Manual* (TMR 2008). Proactive routine maintenance should generally be aligned with the Level 1 inspection cycle, ideally being carried out prior to inspection to provide inspectors with clear access to the structure, and a clear view of any defects (TMR 2008).

Records of routine maintenance completed should be maintained as part of the structures management system (although this is rarely done comprehensively as part of current practice). These will assist the structures manager with the assessment of maintenance effectiveness and ongoing maintenance planning. Costs of maintenance completed and predicted future maintenance costs should be recorded and linked to financial management processes as part of the management of operational expenditure.

Non-routine maintenance

Non-routine maintenance and repair is likely to involve tasks which require Council to consult with an external party such as a structural engineer or consultant skilled in bridge repair. These tasks are often bespoke and not repetitive. While another asset may have similar requirements, the scope of works can be expected to be structure specific. Non-routine maintenance will generally be conducted with the aim of improving structure condition.

Many non-routine maintenance and repair tasks are detailed in the maintenance manuals produced by the state/territory road agencies, although the guidance provided may need to be supplemented by separate technical advice. In some cases, non-routine maintenance tasks can be undertaken by in-house staff after seeking technical advice.

Some examples of non-routine and specialist maintenance could include:

- replacement of structural timber members (girders, piles, corbels etc.)
- repair of structural cracking in concrete
- treatment of fatigue cracking in steel.

If a structure requires high priority non-routine maintenance, it will usually be cost-effective to carry out other maintenance on the structure at the same time. For example, if a bridge needs to have traffic barriers replaced due to a risk to public safety, it would be cost-effective to also service joints while the structure is under traffic control. This provides cost savings and helps ensure that non-critical maintenance is not neglected due to budgetary restraints. To facilitate the coordination of maintenance tasks the structures manager must have easy access to information on what maintenance works are required for each structure.

As for routine maintenance, information relating to the work done and the costs incurred should be stored in the structures management database. A history of work completed is necessary to identify those bridges with high or increasing maintenance costs. Records of work completed for a structure also allow Council to show that an adequate duty of care has been provided in the event of an accident.

Specialist maintenance

Specialist maintenance, rehabilitation and upgrade involves tasks which may require structural/multidisciplinary engineering input or specialist equipment that a council or typical maintenance contractor might not have access to. Specialist maintenance will usually need to be assessed on a case-by-case basis as to the determination of costs and resourcing requirements.

Bearing replacement is an example of a specialist maintenance task that might be required for an average bridge. Bridges typically need to be jacked in order to replace bearings and structural engineering input is required to ensure that forces generated during jacking do not damage the bridge. Bridge jacks are an example of specialist equipment, and a contractor experienced in bearing replacement would generally need to be engaged.

Maintenance could also be considered specialist if it is to be carried out on an unusual structure type, such as a cable-stayed bridge (Figure 2.19). In this case, a contractor familiar with the structure type in question would need to be procured which may result in elevated costs if there is a lack of competition. This is just an example, and it is recognised that most councils will not possess such a bridge.

Figure 2.19: Cable-stayed bridge: Macintosh Island pedestrian bridge

In some cases, routine maintenance tasks may require specialist input. One such example of this could be waterway modification works to prevent scour (Figure 2.20). In this case, the maintenance works may not be particularly complicated to undertake, but hydrological advice may need to be sought in order to prevent adverse impacts such as increased flooding potential.

Figure 2.20: Scour protection works – before and after

2.10.2 Establishing Maintenance Investment Priority

The assessment of priorities is of fundamental importance in maintenance planning. For prioritisation purposes, maintenance and repair tasks can be compartmentalised into three categories based on the type of risk that the maintenance is associated with, namely:

- user safety
- structural
- durability.

User safety risks are related to serious defects or deficiencies in elements which are directly linked to maintaining the safety of bridge users. Such elements can include traffic barriers, guardrails, delineation, signage, footpaths, handrails, safety fencing and others. To be considered a user safety risk, the condition of the element should be such that it no longer functions as intended. User safety risks may also be associated with elements which are substandard or missing altogether, including situations where the original design of the bridge did not include a certain safety-related element. A user safety risk could also be linked to the roadway envelope such as narrow trafficable width, poor sight distances, or slippery/grooved decking. An example of a user safety related defect is shown in Figure 2.21 where bridge guardrail has been damaged and completely washed away in parts during a flood event.

Figure 2.21: Damaged and missing guardrail due to flood event

Structural risks are related to serious defects or damage to elements which directly impact the structural integrity of the structure. Such elements can include decking, girders, piles, headstocks, corbels, halving joints, culvert barrels and others depending on the design and structure type. Structural elements vary depending on structure type and design, and structural engineering advice should be sought if there is any uncertainty around the structural importance of an element. If there is a risk of bridge collapse due to defects in structural elements, the structural risk will also represent a risk to user safety. An example of a structural defect is shown in Figure 2.22.

Figure 2.22: Structural defect in timber girder

Durability risks are related to defects or damage which impact on the durability of structural or non-structural elements. These are defects which will result in ongoing deterioration if left untreated, but do not pose an immediate threat to structural integrity or user safety. For example, a developing paint system failure on a steel bridge barrier would be considered a durability risk if the strength of the bridge barrier was not compromised. If not treated, paint system failure will (depending on environmental conditions) eventually lead to steel corrosion and section loss, and in the case of a bridge barrier, a user safety risk would result once the strength of the barrier was compromised. An example of a durability-related defect is shown in Figure 2.23, where the wingwall is still functioning as intended, but may continue to deteriorate if the cracking is not addressed.

Figure 2.23: Crack in culvert wingwall

Structural defects and defects in elements designed to maintain user safety should usually be prioritised for maintenance over defects related to durability and asset preservation. The level of risk associated with each defect will be influenced by a wide range of factors, and it is important for these factors to be identified and understood on a case-by-case basis. Critically, if it was found that a council was aware of a user safety risk and had not taken any appropriate action, the council may be found to be negligent.

For example, the risk of user harm associated with a traffic barrier defect will be controlled by factors including trafficable width, average road speed and the site-specific details of the waterway/gulley/roadway that the bridge spans. These factors affect the likelihood of a barrier strike, the force at which a vehicle is likely to strike the barrier, and the damage that will occur to the vehicle in the event of it leaving the bridge roadway. Crash history could also be considered in some cases. In such circumstances, a key interface exists between the road safety audit process and the bridge maintenance process, and thus needs to be managed appropriately.

Considering an example of structural risk, the risk of user harm associated with a rotted timber girder would be impacted upon by expected vehicle masses, road speed and the redundancy of the structure design in addition to the severity of the rot itself and the condition of other associated structural elements.

It may not be possible to immediately undertake works to correct all issues which impact on user safety. In this situation, an operational decision process is required to complement the maintenance decision process to avoid or mitigate user risks in the first instance, then identify the most critical tasks, and how funding should be allocated in order to best achieve organisational structures management goals. This process should include assessment of likely benefit, costs and risk exposure associated with the completion or non-completion of each maintenance task or group of tasks as appropriate. Depending on the situation, it may be suitable to:

- consider a maintenance task in isolation
- consider a group of tasks on a single structure
- consider maintenance requirements for a group of structures (e.g. all structures located on a certain road link or a group of structures which require similar maintenance).

Fundamentally, this decision-making process should be applied for the prioritisation of all maintenance and repair tasks, not just in relation to user safety issues. The process described here should be adapted from the decision-making process outlined in Section 2.4.2 and the principles described there apply.

While user harm may be considered to be the most critical risk in many situations, there are a range of other factors which need to be considered when prioritising maintenance works. These can include:

- economic risk e.g. cost to local industry, freight operators and employees associated with loss of structure or reduction in performance
- social risks e.g. increased travel times, loss of services such as garbage trucks, school buses
- asset damage: failure to address certain issues leads to further asset damage and need for more costly repair or replacement
- environmental risks e.g. chemical, fuel spills into waterways, drinking/livestock water catchments.

Inspections conducted with consideration of required structures management actions will provide a valuable starting point, but the fundamental assessment of maintenance priorities should be undertaken based on engineering judgement and risk assessment, noting the following:

1. A computer-based maintenance prioritisation system may be used as standalone software or as part of a structures management software package (Section 2.4.1). It should be recognised that these systems are only intended to provide a framework to assist with the task of prioritising maintenance, and that the system itself should not dictate prioritisation.
2. As discussed in Section 2.6, there is significant opportunity to improve alignment between corporate and bridge risk framing and such improvement will significantly advance the establishment of maintenance priorities.
3. External advice may be sought to assist in maintenance planning in some circumstances, but there must be close collaboration to ensure that the specific requirements of the network and the structures management approach taken by the client are well understood by the external party.

To assist in prioritisation and works progress tracking, each maintenance task may be assigned a priority rating which provides an indication of how critical the task is. Suggested ratings are:

- Immediate: complete works as soon as possible. Bridge should be closed until works are undertaken and structure is deemed safe by a structural engineer. This corresponds to a structure condition rating of CS5.
- Urgent: complete works in next 6 months. Temporary functional restrictions or structural support may be required until works are undertaken. Monitor defects if required.
- High: complete works in next year. Increased monitoring of defects may be required.
- Medium: complete works in next 2 years. Monitoring may be required.
- Low: complete works in next 5 years. Monitoring may be required.

The rating assigned to each task will vary depending on site-specific factors, meaning that the same task on two different structures may be assigned a different rating. These ratings are intended to be indicative only and are not intended to serve as a substitute for a detailed decision-making process. In practice, work packages will be developed based on established priorities. Given access and traffic management considerations, it is likely that some relatively low priority activities will be undertaken with high priority activities for opportunity/convenience.

The nature of the maintenance task to be performed can be categorised as ‘routine’, ‘non-routine’ or ‘specialist’ depending on the complexity of the activity and the skills which will be required. In general, non-routine or specialist maintenance will require the council to seek external technical advice or services. Categorising tasks in this way allows the structures manager to gain an understanding of the resourcing required to complete the necessary program of maintenance. Certain tasks can be completed by council road maintenance staff, while others will require procurement of personnel with specialist skills or equipment. An example of categorisation of maintenance tasks is provided in Table 2.4. This shows typical tasks which fit into each category, along with reasons for the completion of each task. The relative level of risk exposure associated with the non-completion of each of these tasks will vary according to site-specific factors.

Table 2.4: Risk categories and examples

Risk category	Maintenance examples	Maintenance category	Maintenance purpose
User safety	Repair or replace damaged or non-standard bridge barriers	Routine	Prevent vehicles which crash into barrier from leaving the roadway which may intensify injury
	Improve poor delineation	Routine	Reduce likelihood of vehicles crossing the bridge impacting bridge or other vehicles
	Repair uneven road surface on bridge approach	Routine	Prevent damage to vehicles and bridge due to impact loadings
	Trim vegetation overhanging roadway	Routine	Prevent damage to vehicles, rectify sight distance issues
Structural	Repair/replace rotting timber deck planks	Routine	Maintain user safety and prevent further damage to bridge
	Determine and address cause of structural cracking in concrete deck unit	Non-routine	Maintain user safety and prevent further damage to bridge. Extend service life of bridge.
	Replacement of deteriorated timber girder	Non-routine/specialist	Maintain user safety and extend service life of bridge
	Bearing replacement	Specialist	Extend service life of bridge
Durability	Repair non-structural cracks in wingwall	Non-routine	Prevent ingress of water and contaminants which cause reinforcement corrosion
	Clean expansion joints	Routine	Prevent deterioration of joints, prolong joint service life
	Clean bridge drainage system	Routine	Prevent water from impacting on structural members which can lead to deterioration

The following questions may be useful as prompts when reviewing structure maintenance programs.

- Does the maintenance of the structure or asset relate to the strategic objectives set?
- Is the maintenance management system user friendly?
- Are the costs/resources measured /recorded?
- Is documentation and data adequate and well managed?

- Is the level of sophistication of the system appropriate?
- What is the priority setting for carrying out maintenance activities?
- Are the objectives of maintenance clearly defined?
- Is there a regular review of maintenance practices?
- Is the maintenance capable of being completed by contract?
- Is risk management practised?
- How are maintenance practices optimised?
- Is the level of maintenance justified economically against replacement cost scenarios?
- Is the maintenance coordinated with other road and bridge works and does it take account of transport special events?
- How is an audit of maintenance completed?
  - by internal process?
  - by external independent review?

Details of the benefits, costs and levels of risk exposure for the maintenance program/plan should be made available to councillors in order to acquire adequate funding for structure maintenance in competition with submissions from other areas of council responsibility.

2.10.3 Relevant Inspection Standards and Manuals

Several state road agencies have developed manuals which provide details on how to perform a range of bridge maintenance and repair tasks. These include:

- VicRoads *Bridge Maintenance and Repair Manual* (VicRoads 2018a)
- TMR *Bridge/culvert Servicing Manual* (Queensland Department of Transport and Main Roads 2008)
- TMR *Timber Bridge Maintenance Manual* (Queensland Department of Transport and Main Roads 2005)
- RMS *Timber Bridge Manual* (Roads and Traffic Authority 2008)
- MRWA *Timber Bridge Maintenance and Refurbishment Preventive Maintenance Standards* (Main Roads Western Australia 2010)

The procedures detailed in these manuals are not exhaustive and depending on the nature of the defect being treated, there may be a range of potential solutions available. For routine maintenance tasks relating to non-structural defects, it will generally be feasible for council staff with experience in road and bridge maintenance to complete maintenance as defined by the manuals. It is important for the structures manager to be confident in their understanding of defect type and causation before maintenance is performed. For example, if crack repair was carried out on a structural crack without recognition of the fact that the crack is structural in nature, it is likely that further cracks will develop as the cause of the original crack has not been addressed.

2.10.4 Procuring Relevant Service

It is common practice for maintenance and repair works to be contracted out to suitable service providers. By doing this specialist skills and equipment can be procured for specific tasks. Competitive bidding can reduce costs and in-house resources can be held at levels that are appropriate to fluctuations in work programs. In some circumstances a council may outsource all maintenance activities, although it is often cost-effective and convenient for councils to undertake routine proactive maintenance tasks with in-house road maintenance staff. This also has the benefit of ensuring agency familiarity with the asset base.

When procuring maintenance services, it is ideal to create work packages which consist of similar jobs to be conducted on a certain number of structures. For example, it will be more attractive for a contractor to carry out joint rehabilitation works on a package of 20 structures rather than a single structure. This practice is most applicable to tasks which do not vary widely in scope from structure to structure, although it is equally viable to engage one contractor to carry out a package of varying works across a range of structures if the contractor in question is capable of all works required.

It is usually a requirement that both council and contractor operate within a quality assurance program. The maintenance contractor is normally required to provide a quality plan for the work, which sets out the proposed methodology of service delivery. The contractor is required to report performance against this quality plan and the client arranges audits to assess conformance. Appropriate attention to occupational, health and safety matters is needed in conformance with legislative requirements.

Clear and comprehensive photographic evidence of works completed should be provided for each structure which has undergone maintenance. For large scale or complex works, verification of works quality in person will be ideal. Invoices for works completed should not be paid until satisfactory proof of works quality is provided. A Level 2 inspection should be conducted as soon as possible after the completion of large-scale rehabilitation works on a structure in order to verify quality of works and benchmark the new condition of the structure.

Information is a critical commodity in the management of maintenance contracts. Information is commonly transferred electronically, and it is important that there is a high level of compatibility between the information systems of council and contractors. Council must ensure that data relating to maintenance works is collected in an appropriate format and entered into the council structures management system to allow for tracking of works programs against structure performance, condition and other metrics. This is key to supporting the review of maintenance program effectiveness.

There is a strong trend towards achieving a true partnering approach to contract work. While the contractual responsibilities are not diminished, partnering involves a shared commitment to provision of a high level of service to the community. Considerable attention is given to developing and maintaining an open operating relationship between the client and contractor. There is provision for keeping each other fully informed in relation to all aspects of the services being provided. For this approach to succeed, the contractor must have a clear understanding of the client’s strategic and operational objectives and be willing to work collaboratively to achieve them.

In some cases, Council may choose to engage a third-party to develop a maintenance and repair strategy for a set period of time. Works may be carried out by the contractor that developed the strategy, or by other suitable parties including council road maintenance staff. Another option is for a contract to be developed which requires that bridges be maintained at a specific performance level over a predetermined number of years. For this type of contract to be successful there is a requirement for comprehensive, sound information on the condition of the structure network at the outset, along with information on previous interventions and on environmental factors. Provision is made for contract variations to cover unpredictable needs as they arise, such as repairs for damage caused by vehicle impacts.

Reactive and specialist maintenance tasks are most often directed and controlled with a work order system. A work order is created when a task needs to be carried out. It sets out clearly the nature of the task, how it is to be done, and when it is to be carried out. The work under the work order is monitored until the task is completed and the work order is closed. Often, work orders may cover a package of works on one or several bridges depending on the scope of maintenance activities required.

2.11 Repurposing and Disposal of Assets

Disposal is typically considered to refer to the retirement of an asset which has reached the end of its useful life (Section 2.3). This may be required when an existing structure is deemed to be unsafe for use or when an existing structure no longer provides an acceptable functional level of service. The structural life of a bridge, in the absence of overload or natural disaster, may be from 20 to over 100 years depending on the type of construction. Normally repurposing or disposal of a bridge asset is initiated because the structure:

- has exceeded its economic life (replacement would be cheaper than retention)
- will no longer be safe for use without intervention
- may simply no longer provide an adequate level of service.

In these cases, a decision must be made whether to rehabilitate, modify or replace the structure. It is important to consider the level of service demand of the structure over its targeted service life following intervention if a major upgrade is proposed. It is also likely that the level of service requirements will have changed since the asset was acquired. Examples include:

1. Remote regional council – population of the service area has reduced meaning that the reduced level of service provided by a causeway might be more appropriate than the bridge previously provided.
2. Urban council – the demand for active transport means that a structure with capacity limitations (for emerging heavy vehicle demand) is better re-purposed for pedestrian and cyclist access with a new purpose-built asset constructed to meet increased capability requirements.

Costs associated with each option should be considered in conjunction with the expected remaining structure lifetime that would be achievable through rehabilitation or modification. The discussion in Section 2.7.1 regarding depreciation is relevant in this regard. From an accounting perspective, assets are often considered to have residual value (e.g. a used car has a value at disposal). In contrast, bridges are more likely to represent a financial liability (demolition cost) unless the asset can be re-purposed or contributed to another asset owner. In some circumstances, the asset may be able to stay in place and deteriorate until it reaches the end of its physical life, but increasingly this is unlikely to remain an acceptable scenario. In addition, if the asset becomes heritage listed, (even following decommissioning) the obligations of the asset owner (should they be identified) may be even more onerous. These constraints are likely to become increasingly important in planning/disposal considerations.

As discussed in Section 2.8.1, asset disposal will be considered in the context of asset planning and will typically encompass activities targeted at managing the assets through to its disposal or remediation, including:

- changing the offered level of service (i.e. posting a load limit)
- community consultation regarding the current offered level of service
- deviation of non-critical heavy vehicle access and access management for critical heavy vehicle access
- controls targeting mitigation of a plausible failure scenario (i.e. creating a fail-safe).

While asset disposal may become required due to a sudden failure or catastrophic damage, it is more likely that the level of service demand will surpass that which is feasible for the asset to provide, resulting in a functional inadequacy. Well considered life cycle planning aims to reduce the occurrence of this, as planning for new structures should consider expected future level of service requirements. During this period of functional inadequacy, many options may be considered to address the level of service such as:

- decommissioning the asset and constructing a new one in place
- accepting the level of service and providing alternative routes
- remediating the existing structure to improve the level of service.

The merits of available options must be considered as part of a thorough planning process, however the management of the asset during this time may be heavily influenced by the pursued option, so coordination with the planning activities is important.

It is rare to be presented with a plausible, urgent need to close a structure due to risk of immediate failure. Whilst such circumstances are not without precedent, the more common presentation of a problem is the identification of a major issue which has significantly impacted capacity but has not been addressed and ameliorated. During the period in which a plan is formulated to ameliorate the issue, a management strategy must be identified and enacted, which is likely to impact both operations and maintenance activities. Under these circumstances, the most critical consideration is managing the level of service reduction.

Understanding the functional use cases that form the level of service envelope will assist in understanding what form of management is necessary. Should the level of service of a structure be controlled by heavy vehicles, for which an alternative route is a viable option for the disposal time period, then the current level of service may be adequate for other vehicles (which may include community vehicles, such as buses and waste disposal vehicles). If these community vehicles also cannot be serviced, then the management becomes a more significant issue with multiple stakeholders and potential significant community impact.

Importantly, the more critical the asset to the network, the more vital it is to pursue an understanding of the level of service envelope and identify what level of service changes are intolerable to the community. Additionally, the more intolerable the change is, the more planning that should be done prior to disposal to ensure such risks are mitigated or effectively managed.

If a structure has been deemed unsafe for users it must be, in the first instance, closed immediately with reasonable efforts made to prevent vehicles or pedestrians accessing the bridge. User safety must be a primary concern of the structures manager and the council is responsible for the provision and maintenance of any signs and barriers designed to prevent access to closed bridges. The question of who has the power to deem a structure unsafe is a complicated one and such situations should be clearly defined with a policy statement regarding how to deal with such issues. Sometimes a consultant may advise a council that a structure is unsafe, however engineering can be very subjective and sensitive to risk bias. Advice from consultants should always be sanity checked and a second opinion sought where serious action has been suggested. However, in the first instance a conservative approach to ensure public protection is advisable until the seriousness of the situation can be confirmed, and appropriate action plans developed.

Costs associated with demolishing a structure include those associated with required plant and personnel in addition to costs associated with removing and disposing of old materials. In some cases, costs can be recouped by recycling materials from demolished bridges. Possible recycling methods include using recycled concrete in road base or as recycled aggregate in new concrete. Recycling of construction materials is a developing area and there may be new and innovative methods which a council can explore. Indirect costs of demolishing a structure include those associated with disruption to road users and the need for detouring. The construction of a side-track during the demolition and reconstruction process may be a viable option in some circumstances but this will add cost and may not be necessary if there is a relatively short detour available which is suitable for heavy vehicles as required.

In some cases, a structure may be decommissioned for traffic use but not demolished. This may occur if a structure is heritage listed, or otherwise has some intrinsic value to the community. In some cases, a structure may be repurposed for cyclist or pedestrian use or may continue to carry services. If repurposing is to occur, the existing structure must be safe for its new purpose. Inspection and maintenance of the structure should continue for the repurposed structure to ensure that it remains safe for users. Rehabilitation work may be required before the structure is suitable for its new purpose in some circumstances. An example of an existing road structure repurposed for pedestrian and cyclist use is shown in Figure 2.24. In this case, the timber girders had deteriorated, but the structure was still capable of supporting pedestrian loadings, thereby allowing it to service pedestrian movements.

Figure 2.24: Deteriorated timber road bridge repurposed as pedestrian bridge

3 Design

The *Austroads Guide to Bridge Technology Part 4: Design Procurement and Concept Design* (Austroads 2018a) can be consulted for detailed guidance regarding the effective specification and scoping of contractual requirements for bridge design. Based on stakeholder feedback during the preparation of this guide, most Local Government agencies will be procuring designs (including pre-engineered systems), so comprehensive technical coverage of design was defined as out of scope. Some elements of design are covered in Section 2.8.2 as they relate to the asset delivery phase of the structure life cycle.

3.1 Transport Infrastructure Product Evaluation Scheme

There are numerous materials and products available in the market that can be used in the construction and maintenance of road assets. It can be difficult to ascertain whether these materials and products are suitable for a project purely based on the information and data provided by the suppliers. A way to determine their suitability is to utilise independent assessment and certification schemes such as the Australian Paint Approval Scheme (APAS) or the Transport Infrastructure Product Evaluation Scheme (TIPES).

TIPES is a process aimed at providing an independent fit-for-purpose assessment of innovative road construction products. TIPES is intended for the evaluation products that fall outside the scope of established standards and specifications.

Understanding how well a proprietary product will perform for in-service assets reduces risk and can also provide cost-saving design options or construction techniques.

TIPES is a national scheme endorsed by all Australian state and territory road agencies as well as IPWEA (QLD), the Queensland Local Roads Alliance and WALGA.

3.1.1 Process of Obtaining TIPES Certification

Products are assessed by an expert panel (inclusive of road agency representatives), who determine what is required to substantiate the proponent's claims for a product. This involves products being evaluated through a gating process where products need to pass each stage to move to the next phase of evaluation.

The stages of a TIPES production evaluation are:

1. Stage 1: Evaluation
    a. an evaluation of available product information by the expert panel
2. Stage 2: Test
    b. an independent series of laboratory tests recommended by the expert panel based on the product application and claims
3. Stage 3: Trial
    c. field trials to assess real-world performance. These are often incorporated into existing road authority and Local Government projects
4. Stage 4: Certification
    d. final assessment of results and certification of product.

Figure 3.1: TIPES certification

4 Construction

Some elements of construction related to the asset management process have been discussed as part of Acquisition, Section 2.8. The Austroads *Guide to Bridge Technology Part 6: Bridge Construction* (Austroads 2018b) can be consulted for detailed information relating to the road structure construction process with focus on the structure asset owner's perspective. Based on stakeholder feedback during the preparation of this guide, most Local Government agencies will be procuring construction (including pre-engineered systems), so comprehensive technical coverage of construction was defined as out of scope. In some cases, Local Government agencies may consider self-performing construction. Construction of culverts is routinely undertaken by many Local Government agencies, so does not warrant comprehensive coverage in this guide. Construction of pre-engineered systems is an area of interest for Local Government, and some guidance on this can be found at *S31 – In-line Timber Bridge Replacement Options* (Pathirage & Mahagamage 2018).

5 Operation and Maintenance

In keeping with the asset management-based approach taken by this guide, operation (Section 2.9) and maintenance (Section 2.10) of bridge and culverts are covered as subsections of Asset Management (Section 0). Operation and maintenance are also discussed in the context of the structure life cycle in Section 2.3.

References

AssetWorks 2017, *The asset lifecycle*, AssetWorks, Wayne, PA, USA, viewed 24 February 2020, <https://2166ol2zi28o11a6id19mtlq-wpengine.netdna-ssl.com/wp-content/uploads/2017/11/AssetLifecycleInfographic.pdf>.

Austroads 2013, *Bridge management using performance models*, by N Lake, J Seskis, AP-T258-13, Austroads, Sydney, NSW.

Austroads 2014, *Review of axle spacing mass schedules and future framework for assessment of heavy vehicle access applications*, by N Lake, J Seskis, H Ngo, R Kotze, AP-R466-14, Austroads, Sydney, NSW.

Austroads 2018a, *Guide to bridge technology part 4: design procurement and concept design*, AGBT04-18, Austroads, Sydney, NSW.

Austroads 2018b, *Guide to bridge technology part 6: bridge construction*, AGBT06-18, Austroads, Sydney, NSW.

Austroads 2018c, *Higher order bridge assessment in Australia*, AP-R582-18, Austroads, Sydney, NSW.

Austroads 2019, *Bridge assessment: a comparison of approaches by bridge engineers and the Performance Based Standards Scheme*, AP-C103-19, Austroads, Sydney, NSW.

Austroads 2020, *Investigation and development of bridge formulae for inclusion in the performance-based standards,* AP-R615-20, Austroads, Sydney, NSW.

City of Gold Coast 2018, *Non-current asset accounting policy*, FN338/171/01, City of Gold Coast, Southport, Qld.

Comrie, J 2014, *Debt is not a dirty word: role and use of debt in Local Government*, Institute of Public Works Engineering Australasia, Sydney, NSW.

CPA Australia 2016, *Guide to valuation and depreciation*, CPA Australia, Southbank, Vic, viewed 24 February 2020, <https://www.cpaaustralia.com.au/~/media/corporate/allfiles/document/professional-resources/public-sector/guide-to-valuation-and-depreciation>.

Federal Highway Administration 2018, *Bridge preservation guide: maintaining a resilient infrastructure to preserve mobility*, FHWA-HIF-18-022, FHWA, Washington, DC, USA.

Heywood, R, Shaw, P, Mitchell, J & Jager, C 2017, ‘Operational and inventory management of bridges’, *Austroads bridge conference*, *10th*, *2017*, *Melbourne, Victoria*, Austroads, Sydney, NSW, 14 pp.

Institute of Public Works Engineering Australia 2012, *Practice note 6: long-term financial planning*, report PN6, IPWEA, Sydney, NSW.

Institute of Public Works Engineering Australia 2015a, *Australian infrastructure financial management manual*, 2nd edn, IPWEA, Sydney, NSW.

Institute of Public Works Engineering Australia 2015b, *International infrastructure management manual*, 5th edn, IPWEA, Sydney, NSW.

International Organization for Standardization 2019, *Asset management: guidance on the alignment of financial and non-financial functions in asset management*, report ISO/TS 55010:2019, ISO, Geneva, Switzerland.

Jennions, I 2018, *The P-F Interval explained,* webpage, Barrett Byrd Associates, Tunbridge Wells, UK, viewed 24 February 2020, <https://www.maintenanceandengineering.com/2018/08/03/the-p-f-interval-explained/>.

Kleywegt, HS 2010, 'Maximizing return on investment utilizing a bridge depreciation model', *International IABMAS conference*, *5th*, *2010*, *Philadelphia, PA, USA*, CRC Press, Melbourne, Vic, 7 pp.

Lake, N, Kotze, R & Ngo, H 2012, 'Level 2 bridge inspection contracts: how to get what you really want!', *ARRB conference - shaping the future: linking policy, research and outcomes, 25th, 2012*, *Perth, WA*, ARRB Group, Vermont South, Vic, 11 pp.

McCarten, PS 2018, 'Bridge risk management: credibility gaps', *International conference on bridge maintenance, safety and management (IABMAS 2018)*, *9th*, *2018*, *Melbourne, Victoria,* CRC Press, Melbourne, Vic, pp. 1177-84.

Main Roads Western Australia 2010, *Timber bridge maintenance and refurbishment preventive maintenance standards,* document no. 6706-02-2226, MRWA, Perth, WA.

Main Roads Western Australia 2019, *Inspection guidelines*, MRWA, Perth, WA, viewed 24 February 2020, <https://www.mainroads.wa.gov.au/BuildingRoads/StandardsTechnical/StructuresEngineering/Pages/Asset_Management.aspx>.

Pathirage, T & Mahagamage, J 2018, *In-line timber bridge replacement options*, PRG17023, Queensland Department of Transport and Main Roads, Brisbane, Qld.

Queensland Department of Transport and Main Roads 2005, *Timber bridge maintenance manual*, webpage, TMR, Brisbane, Qld, viewed 24 February 2020, <https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Timber-bridge-maintenance-manual>.

Queensland Department of Transport and Main Roads 2008, *Bridge/culvert servicing manual*, TMR, Brisbane, Qld.

Queensland Department of Transport and Main Roads 2016, *Structures inspection manual*, TMR, Brisbane, Qld.

Rawlinsons Group 2019, *Rawlinsons Australian construction handbook*, 37th edn, Rawlinsons Group, Rivervale, WA.

Roads and Traffic Authority 2007, *Bridge inspection procedure manual,* RTA, Sydney, NSW.

Roads and Traffic Authority 2008, *Timber bridge manual,* RTA, Sydney, NSW.

Robinson, RM & Francis, G 2019, *Engineering due diligence*, 11th edn*,* R2A Pty Ltd, Melbourne, Vic.

Seskis, J & Lake, N 2012, 'Condition based deterioration modelling: practicalities and limitations, *Australian small bridges conference, 5th, 2012, Surfers Paradise, Queensland*, CommStrat Publications, Melbourne, Vic.

The Institute of Asset Management 2015a, *Asset management: an anatomy,* version 3, IAM, London, UK.

The Institute of Asset Management 2015b, *Strategy and planning: asset management policy, strategy and plans*, Version 1.1, IAM, London, UK.

VicRoads 2018a, *Bridge maintenance & repair manual,* VicRoads, Kew, Vic.

VicRoads 2018b, *Road structures inspection manual,* VicRoads, Kew, Vic.

Victorian Auditor-General's Office 2019, *Local Government assets: asset management and compliance*, report 2018-19:19, VAGO, Melbourne, Vic.

Standards Australia

AS/NZS 4536:1999 (R2014), *Life cycle costing – an application guide.*

AS 5100:2017, *Bridge design series.*

AS 5100.7:2017, *Bridge design - part 7: bridge assessment.*

AS ISO 13822:2005 (R2016), *Basis for design of structures: assessment of existing structures.*

AS ISO 31000:2018, *Risk management – guidelines.*

AS ISO 55001:2014, *Asset management – management systems – requirements.*

AS ISO 55002:2019, *Asset management – management systems – guidelines for the application of ISO 55001.*

Australian Accounting Standards Board

AASB 13:15, *Fair value measurement.*

AASB 108:15, *Accounting policies, changes in accounting estimates and errors.*

AASB 116:15, *Property, plant and equipment.*

AASB 136:16, *Impairment of assets.*

AASB 1030:14, *Depreciation of long-lived physical assets: condition-based depreciation and related methods.*

Appendix A Procurement: Sample Level 2 Scope of Services

A.1 Definitions

The following definitions apply to this Scope of Services document:

- <Insert definitions as required>

A.2 Purpose

The purpose of this Scope of Services document is to describe the scope of work and the responsibilities of the Consultant and Council in connection with the delivery of the Level 2 structures inspection program.

A.3 Aims/Background

The aim of the Level 2 structures inspection program is to provide input into Council's <asset management planning> and to act as a key risk control for structures.

<Insert further specific aims/background as required>

A.4 Scope

The Council requires that all structures nominated in <Attachment A> undergo Level 2 Condition Rating Inspections generally in accordance with <Inspection Manual/Standard>, customised to Council's requirements.

A.4.1 Activities

The Scope of Services includes, but is not limited to the following activities:

1. Carry out Level 2 Condition Rating Inspections of all structures listed in <Attachment A> in accordance with <Inspection Manual/Standard>.
    a. Inspections must cover all accessible components of the structure above ground and water level.
    b. <Conduct Scour Sounding Surveys on all structures in accordance with <Inspection Manual/Standard>.
    c. <Conduct Timber Drilling Surveys on all timber structures in accordance with <Inspection Manual/Standard>.
        i. One sample shall be taken at each drilling location as specified in <Inspection Manual/Standard>.
        ii. Where a location has been drilled as part of a previous inspection, the Consultant shall utilise the existing drill hole to obtain relevant condition data.
        iii. All drill holes shall be plugged with treated dowels or plugs.
2. Prepare for each site inspection in accordance with the access requirements outlined in Appendix A.5.2 and Appendix A.5.3.
3. Undertake appropriate and reasonable measures to ensure the structure is likely to be accessible. The Consultant will be expected to plan the inspections in such a manner that rainfall, tidal or other events

will not render the structure 'inaccessible'. In the unlikely event that a structure is inaccessible, then the provisions in Appendix A.5.1 will apply.

4. Produce a Level 2 Inspection report in accordance with <Inspection Manual/Standard>.
5. Submission of all deliverables including <reports, photographs and registers> in the following electronic formats:
    a. <PDF, Excel as required by Council>.
    b. <Other deliverables as required by Council>.
6. <Other activities as required by Council>.

A.4.2 Information Provided to Consultant

The following information for each structure will be provided in <Attachment A>:

- <Structure ID>
- <Structure Name>
- <Road Name>
- <Coordinates (Latitude and Longitude)>
- <Structure Type (Bridge, Culvert, Retaining Wall etc.)>
- <Superstructure Type (Girders, Deck Units, Trusses etc.)>
- <Superstructure Material>
- <Substructure Type (Piles, Wall etc.)>
- <Substructure Material>
- <Overall Length>
- <Overall Width>
- <Number of Spans>
- <Number of Girders>
- <Height to Waterway/road>
- <Traffic Lanes>
- <Access Equipment Required>
- <Traffic Management Requirements>

Structural plans (where available) are provided in <Attachment B>.

The following photographs (where accessible) have been provided for each structure in <Attachment C>:

- View from approach 1
- Left hand elevation
- View of superstructure.

A.4.3 Inspector Qualifications

Personnel carrying out Level 2 Condition Rating Inspections shall have the following qualifications:

- An experienced structures inspector with <5> years demonstrated experience in the inspection of roading structures who has attended a Level 2 inspection training course.

- An experienced structural engineer with <5> years demonstrated experience in roading structures engineering or <RPEQ> qualification.

All reporting is to be undertaken by or under the direct supervision of an engineer with <RPEQ> qualification or <5> years' experience.

A.5 Special Provisions

A.5.1 Inaccessible Components/Structures and Reinspection

Where components on a structure are not visible and work within the scope of this Contract is unable to be undertaken to make them visible, these components should be recorded on an exceptions report, along with the reason they are not visible.

Where structures are unable to be inspected in accordance with Appendix A.4.1, and Council is satisfied that the Consultant has made all reasonable efforts to access the structure, a date for reinspection will be agreed between Council and the Consultant. Where structures are unable to be inspected due to a *force majeure* event (e.g. recent flooding) and the structures are unable to be reinspected in the original program, the Consultant is to notify Council and arrange an inspection at a later date that is agreeable to both parties.

A.5.2 Access Requirements

The access requirements for each structure are outlined in <Attachment A>. Where access requirements are not specified, it shall be the Consultant's responsibility to provide an appropriate access strategy and communicate this to Council.

- The Consultant is to include a provisional sum for the use of the <UBIU>, <powered watercraft>, <access to the rail corridor> or other specialist access equipment as required. Council reserves the right to retender this portion of the Contract.

Where vegetation removal is required to obtain access, this shall be undertaken in accordance with Appendix A.10.1.

Where access is required to the <Queensland Rail> corridor, all approval for appropriate access must be arranged by the Consultant.

If inspection is required from water, any vessel used for this purpose and its operation will be required to satisfy the legal obligations of *Maritime Safety (Domestic Commercial Vessel) National Law Act* 2012, other relevant acts and associated regulations.

Where access from an Under-Bridge Inspection Unit (UBIU) is required, appropriate traffic management will be arranged in accordance with Appendix A.5.3, and appropriate environmental protection will be applied in accordance with Appendix A.10.

A.5.3 Traffic Management Requirements

All traffic management requirements (both those identified by Council in <Attachment A> and by the Consultant) must be the responsibility of the Consultant:

- All works are to comply with the *Manual of Uniform Traffic Control Devices (MUTCD) Part 3 – Works on Roads* <2014>.
- No works are to commence until all documentation has been approved by Council's <Traffic Control Department>.
- All traffic management documentation must be submitted to <Council's Traffic Control Department>/

- The Consultant must comply with the following requirements:
  - The following locations can be submitted as generic plans:
    - <Insert as required>.
  - Site specific plans are required for the following locations:
    - <Insert as required>.
  - Council will reserve the right to request additional plans if it is considered that the implementation of a plan at a specific site is considered hazardous to pedestrians for vehicular traffic.
  - Plans must be submitted in accordance with the MUTCD Part 3 and be prepared by personnel with the <Traffic Management Design> qualification.

A.6 Program

The following key dates will apply to this Contract:

- <Insert as required>

A.7 Communications

The Consultant shall nominate a senior staff member to act as <project executive> and be responsible for contract management as a whole and be the point of contact for Council's <project manager>. It is expected that enquiries (email or phone) will be answered within <24 hours>.

The Consultant will be required to:

- <Attend a project inception meeting prior to commencement of works to discuss the aims and expected outcomes for the program and agree the project management plan.>
- <Attend <monthly> project review meetings to discuss the results of the project and to ensure any issues or delays are raised and addressed. The schedule will be agreed <at contract signing>.>
- <Deliver a project closeout workshop for key Council staff to discuss the outcomes of the program and to assist in planning any future works>.

A.8 Deliverables

The following deliverables are required as part of this Contract:

- Project Management Plan (<PDF> format) covering the following information:
  - Key Personnel
  - Organisational Structure
  - Project Scope & Deliverables
  - Project Methodology
  - Project Program in Gantt Chart Format
  - Risk Management Plan
  - Quality Management Plan
  - Safety Management Plan
  - Traffic Management Plan (where required)

- Level 2 Inspection Report in accordance with <Inspection Manual/Standard> containing at a minimum the following information:
  - Structure Inventory Report (<PDF> format)
  - Component Condition Inspection Report (<PDF> format)
  - Photograph Record (<PDF> format)
  - Original photographs with time and date stamp (<JPEG> format)
  - <Exceptions Report (<PDF> format)>
  - <Scour Sounding Survey Report (<PDF> format)>
  - <Timber Drilling Survey Report (<PDF> format)>
- Any documentation required for specialist access as outlined in Appendix A.5
- All Workplace Health and Safety documentation as outlined in Appendix A.9
- All Environmental Protection documentation as outlined in Appendix A.10
- All Quality documentation as outlined in Appendix A.11
- <Additional deliverables as required by Council>.

A.9 Workplace Health and Safety

The Consultant is responsible for undertaking all activities in accordance with the <*Work Health and Safety Act* 2011 (Qld)> and the <*Work Health and Safety Regulation* 2011 (Qld)> and all other relevant legislation, regulation and codes of practice that may affect the work.

Prior to commencing site inspections, the Consultant is to provide a Safety Management Plan as part of the overall Project Management Plan including the following information:

- Fieldwork briefing checklist
- Safe Work Method Statement (SWMS)
- Site induction and risk assessment form (Take 5 form)
- All relevant safety cards for participating inspection staff including:
  - Construction induction card
  - Current first aid certificate
  - <Working at heights certification>
  - <Confined spaces certification>
  - <Elevated working platform licence>
  - <Recreational Boating or Coxswain licence>
  - <Rail Industry Worker card.>

  Due to specific hazards, the following sites will require individual Safety Management Plans:
- <Site – Hazard>.

Should any sites be identified as requiring confined space access, a Work Method Statement and Risk Management Plan should be submitted to Council prior to carrying out the inspection. No additional payment will be made for these services.

All Personal Protective Equipment (PPE) shall be supplied by the Consultant at no cost to Council.

The consultant will comply with all traffic management requirements as outlined in Appendix A.5.3.

For working in water courses and tidal areas, the Consultant should make appropriate allowances in the program for safe access to these structures. Council will not accept any claim for a cost or time variation resulting from the Consultant failing to fulfil these conditions.

The following conditions will apply to site inspections:

- Two employees are required on site at all times.
- Standard working hours are between <7:00 am> and <5:00 pm>.

The consultant is to comply with Council's <WHS Policy> as outlined below.

<Insert WHS Policy or excerpts>.

A.10 Environmental Protection

A high percentage of Council's structures span waterways, which are protected by the <*Environmental Protection Act* 1994 (Qld)>, associated regulation and Council's <Environment Policy>. The following conditions will apply:

- No materials from the structure (such as concrete spalls or paint flakes) are to be dropped into the waterway.
- There is to be no disturbance to the waterway.
- No waste is to be left on site. All waste is to be transported from site and disposed appropriately at no cost to Council.
- No harm is to occur to native animals.
- Vegetation removal is to be carried out in accordance with Appendix A.10.1 below.

A.10.1 Vegetation Removal

<No removal of vegetation is to be carried out by the Consultant. If the Consultant is unable to inspect less than 50% of a critical component and removal of vegetation can be required, the Consultant must contact Council to carry out the removal.>

<The Consultant may clear, trim or push away any vegetation up to <1 metre> width along the sides of the structure for the purposes of viewing structural components, taking measurements and photographs. The Consultant shall keep clearance to the minimum required for the work.>

<The Consultant must seek approval from Council if clearing more than <1 metre> width of vegetation.>

<If more than <1 metre> width of vegetation clearance is required, then the Consultant shall contact Council to undertake the work.>

A.11 Quality

The consultant is to maintain a Quality System in accordance with AS/NZS ISO 9001:<2015> for the duration of and in accordance with the requirements of the Contract. If the Consultant does maintain or intend to develop such a system, they should demonstrate how their system complies with AS/NZS ISO 9001:<2015>.

A.12 Hazards

Should any hazards be identified in the course of undertaking inspections, the Consultant shall report them to Council's <Customer Service> and the Council <Representative> as required.

Any hazards which are observed shall be reported to Council's <Customer Service> via email, mobile application or phone with the following information to be provided at a minimum:

- the name of the person identifying the hazard
- the mobile phone number of the person reporting the hazard;
- details of exact location (address) including landmarks within open space including recommendation for treatment
- hazards which are evident (including photographs)
- assets which are damaged (including photographs).

Any required maintenance works or repairs which fall outside the scope of this Contract and require immediate action by Council shall also be reported to Council's <Customer Service> and <Representative>.

Appendix B Sample Level 1 Report Form

LEVEL 1 – ROUTINE MAINTENANCE INSPECTION REPORT					SHEET 1 OF 3
Structure ID		**Bridge name**		Optional Photo	
Crossing		**Road number**			
Structure type		**Road name**			
Construction type		**Owner**			
Construction material		**District**			
Inspector		**Local authority**			
Inventory Items					
Form filled in by		**Form checked by**			
Date of inspection		**Next inspection**			
Date of construction		**Water level**			
Road type		**Number of spans**			
Length (m)		**Width** (m)			
Latitude (dec)		**Longitude** (dec)			

Inspection type		**Inspection was**	Programmed Exceptional Underwater	**Map no.**	**Ref.**

Chainage	**(km) on the**	**to**	**Road**

Inspection elements ** Refer to notes*	**Inspected**	**Maintenance required**	**Level 2 inspection required**	**Location and comments**
	Y/N/NA	Y/N/NA	Yes?	

Approaches				
1. Signs and Delineation				
Missing, damaged, obscured				
ID plate				
2. Guardrail				
Accident damage				
Incorrect alignment or height				
Connection to bridge				
Delineators				
3. Road drainage				
Blocked inlets/outlets				
Scour of outlets/embankments				
4. Road surface				
Material defects *: surface				
Material defects *: concrete				
Settlement, depressions				
Rough joint transition				
Bridge Surface				
5. Bridge Surface				
Material defects *: surface				
Material defects *: concrete				
Material defects *: timber				
Scuppers				
6. Footpaths				
Clean				
Even				
7. Barriers				
Impact damage				
Loose/damaged fixings				
Loose post base				
Material defects *				
Delineators				
8. Expansion joints				
Loose/damaged fixings				
Damaged/missing seals				
Deck/nosing/ballast wall damage				

Obstructions in gap				
Waterway				
9. General				
Trees or bushes under bridge				
Debris against structure				
River/embankment erosion				
Scour holes in bed				
Damaged bed protection				

LEVEL 1 – ROUTINE MAINTENANCE INSPECTION REPORT				SHEET 2 OF 3
Structure ID:	**Bridge name:**			
Inspection date:				
Inspection elements ** Refer to notes*	**Inspected** Y/N/NA	**Maintenance required** Y/N/NA	**Level 2 inspection required** Yes?	**Location and comments**
Substructure				
10. Material defects *				
Piles				
Footings				
Walls/stems				
Headstocks				
11. General				
Forward movement of abutment/wings				
Blocked drains/weep holes				
Debris on shelf/bearing				
Scour/erosion of spillthrough				
Dampness/leakage from deck				
Substructure protection				
12. Bearings				
Gap closed/deck in contact/damaged				
Bearing displaced/damaged				
Poorly seated				
Corroded/seized/no lubricant				
Superstructure				
13. Material defects in *				
Girders				
Cross girders				
Deck				

Coatings				
14. General				
Debris/dirt build up				
Impact damage				
Excessive movement/vibration				
Dampness				
Vent holes				
Miscellaneous				
15. Damage to services				
Fasteners/brackets				
Pipe/conduit				
Openings				
16. Roadway under bridge				
Delineation				
Barriers				
Road drainage				
Culverts				
17. Material defects in *				
Walls				
Roofs				
Aprons				
Wingwalls/headwalls				
Steel culverts **				

LEVEL 1 – ROUTINE MAINTENANCE INSPECTION REPORT	SHEET 3 OF 3

Structure ID:	**Bridge name:**

Inspection date:

* MATERIAL	DEFECTS DESCRIPTION
Concrete	Cracking, spalling, corrosion of reinforcement, drummy areas
Steel	Bending, buckling, cracking, distortion, loose bolts, rivets, corrosion, coating damage
Timber	Splitting, crushing, decay, infestation, loose bolts or pins
Masonry	Cracking, opening joints, mortar loss, bulging
Bituminous surfacing	Cracking, crazing, breaking up, lifting off, rutting, pushing
Protective coatings	Cracked, peeling, weathered
** Steel culverts	Probe or sound culvert walls at normal water level, check for pitting or loss of culvert material