Cost & Carbon Management in Infrastructure Guideline

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Acknowledgement of Country

Transport for NSW acknowledges the traditional custodians of the land on which we work and live.

We pay our respects to Elders past and present and celebrate the diversity of Aboriginal people and their ongoing cultures and connections to the lands and waters of NSW.

Many of the transport routes we use today – from rail lines, to roads, to water crossings – follow the traditional Songlines, trade routes and ceremonial paths in Country that our nation's First Peoples followed for tens of thousands of years.

Transport for NSW is committed to honouring Aboriginal peoples' cultural and spiritual connections to the lands, waters and seas and their rich contribution to society.

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Glossary of terms

Term	Definition and use
Actual cost	The actual expenditure at the time of completion of the project.
Agency	All infrastructure delivery agencies
Assets	All non-financial assets recognised by the agency including, but not limited to, land and buildings, plant and equipment, infrastructure systems, leased assets, works in progress, cultural and heritage collections, ICT systems and digital services. Note that this guideline is focused on capital assets including buildings and other infrastructure assets and systems.
Asset life cycle	An asset's life cycle is its evolution from need identification through to disposal and decommissioning.
ATAP	Australian Transport Assessment and Planning
Base estimate	The best prediction cost (or carbon) of a project in current dollars (or tonnes of CO2-e) based on the scope definition available at the time the estimate is prepared but excluding cost escalation and contingency associated with risk.
Base Case	A 'business as usual' situation, assuming Government policies remain as they are and generally, retains the status quo. That is, continuation of current quantity and quality of services including planned maintenance and usage.
Baseline	A reference point for measuring cost and carbon performance, established at the outset of a project phase or assessment. It is set from the base case or a reference design, and includes initial estimates for costs and emissions, against which actual data is compared to track progress and identify variances.
Benefit-Cost Ratio (BCR)	The ratio of social benefits to costs that is obtained by dividing the total value of social benefits by the costs to achieve such benefits. The BCR highlights the relationship between the expected gains, and the resources expended to achieve those benefits.
Benchmark rate	A benchmark rate is a standardised rate for cost and carbon that practitioners can use when actual figures are unknown, serving as a general average. Benchmark rates are developed using bottom-up calculations based on typical projects and assumptions regarding resources, items and assets.
BIM model	3-dimensional digital representation of grouped assets represented by geometrical information contained within a model. The BIM model also contains non-geometrical information. The BIM models are typically developed for each discipline in native format.
Bill of quantities	An itemised list of building materials for the development prepared by a qualified quantity surveyor.
Capital expenditure	A form of expenditure that is incurred when money is spent to buy, construct, renovate or acquire an asset. Capital expenditure is clearly assigned to the acquisition and maintenance of capital assets including property, raw materials, or technology.
Carbon	Carbon dioxide equivalent for all greenhouse gas emissions. This report uses 'carbon' as synonymous with 'carbon dioxide equivalent emissions'.
Carbon budget	The estimated amount of carbon dioxide equivalent emissions allocated to a project or portfolio to limit contributions to global temperature rise, aligning with the goals of the Paris Agreement or other policy objectives.
Carbon emissions	Emissions of greenhouse gases, measured in tonnes of carbon dioxide equivalent emissions (CO2-e).

Term	Definition and use
Carbon Reduction Hierarchy	A decision-making process to minimise carbon emissions in the development of new, or the refurbishment of existing, assets or networks.
Carbon Reduction Target	A carbon reduction target is a goal to reduce carbon emissions by a specific percentage relevant to baseline emissions, measured against a business-as-usual scenario throughout the stages or lifecycle of an infrastructure project.
Circular economy	An economy that is restorative and regenerative by design, and which aims to keep products, components and materials in circulation through processes like reuse, refurbishment, and recycling (as opposed to a linear "take-make-dispose" model).
Classification	System on how objects, concepts or data are classified or arranged based on common purpose, functionality and characteristics.
Infrastructure Common Data Model (ICDM)	A standardised data model, based on a top-down ontology, developed for a business sector to exchange data in a connected digital ecosystem. Transport for NSW have created a Infrastructure Common Data Model (ICDM) considering the Project Management Body of Knowledge (PMBOK) knowledge areas to better share and exchange critical data through the *Digital Engineering Framework*. This includes cost, schedule, risk, scope, quality, procurement, resources and other functions, also considers Environmental Social & Governance (ESG) matters. It will provide a novel solution for specifying, managing and exchanging structured data. It will apply "top-down" and "bottom-up" methodologies for data modelling, applicable for specification and production of information deliverables within the digital thread.
Concept estimate	A Project estimate prepared during the project concept design stage (Investment Decision phase) that is used in the project final business case (FBC).
Contribution analysis	Contribution analysis identifies how specific elements, processes, materials, or life cycle stages affect cost or carbon outcomes, enabling targeted improvements by focusing on key impact areas.
Contingency	Specific allocation of cost (or carbon) required in addition to the base estimate to cover project risks for the desired confidence level. It also considers variation in rates and quantities and includes an allowance in the overall contingency. It involves the evaluation of the possibility, probability, risk and consequences of events which can cause the costs to exceed the base estimate or base schedule. The contingency must be equivalent to the difference between the cost (or carbon) determined using a deterministic approach or probabilistic simulation and the cost (or carbon) adopted in the base estimate.
Cost breakdown structure (CBS)	A breakdown of project expenditure that provides meaningful groupings of capital (and sometimes operational) expenditure. The CBS is often associated with the lowest level of the work breakdown structure (WBS).
Cost or carbon rate	Predetermined values assigned to specific items, materials, and services, expressed per unit of measurement (e.g., per kilogram, per cubic metre)
Design information	Information that details the scope or physical characteristics of a project, from which quantity data can be determined.
Digital engineering	A collaborative way of working, using digital processes, to enable more productive methods of planning, designing, constructing, operating and maintaining assets.
Digital model	Structured data representation of an existing or proposed design, object, system or process. Can include data across dimensions, simulation, including non-geometrical data (e.g., schedules, cost etc). It visualises spatial elements and links them to various datasets for comprehensive management and analysis.
Direct costs	The estimated/actual cost of construction of the physical project work, exclusive of all margins, overheads, contractors risk, and so on. Direct costs are composed of plant, materials and labour.

Term	Definition and use
Embodied carbon	The greenhouse gas emissions and removals associated with the creation and end-of life disposal of an asset. This includes the emissions associated with the production and transportation of materials, construction related emissions, end-of-life emissions. In-use stage material-related emissions associated with maintenance, repair, replacement and refurbishment over the asset life are considered part of embodied carbon. Note: this aligns with definitions in PAS 2080:2023 and RICS Whole life carbon assessment for the built environment, excluding in-use stage emissions relating to operational expenditure, which is part of operational carbon (see definition below).
Emission factor	A conversion factor used to estimate quantity of carbon dioxide equivalent emissions generated by an activity or process (e.g. the manufacture of a product).
End-of-life carbon	Carbon associated with the deconstruction, transport, waste processing, and disposal of capital assets and the end of their useful life. This forms part of embodied carbon.
Engineering Cost & Carbon Library	A database of cost and carbon rates with consistent units of measurement and classification. Contains benchmark rates for resources, items and assets with pre-mapped *Master Classification Library (MCL)*, Pay Item and *ICMS3* classification codes.
Estimate	A document recording the calculated cost prediction to undertake a specific scope of work. It is prepared in a systematic manner appropriate to the size and complexity of the project, and to a level of accuracy proportionate to the available information and the intended use of the information developed.
Estimated total cost	The projected overall expenditure required to complete an infrastructure project. This encompasses all anticipated costs associated with the planning, design, construction, and commissioning phases of the project.
First principles Estimating	An accurate, high order estimating method that applies detailed breakdowns of prices for plant, labour and materials to develop direct costs and a calculation of expected indirect costs.
Global estimating	Also referred to as order of magnitude estimating. A very approximate, low order estimating method based on all in or global rates, such as $/km of motorway. A global estimate should generally be expressed as a rounded range of potential cost outcomes, in outturn dollars, assuming construction over a stated time frame. This method is only to be used for early-stage strategic estimates when a proposal is being scoped. It is considered not satisfactory for more developed projects.
ICMS3	The third edition of the International Cost Management Standard (ICMS), is a global standard that provides a consistent framework for benchmarking and reporting lifecycle costs and carbon emissions, ensuring uniformity in classifying, measuring and presenting these metrics across buildings and infrastructure projects.
Indirect costs	Costs not directly attributable to work items. For construction activities these costs include on site overheads (such as site supervision above the site supervisor level) off-site overheads, insurances and design but exclude contractor’s contingency and profit.
Item-level	Cost and carbon estimates defined at the level where payment of specific components and packages are tracked against (e.g., R78P1.02 Insitu Pavement Stabilisation using slow setting binders 101-150mm thick).
Level Of Definition (LOD)	The collective term used for and including the 'level of detail' (graphical/ geometrical) and 'level of information' (non-graphical/ non-geometrical). This is equivalent to the US BIM Forum (Building SMART US Chapter) Level of Development.

Term	Definition and use
Level of Detail (LoD)	Level of detail is the amount of geometrical (graphical) information contained in a 3D model.
Level Of Information (LoI)	Level of information is the amount of non-geometrical (non-graphical) data embedded within an information model.
Margin	An allowance that includes the construction contractor's profit.
Miraway	A digital platform based on the Transport for NSW *Infrastructure Common Data Model (ICDM)* that connects infrastructure planning, delivery and management processes to improve data consistency, automation and transparency across projects.
Net Present Value (NPV)	The difference between the present value of benefits and present value of costs.
Operational carbon	Emissions generated during the use of the asset and can include operational energy, operational water, other operational processes and user's utilisation of the asset.
P50	The probability of achievement at 50% confidence generated by a Monte Carlo simulation or by deterministic method.
P90	The probability of achievement at 90% confidence generated by a Monte Carlo simulation or by deterministic method.
Probabilistic estimate	An estimate (in current dollars, or when specified, in outturn dollars) prepared by allocating occurrence probabilities to project events and then using the Monte Carlo simulation (or similar) to determine a cost-distribution profile. Probabilistic estimates take into consideration that input data is uncertain (quantities measured, or allowed for, can change, rates assumed can vary) and identified risk events may materialise.
Project estimate	The total estimated cost in current or outturn dollars (when stipulated) of a project.
Project phase	A distinct phase of the project lifecycle, as defined by the Infrastructure NSW Investor Assurance Framework, ranging from needs confirmation through to benefits realisation.
Reference design	Technical blueprint containing essential elements of the proposed solution, used to bridge the gap between design conception and detailed design.
Resource-level	Detailed cost and carbon estimates for specific components required to complete an item, including labour, materials, equipment and service costs. (E.g., asphalt, aggregate, diesel).
Risk	Risk is effect of uncertainty on objectives as per ISO 31000. Risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.
Schedule of rates (SOR)	An output containing a detailed list of predetermined standardised cost and carbon rates for specific items, materials, and services required in a project.
Strategic estimate	A Project estimate prior to the development of a concept for the purpose of program management, comparing options, project feasibility, reporting and use in the project strategic business case.
Standard Estimating Summary Sheet (SESS)	A standardised cost estimate template to present project cost estimates in a consistent format across all project types and phases. It provides a structured breakdown of cost elements, enabling comparison, review, and assurance of estimates throughout the project life cycle.
Tender estimate	A tender estimate is a subset of the latest estimate developed prior to tendering for construction. For construct only contracts it can be extracted directly from the detailed design estimate

Term	Definition and use
Uniclass	A unified classification system covering all construction sectors and items for the construction industry.
Unit of measurement	A standard quantity used to express and quantify the physical dimensions of an item, material, or service. Units of measurement provide a consistent basis for quantifying materials, resources, and emissions, ensuring accuracy and uniformity in data collection, analysis, and reporting.
Upfront carbon	The carbon emissions and removals associated with the creation of an asset, network or system up to practical completion. This includes the emissions associated with the production and transportation of materials and construction related emissions. Upfront carbon is distinct from embodied carbon, as upfront carbon does not include emissions associated with the use and end of life phase of an asset
Value chain	The value chain encompasses the various members responsible for different stages of the asset's life cycle, including asset owners and managers, designers, constructors, and product or material suppliers (as defined under *PAS2080:2023*)
Variance	A variance is defined in the estimating as time, quantities, or cost deviation from the base estimate due to the uncertainty in the project information.
Whole life carbon (or whole of life carbon)	The total greenhouse gas emissions and removals associated with the creation, operation, use, maintenance and end-of-life disposal of an asset. This includes upfront carbon as well as in-use emissions (from maintenance, repair, refurbishment, and operation and use of the asset), end-of-life disposal, and benefits and loads beyond the system boundary (e.g. avoided material production from utilisation of recycled or reused products).
Work breakdown structure (WBS)	Sub-division of a project into smaller parts for managing scope, time, cost, resourcing and other project functions.
Quantity Data	Data that quantifies the physical aspects of materials and resources used in a project, expressed in specific units of measurement (e.g., cubic metres, square metres, kilograms), and classified in a consistent manner.
Quantity take-off	The process of measuring the quantity of materials in a construction design, normally used in reference to extract data from digital models or drawings.

Executive Summary

To support Transport for NSW and Infrastructure NSW's *Decarbonising Infrastructure Roadmap*, Transport for NSW is undertaking work to improve its carbon management procedures and enable the decarbonisation of infrastructure it commissions.

This document provides a strategic overview of how Transport for NSW can leverage existing cost and design management procedures to also manage the carbon emissions associated with its infrastructure.

In doing so, this document:

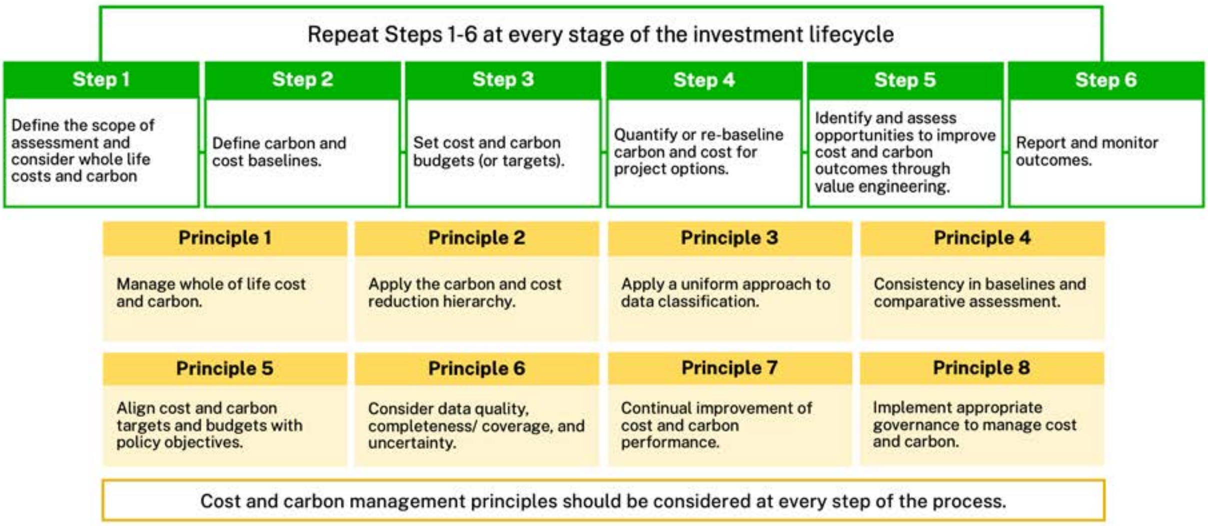
- Describes relevant steps, principles, and concepts that practitioners should apply for effective cost and carbon management.
- Describes the alignment with established international standards such as the International Cost Management Standard *(3rd Edition), PAS2080:2023 Carbon Management in Infrastructure and the Built Environment, and RICS Whole Life Carbon Assessment for the Built Environment (2nd Edition)*.
- Introduces *Miraway*, Transport for NSW's digital platform that enables consistent and efficient management of project data, including costs and carbon emissions, by incorporating the assured benchmark rates of the Transport for NSW *Engineering Cost and Carbon Library*.

The process of cost and carbon management introduced in this document is applicable at all phases of the project lifecycle under the *Infrastructure NSW Infrastructure Investor Assurance Framework* and is relevant for several members of the infrastructure value chain, including professional service contractors, designers, constructors, and product or material suppliers.

This document will be periodically updated to reflect changes to Transport for NSW standards, specifications, and frameworks. These changes may be made to ensure alignment with existing Transport for NSW policy and procedures relating to design, cost estimation and carbon estimation.

Part A of this document outlines the process for managing cost and carbon, with six key steps for each project life cycle phase. The steps and principles for cost and carbon management are shown in figure ES 1.

ES 1 Cost and carbon management process and principles



Part B of this document presents idealised workflows for managing cost and carbon throughout the project lifecycle, building on the processes outlined in Part A. The workflows demonstrate how practitioners can set baselines and targets, develop options to improve carbon or cost outcomes, evaluate them using *Miraway*, and progress through Infrastructure NSW investment assurance gates. Part B also provides detail on how these processes interface with existing and emerging guidance, including the *Sustainable Procurement in Infrastructure Standard and the Valuing Sustainable Outcomes Technical Guidance*.

1. Introduction

1.1. Policy context

NSW Government and Transport for NSW have committed to a series of policy mandates to reduce emissions and improve sustainability considerations in infrastructure investment decision making. The following sections outline the policy context and explain how this document aims to align carbon management processes alongside existing cost management and design processes, laying the foundation for streamlined cost and carbon management in infrastructure.

1.1.1. Paris Agreement and Climate Change (Net Zero Future) Act 2023

As a signatory to the Paris Climate Agreement, Australia is committed to reducing greenhouse gas emissions to limit global temperature increases below 2°C and achieve net zero emissions by 2050.

Aligned with the national goal, the NSW Government has set a target of net zero emissions by 2050 under the *Climate Change (Net Zero Future) Act 2023*. The Act outlines additional emission reduction targets, including:

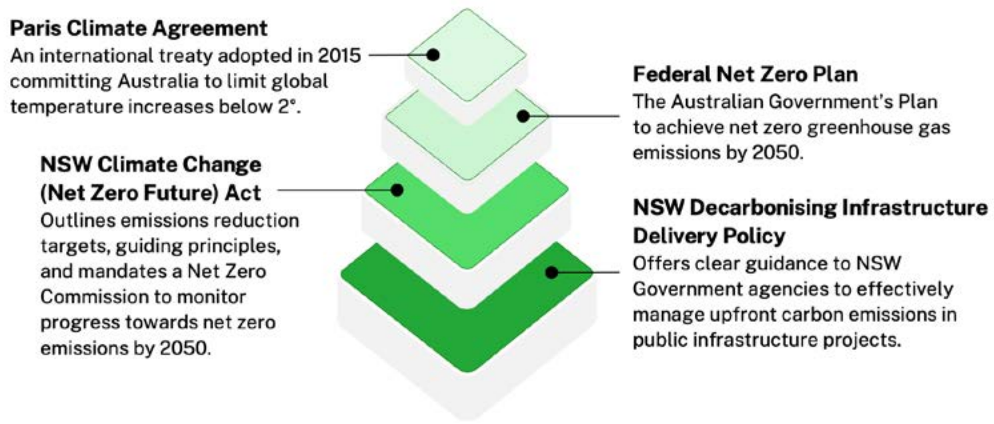
- A 50% reduction in emissions from 2005 levels by 2030
- A 70% reduction in emissions from 2005 levels by 2035
- Net zero emissions by 2050.

To achieve these goals, NSW Government must adequately monitor and manage its emissions at the whole of government, investment portfolio and project levels.

1.1.2. NSW Decarbonising Infrastructure Delivery

The *NSW Decarbonising Infrastructure Delivery Policy* aligns with the *Climate Change (Net Zero Future) Act 2023* and offers guidance to effectively manage upfront carbon emissions in public infrastructure projects. Figure 1.1 provides an overview of the relevant policy context.

Figure 1.1 Net zero policy context



To support NSW's carbon reduction targets, Infrastructure NSW and Transport for NSW developed the *Decarbonising Infrastructure Delivery Roadmap*, which outlines a series of activities focused on embodied carbon reductions. This roadmap features the Sustainable Infrastructure Program (SIP) which supports decarbonisation and the circular economy through digitisation, focusing on net zero procurement, engineering and innovation, decarbonising the development and construction phases, and aligning systems for consistent carbon management.

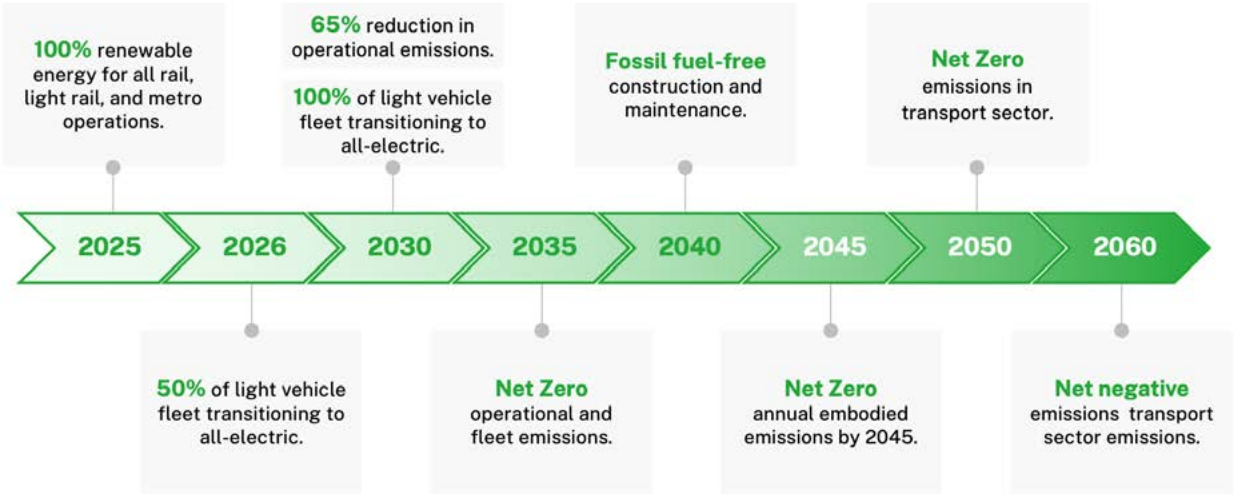
This guideline is a key component of the SIP, facilitating the integration of carbon management in the investment assurance process and aligning it with established cost management procedures.

1.1.3. Net Zero and Climate Change Policy

The *Transport for NSW Net Zero and Climate Change Policy* sets emissions reduction targets and reporting requirements to achieve net zero transport sector emissions by 2050. These targets are outlined in Figure 1.2.

The policy aims to integrate emissions reduction and climate change risk management into all decision-making processes. This document supports the implementation of the policy by providing a structured process for integrating cost and carbon management in infrastructure projects, including continuous improvement, reporting and assessment.

Figure 1.2 Transport sector emissions reduction targets



1.2. Purpose of this document

This document provides an overview for key members of the infrastructure value chain on how to leverage existing cost management processes to manage carbon across the infrastructure investment lifecycle. The document also introduces *Miraway* and the *Engineering Cost and Carbon Library* as digital tools/databases available to practitioners to integrate cost and carbon management.

Fundamentally, the steps, concepts and principles introduced in this document do not differ from current cost estimation practices and only involve minor reconfiguration to enable more streamlined carbon estimation and management.

The guidance provided in this document is strategic in nature and provides a generalised introduction to the cost and carbon management process. This guidance will be further developed alongside other Transport for NSW standards, specifications and frameworks to ensure alignment and to reflect the latest best practice in cost and carbon management.

1.2.1. How to use this document

Part A of this document provides an overview of the cost and carbon management process, outlining six key steps to follow at each phase of the project life cycle. It is important to begin by reviewing **Part A**, which also introduces several important principles and concepts of cost and carbon management which are cross referenced in **Part B**.

Part B offers idealised workflows for managing cost and carbon at each phase of the infrastructure investment life cycle, and provides a more specific application of the process introduced in Part A. The workflows illustrate when to set baselines and targets, develop options to improve carbon or cost outcomes, evaluate options using the *Miraway* and the *Engineering Cost and Carbon Library*, and when to proceed to Infrastructure NSW investment assurance gates. Part B also provides detail on how these processes interface with other existing guidance or decision-making frameworks for each phase.

Part B should be considered as illustrative workflows for each project stage. It should also be noted that workflows may vary depending on the specific nature of each project and contract arrangement. Part B does not represent a comprehensive statement of all requirements applicable to a project under the Transport for NSW Cost Estimating Procedure or the Project Management Framework, and should instead be read in conjunction with other applicable project requirements.

1.3. Interfacing guidance documents

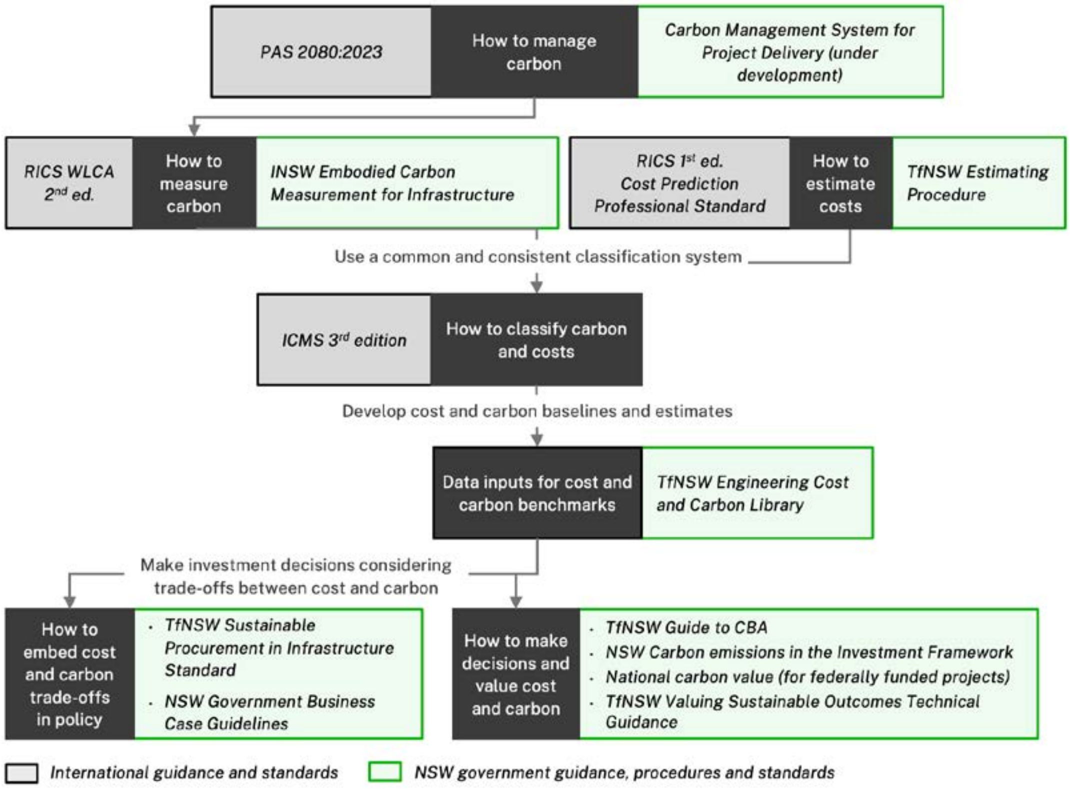
This document interfaces with several other guidance documents listed in Table 1.1. The relationship between these documents is presented in Figure 1.3. Transport for NSW is pursuing efforts to progressively update the documents listed to ensure alignment between them.

Table 1.1 Alignment and interface with other guidance documents

Document	Description and relevance
Government publications and guidance documents	
Transport for NSW Estimating Procedure	The *Transport for NSW Estimating Procedure* is designed to assist staff and industry partners engaged in estimating the cost of infrastructure construction projects. It details the required estimates, inputs, estimation methods, contingency calculations, risk modelling, and presentation of outturn dollars for each project phase.
Transport for NSW Cost Benefit Analysis (CBA) Guide	Outlines the principles, methodology, and procedures for conducting CBA on NSW Transport initiatives. Estimates produced following this guidance must also align with NSW Government CBA requirements for appraising project value-for-money in business cases.
Sustainable Procurement and Infrastructure Standard (SPIS)	The SPIS outlines Transport for NSW's procurement requirements supporting its Net Zero and Climate Change Policy and Transport Sustainability Plan 2021. The guidance integrates sustainable procurement into all project phases, focusing on carbon reduction and circular economy goals.
INSW Embodied Carbon Measurement for Infrastructure: Technical Guidance	This guidance supports consistent embodied carbon measurement practices for NSW Government agencies and partners by providing common methodologies, data use approaches, and reporting standards. It establishes minimum expectations for carbon measurement and reporting and offers guidance for capturing broader emission modules.
Engineering Cost and Carbon Library	A database of standardised cost and carbon rates at the resource, item and global strategic-levels. It allows practitioners to apply consistent benchmark rates to develop baseline cost and carbon estimates and will streamline cost and carbon reporting. The library, originally shared with industry as an excel file, is now a database embedded in *Miraway* that supports the quantification of carbon from cost estimation.
Valuing Sustainable Outcomes (VSO) Technical Guidance	The VSO technical guidance supports practitioners, planners and procurement managers in Transport for NSW and other agencies to better incorporate and value sustainable outcomes throughout the project lifecycle. The technical guidance provides definitions, frameworks and metrics for sustainable outcomes, covering economic, social and environmental dimensions and integrates sustainable outcomes consistently across all project phases. The technical guidance has an aligned monetisation framework for integration into value based decision making points like Multi Criteria Analysis, Cost Benefit Analysis, and procurement by using the Most Advantageous Tenderer (MAT) approach for bid evaluation. Elements of this are now embedded in *Miraway*.

Document	Description and relevance
External standards and guidance	
PAS2080:2023 Carbon Management in Buildings and Infrastructure	*PAS2080:2023* is an internationally recognised standard, which specifies requirements for the management of whole life carbon in buildings and infrastructure.
RICS 2nd edition Whole Life Carbon Assessment for the Built Environment *Referred to in this document as 'RICS 2nd edition'*	*RICS 2nd* edition establishes the methodology for measuring and assessing the carbon impacts from buildings and related infrastructure assets throughout their life cycle. It introduces the concept of whole life carbon assessments (WLCA), which is the calculation and reporting of carbon impacts through the investment life cycle. The guidance presented in this document is aligned with the principles and methodology of *RICS 2nd* edition.
*ICMS 3*rd edition (*ICMS 3*) Global Consistency in Presenting Construction Life Cycle Costs and Carbon Emissions	*ICMS 3* introduces a global standard for reporting construction life cycle costs alongside carbon emissions. It promotes consistency and transparency in how cost and carbon data are measured, recorded, and presented, facilitating better benchmarking and decision-making. This guidance and the *Engineering Cost and Carbon Library* are aligned with the *ICMS 3* classification system to define different levels of definition for cost and carbon estimation. The *Engineering Cost and Carbon Library* also introduces two additional levels of definition beyond the four levels presented by *ICMS3* to allow for cost and carbon estimation at a pay item and resource-level (defined further in Part A).
RICS 1st edition Cost Prediction Professional Standard, Global	The RICS professional standard outlines global best practices for cost estimation across clients, consultants and contractors. It incorporates the ICMS hierarchy and framework to classify costs and describes a process for cost prediction consistency and the level of granularity throughout the cost estimation process.

Figure 1.3 Other related guidance documents and their interfaces



1.4. Scope and applicability

1.4.1. Projects and investments

The integrated carbon and cost guidance outlined in this document is relevant to all Transport for NSW infrastructure projects that are assigned Tier 1 to Tier 4 risk profiles under the Infrastructure NSW Infrastructure Investor Assurance Framework (INSW IIAF) and are required to undergo assurance reviews. This includes projects with an Estimated Total Cost (ETC) of over $50 million, or projects with an ETC of over $10 million that are determined to have high risk or a high public profile. The guidance outlined in this document is relevant across the project life cycle from inception through to delivery and benefits realisation, as shown in Figure 1.4.

Projects that do not meet the criteria described above are still required to undertake the ongoing cost management procedures in line with the Transport for NSW Cost Estimating Procedure and Project Management Framework.

Figure 1.4 INSW IIAF project life cycle and assurance process

Project State	Initiation	Planning + Development		Procurement		Delivery	Operation
Project Phase	Needs Confirmation	Needs Analysis	Investment Decision	Procure		Deliver & Initial Operations	Benefits Realisation
	0	1	2	3	4	5	6
Gateway Review	GO/NO GO	Strategic Options	Business Case	Readiness for Market	Tender Evaluation	Readiness for Service	Benefits Realisation
Review Deliverable	· Evidence the problem & service need exists · Registration on GCA reporting & assurance portal · Completed gate 0 template or equivalent	· Well defined service need · Evidence of how the project scope meets the service need · Options analysis · Appropriate level of cost benefit analysis	· Final business case · Detailed risk register · Detailed cost plan · Detailed cost benefit analysis · Procurement and delivery strategy	· Clear scope definition · Procurement documentation · Procurement and commercial approach · Evaluation strategy · Probity plan	· Evaluation report · Probity report · Summary of departures and variations · Evidence of delivery readiness and handover approach	· Independent verifier reports confirming scope delivery · Testing and commissioning documentation · Operational readiness documentation · Handover strategy	· Evidence of operational performance · Benefits realization plan · Record of lessons learnt · Completed Gate 6 template
Project tiers	Tier 1 Tier 2 Tier 3	Tier 1 Tier 2	Tier 1 Tier 2	Tier 1	Tier 1	Tier 1	Tier 1

Source: Adapted from Infrastructure NSW Infrastructure Investor Assurance Framework (2023)

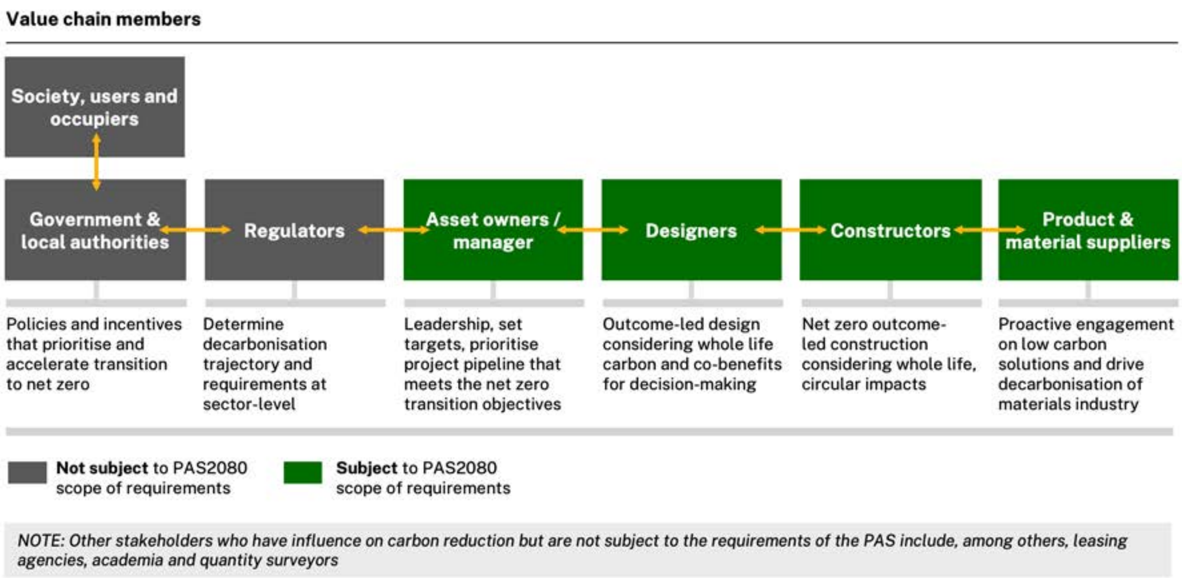
1.4.2. Value chain members influencing cost & carbon

The value chain encompasses those who are involved in different stages of the asset life cycle, including asset owners and managers, designers, constructors, and product or material suppliers. *PAS2080:2023* outlines the requirements for value chain members to establish governance mechanisms that enhance collaboration and reduce whole life carbon. This specification encourages these members to engage early, share carbon objectives, and challenge existing practices to innovate and implement low-carbon solutions effectively.

This document is aligned with *PAS2080:2023* and is relevant to several members of the value chain as shown in Figure 1.5, including:

- **Government and local authorities** – organisations that are responsible for setting regulations, providing funding, and developing policies and frameworks to govern and support infrastructure development. Transport for NSW fulfils aspects of this role through the establishment of policies and incentives to enable emission reduction while also managing and maintaining infrastructure networks.
- **Asset owners and managers** – organisations and individuals that manage and are responsible for providing, operating and maintaining infrastructure networks or assets. For most projects, Transport for NSW is the asset owner and manager.
- **Designers** – organisations that create, prepare or specify the design of an asset or network for construction, maintenance, repair or refurbishment. Designers may be internal to Transport for NSW or external contractors.
- **Constructors** – organisations that undertake work to construct, build, maintain, repair, replace, or demolish an asset or network. Constructors may be internal to Transport for NSW or external contractors.
- **Product or material suppliers** – organisations that extracts, manufactures or produces materials or products for use in works to construct, build, maintain or operate an asset.

Figure 1.5 PAS2080 value chain members



Source: PAS2080 Carbon management in infrastructure and buildings

[1]British Standards Institute (2023) *PAS2080:2023* Carbon management in infrastructure and buildings [online]. Available at: https://www.bsigroup.com/en-GB/standards/pas-2080 (last accessed June 2024).

Part A

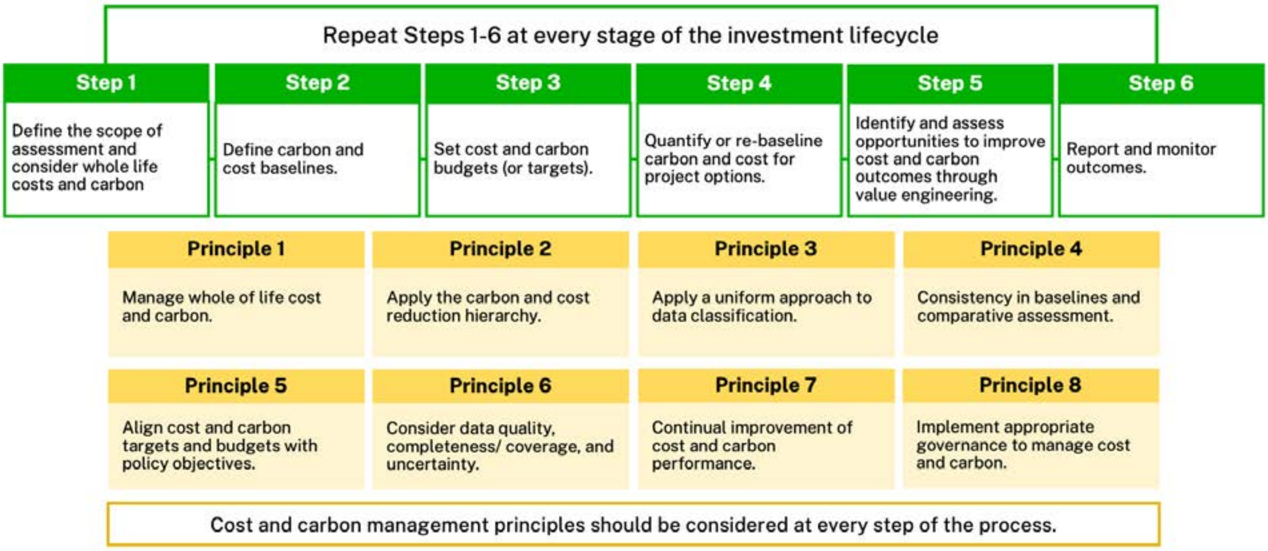
Overview of Cost and Carbon Management in Infrastructure

2. Cost and carbon management process and principles

Effective cost and carbon management requires careful consideration of cost and carbon outcomes throughout the project life cycle. This section introduces the general process for cost and carbon management that should be followed for each phase of the project life cycle (shown in Figure 2.1). This section also introduces *Miraway* and the *Engineering Cost and Carbon Library*, which are a digital platform and database designed to streamline carbon estimation and management alongside existing cost estimation and engineering design processes. More broadly, *Miraway* and the *Engineering Cost and Carbon Library* allow carbon estimation and assessment to be automatically integrated into existing project development and design processes. Fundamentally, the steps, concepts and principles introduced in this document do not differ from current cost estimation practices and only involve minor reconfiguration to enable more streamlined carbon estimation and management.

The process described in this section is consistent with *RICS 2nd* edition, INSW Embodied Carbon Measurement Guidance and *ICMS 3*.

Figure 2.1 Process and principles of cost and carbon management



Supporting the process are core principles which align with best practice guidance and standards.

Principle

Throughout this section, these boxes will introduce fundamental rules or best practice guidance on applying the cost and carbon management steps.

Applying the steps and principles for cost and carbon management will also require an understanding of related and important concepts, some of which are described in this document.

Concept

These boxes highlight the key ideas or tools that practitioners should understand to effectively apply the cost and carbon management steps or principles.

The process outlined in this section is software-agnostic and does not prescribe the use of any specific software.

2.1. Step 1: Define the scope of assessment and consider whole life costs and carbon

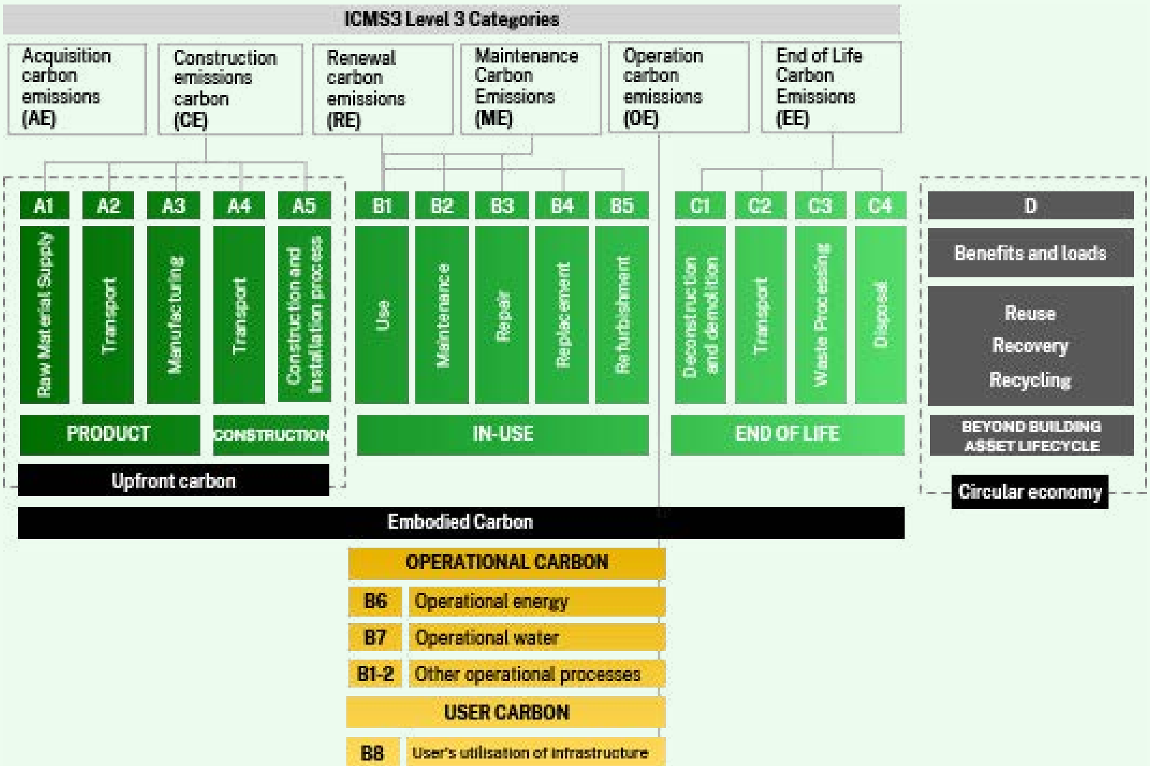
The cost and carbon management process starts with understanding the scope of analysis for both cost and carbon, ensuring that the project's objectives, inclusions and exclusions are defined. Changes in the scope of the project impact how targets are set, how performance is measured and how investment decisions are made. Clearly defining the scope of the project is therefore critical to effective cost and carbon management. Within the defined project scope, practitioners should measure whole life costs and carbon (see **Concept 1**).

Concept 1: Whole life costs and carbon emissions

The costs and carbon emissions of a project can change significantly across its life cycle. Evaluating these impacts holistically helps to make informed decisions that optimise both cost and carbon performance. Whole life costs and carbon emissions refer to the total cost and carbon impact of a project from inception to disposal and renewal. A whole life approach enables circular economy principles to be considered, for example, by encouraging future repurposing of a building or infrastructure asset and its components.

In alignment with *RICS 2nd* edition and *ICMS3* this guide applies a whole life approach to cost and carbon management. Whole life costs and carbon emissions can be considered by breaking the asset life cycle into modules including production, construction, operation, end of life and beyond (Figure 2.2).

Figure 2.2 Sources of whole life carbon emissions and illustration of definitions used in this document (adapted from PAS2080:2023 and modules in EN 17472:2022)



While *RICS 2nd* edition focuses specifically on carbon, this guide aims to align whole life cost and carbon assessment by drawing parallels between the whole life breakdowns. Whole life costs are often classified as:

- **Capital expenditure (Capex)**: incurred when money is spent to acquire, construct, or renovate an asset.
- **Operating expenditure (Opex)**: non-capital expenses incurred in the operation and maintenance of an asset.

Major replacements and refurbishments may be classified as Capex if their costs are significant in relation to the total cost of the asset such that they should be depreciated separately (in accordance with accounting standard *AASB116*). Asset disposal costs (module C4) should be included as Opex if they occur within the appraisal period of the estimate.

Carbon emissions may also be referred to as:

- **Upfront (capital) carbon**: emissions associated with the creation of an asset, network or system up to practical completion (A1-A5). This includes emissions associated with production and transportation of materials and construction-related emissions.
- **Embodied carbon**: emissions associated with the creation (A1-A5), use, maintenance, repair, replacement, and refurbishment (B1-B5), and end-of-life (C1-C4) of an asset. This definition aligns with *PAS2080:2023* and the *RICS 2nd* edition, and excludes operational carbon (B6-B8), which is classified separately.
- **Operational carbon**: emissions associated with the operation (i.e., the in-use stage) of assets, particularly operational energy (module B6) and operational water (module B7). It can also include any module from B1 to B5 linked to operational activities. Examples include fugitive emissions of refrigerants (B1) and maintenance of assets (B2).
- **Asset user (enabled) carbon**: emissions associated with activities enabled by an asset's use (B8) (e.g. emissions from third-party vehicles driving on a road).

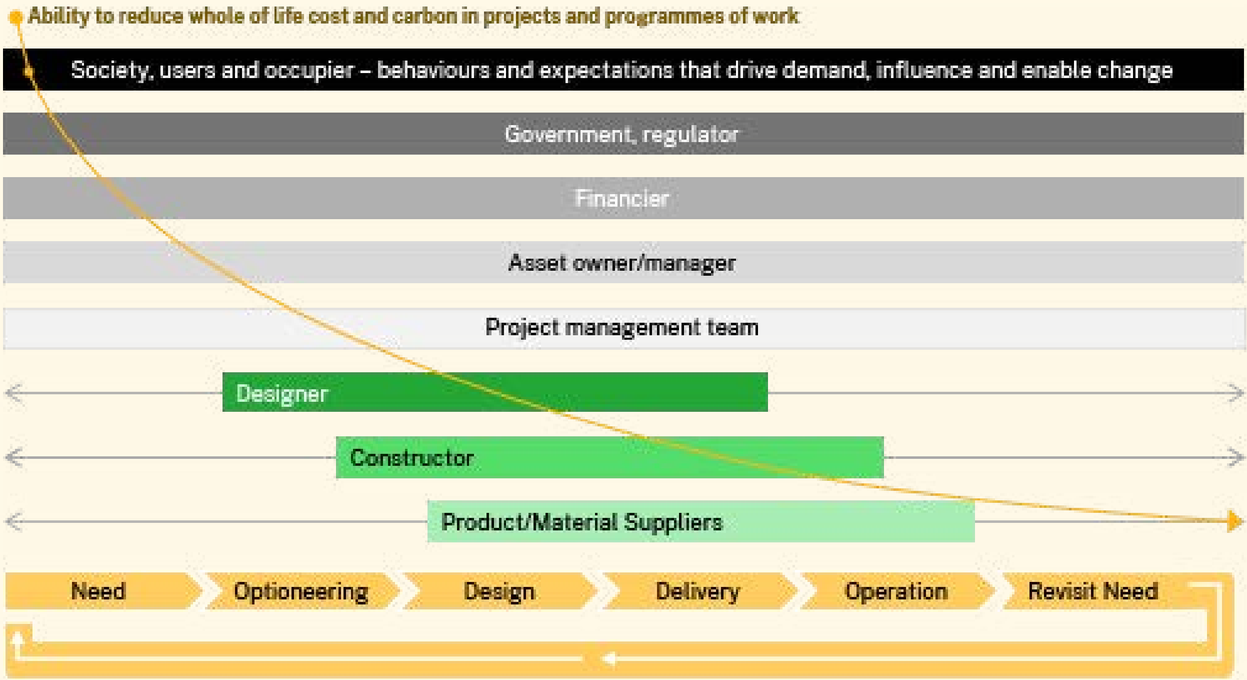
Principle 1 introduces the importance of identifying and managing the sources of whole life cost and whole life carbon that fall within a value chain member's control and influence.

Principle 1: Manage whole life cost and carbon

Value chain members have varying levels of control over cost and carbon outcomes at different phases of the project life cycle. Early engagement and ongoing collaboration enable the use of each value chain member's control and influence to drive decarbonisation and optimise costs.

Transport for NSW, as an asset owner, is responsible for setting up a carbon management process, setting requirements and targets, and clearly communicating roles at each phase. Designers and constructors should look for opportunities to improve beyond the set standards and targets. Product and material suppliers should aim to create and introduce low-carbon solutions to the industry. For more detailed roles of each value chain member through the delivery process, refer to Clause 6 of *PAS2080:2023*. The control and influence of value chain members across the project life cycle are summarised in Figure 2.3.

Figure 2.3 Influence on emissions reduction for members of value chain



By leveraging existing boundaries and aligning with standards, the cost and carbon management process is made more consistent.

Cost breakdown structures

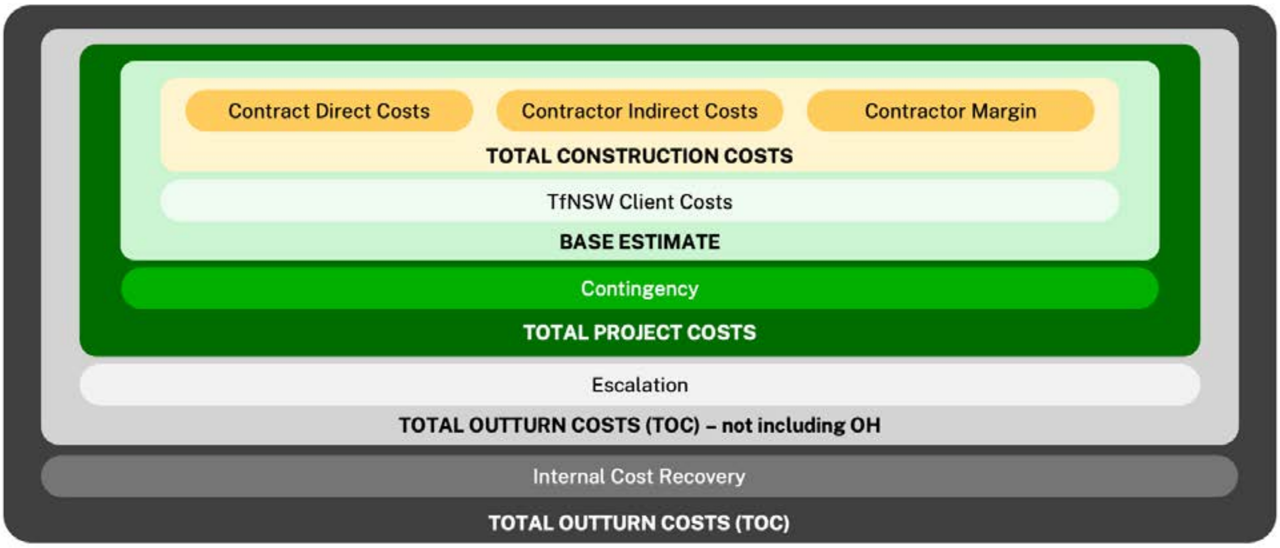
For cost estimation, the breakdown of assessment and methodology should follow the *Transport for NSW Estimating Procedure*, as shown in Figure 2.4, and includes:

- **Contractor Direct Costs**: costs incurred for labour, plant, and materials that are completely attributable to a specific item of work or services.
- **Contractor Indirect Costs**: costs not directly attributable to specific items of work but necessary for overall project delivery, including project management, fees, insurance, site buildings, and offices.
- **Contractor Margin**: corporate overhead to facilitate the contractor's business, head office expenses, executive management, profit, and risk allowances. This is typically applied as a percentage uplift of direct and indirect costs.
- **Internal Cost Recovery**: divisional overheads charged for functional services like management, corporate services, IT, rent, and electricity. This is typically applied as a percentage uplift to the total project cost
- **Contingency**: allowances for unforeseen costs.
- **Escalation**: adjustments for changes in cost over time.
- **Client costs**: the internal cost of all activities undertaken by Transport for NSW teams during the development, delivery and finalisation of a project including (but not limited to) project management team, community engagement activities, studies, technical reviews, audits etc.

[2] (2023, April). Guidance Document for PAS 2080. Retrieved from https://www.ice.org.uk/media/vm0nwehp/2023-03-29-pas_2080_guidance_document_april_2023.pdf

It is noted that, outside of economic analysis, whole life cost estimates do not include user-incurred costs. User costs refer to expenses borne by individuals using the infrastructure, such as fuel costs, vehicle maintenance, and travel time for motorists using a road. These costs, while significant in the broader economic analysis of a project's impact, are not included in the direct project costs managed by Transport for NSW. This contrasts with whole life carbon emissions estimation which includes whole life emissions under the control and influence of the value chain members and therefore should include the emissions released by users of the assets commissioned by the asset owner or manager.

Figure 2.4 Standard cost estimate breakdown



Carbon management standards

PAS2080:2023 Carbon management in buildings and infrastructure and the Royal Institution of Chartered Surveyors (RICS) Whole life carbon assessment for the built environment (2nd edition, 2023) standard require management of whole life carbon. These standards are built upon more detailed environmental life cycle assessment standards, which are:

- *EN 15978:2011* Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.
- *EN 17472:2022* Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation method.

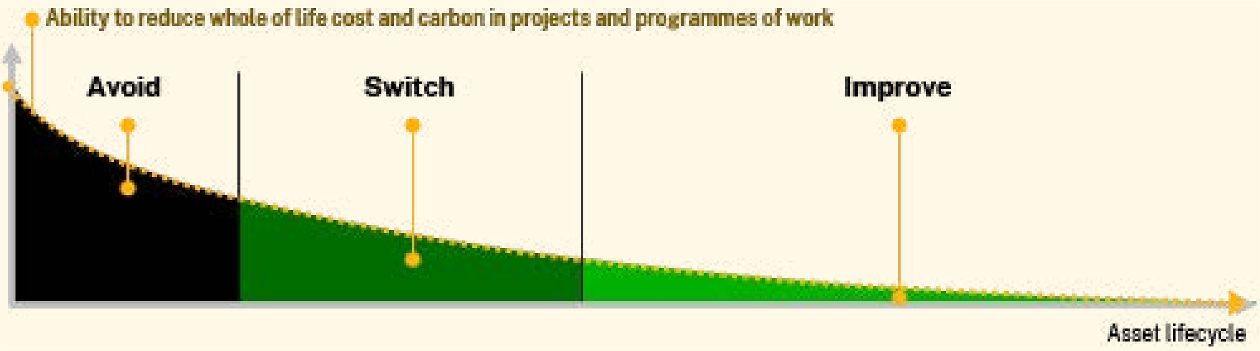
A recommended approach to advancing cost and carbon management processes is to adopt a hierarchy that prioritises cost and carbon considerations from the earliest phases of a project. This is illustrated in **Principle 2** (next page) and adopts the *PAS2080:2023* carbon hierarchy for cost management.

Principle 2: Apply the cost and carbon reduction hierarchy

Considering cost and carbon outcomes from the outset of the investment life cycle enhances an asset owner or manager's ability to achieve carbon reductions and optimise cost. The cost and carbon hierarchy (presented in Figure 2.5) offers a structured framework to assess whether costs or carbon emissions can be avoided, whether components can be substituted with alternative interventions, or whether existing interventions can be improved to optimise for carbon or cost.

The most significant opportunity to reduce whole life carbon emissions occurs during the 'Needs Confirmation' phase, where the necessity of an intervention is assessed and validated.

Figure 2.5 Influence on emissions reduction for members of value chain



Principles	Cost	Carbon
1. Avoid		
1.1 Align project outcomes with cost and carbon policies in early project phases	✓	✓
1.2 Avoid costs and carbon emissions by evaluating the need for projects	✓	✓
1.3 Explore alternative service solutions that achieve the same outcomes without construction of new assets or by repurposing existing assets	✓	✓
1.4 Consider the time value of money, as well as the time value of carbon when managing costs and benefits. Defer items that are not immediately needed	✓	✓
2. Switch		
2.1 Assess alternative options and choose an option that minimises emissions while achieving the same outcomes or achieve greater value for money. Include alternative scopes, design approaches, materials or technologies	✓	✓
2.2 Optimise the balance between capital, resource use, operational and user costs and carbon	✓	✓
3. Improve		
3.1 Enhance the efficiency and performance of existing processes, systems and resources	✓	✓
3.2 Apply circular economy principles to assess materials for waste minimisation after end-of-life, including consideration of end-of-life costs	✓	✓
3.3 Promote network and system decarbonisation	X	✓

[3] The time value of carbon refers to the

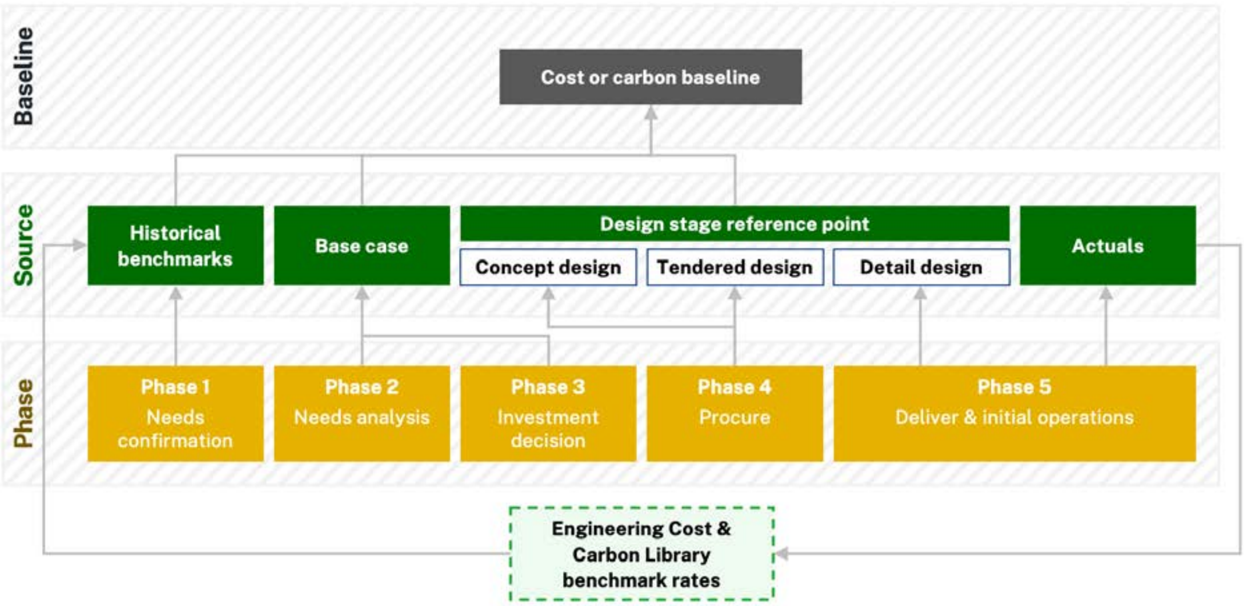
2.2. Step 2: Define cost and carbon baselines

A baseline is a reference point for cost and carbon management, and plays a critical role in setting targets, comparing investment options, evaluating outcomes and guiding decision-making. This section describes the process of setting baselines and introduces *Miraway* and the *Engineering Cost and Carbon Library*, which support the quantification of baselines at different stages of the project lifecycle.

2.2.1. Methods for developing baselines

Figure 2.6 shows how baselines can be formed and refined across the life cycle for a typical design and construct project. In the Needs Confirmation phase, a baseline is used to support the quantification of an existing problem and justify the need for an intervention. When an investment decision is required, the base case serves as the reference point for evaluating investment options against. In design phases, baselines are used as reference points to compare alternative design options against. During the project, baselines should be progressively refined to reflect enhancements in scope and detail.

Figure 2.6 Progression of cost and carbon baselines through design and construct project phases



This guidance makes a distinction between the terms 'base case' and 'baseline' as described in **Concept 2**.

Concept 2: What is the difference between a 'baseline' and the 'base case'?

For this document, 'baseline' is used to refer to a reference point for comparison to a specified level of cost or carbon performance, at a particular point in the project life cycle. The baseline can be used to measure the performance of a proposed design option against a reference design.

The term 'base case' refers to a 'do-minimum' scenario that is used to compare investment options against during the needs analysis and investment decision phases, in particular for cost-benefit analysis. During these phases, cost and carbon outcomes of the base case can be estimated using benchmark rates in the *Engineering Cost and Carbon Library*.

Assured benchmark rates support the development of baselines by enabling cost and carbon outcomes to be quantified when actual cost and carbon data is unknown or unavailable. **Concept 3** introduces the types of benchmark rates, and how they can be used with different types of estimating methods to develop baseline estimates.

Concept 3: Types of benchmark rates and estimating methods

A benchmark rate is a rate of cost (in $ per unit of measurement) or carbon (in tonnes of CO_2-e per unit of measurement) that practitioners can use when the actual cost or carbon is unknown. Benchmark rates are developed using historical project information or generalised build ups of resources based on typical standards or design assumptions.

Benchmark rates can exist at different levels of definition, ranging from broad asset types to detailed resources such as plant, labour and raw materials. It is important that the benchmark rates used effectively reflect the level of project information available. In this document, three types of benchmark rates are introduced:

- **Global strategic benchmarks**: high level asset benchmarks based on historic projects and defined units of measurement, such as lane kilometres (lane km) for roads or area (m2 gross floor area) for buildings, as well as labels for characteristics of the project such as location (urban or rural), terrain type (flood plain or mountainous), etc.
- **Item-level benchmarks**: benchmarks for distinct components or work packages of a project for which payment would be made to a contractor (for example, installation of open-graded asphalt AC14).
- **Resource-level benchmarks**: benchmarks for plant, labour, materials and fuels needed to deliver an item (for example, Asphalt Paver - 3m (Roadtec RP-190), Sub Contractor Supervision (Foreman), Asphalt - Open graded - 14mm, and Fuel - Diesel (on road) fuel)

Estimating is a process that involves utilising benchmark rates, tendered rates, or actual rates to create projections for project costs and carbon emissions. This document considers three types of estimating methods for cost and carbon emissions:

- **Global (order of magnitude) estimating** involves using global strategic benchmarks to produce a coarse or low-order estimate. This method is suitable for early-stage strategic estimates when a proposal is being scoped. As more detailed information becomes available, more accurate methods should be adopted. It is important to understand and adjust these historical rates for factors like time, location, legislation, and project-specific details to ensure accuracy for new projects.
- **Unit rate estimating** involves using item-level benchmark rates and calculated quantities to forecast item-level cost or carbon. While this method provides a more detailed estimate than global estimating, it still requires adjustments to account for unique project constraints, market conditions, and site-specific factors.
- **First principles estimating**: involves breaking down a project into its finest elements or resources and calculating rates specifically for the project. This method considers the direct costs of plant, labour, materials, and fuels, as well as indirect costs like site establishment and insurance. It is the most detailed and time-consuming method, typically used by contractors for preparing detailed estimates for delivery. Although it offers the greatest certainty of outcome, incorrect assumptions or data can lead to inaccurate estimates.

The application of benchmark rates also relies on standardised definitions and classifications of assets, items and resources. Transport for NSW's *Engineering Cost and Carbon Library* adopts the *ICMS 3* classification system, which defines four levels of classifying assets and sub-components. Transport for NSW has also developed two additional levels of classification for items and resources, as outlined in **Concept 4**.

Concept 4: ICMS 3 Classification System

IMS 3 provides a standardised framework for classifying, defining, recording, analysing and presenting life cycle costs and carbon emissions to ensure consistency in reporting life cycle costs and carbon emissions.

The ICMS3 defines four classification levels:

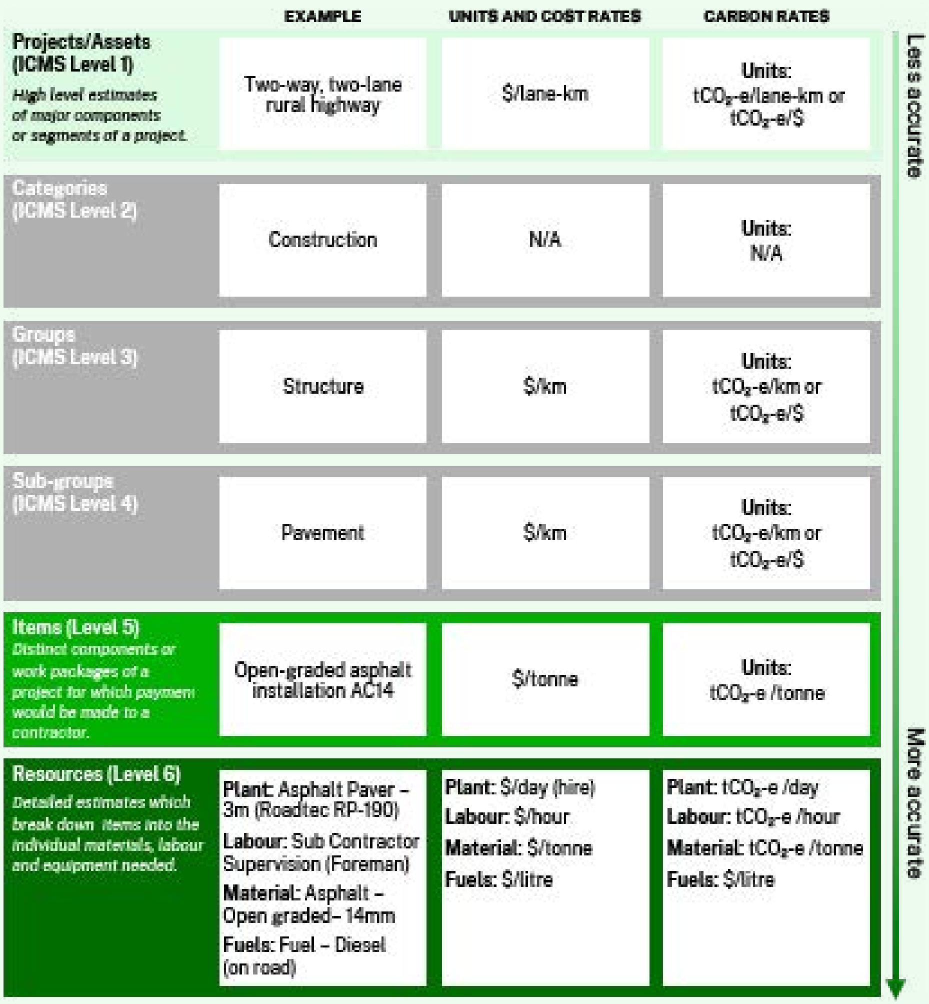
- **Level 1**: Projects are classified based on their core nature and main purpose (e.g., a bridge, road or railway). In cases of complex projects, sub-projects can be developed. In some cases, an investment may include several project types (such as a motorway which will include roads, bridges and/or tunnels).
- **Level 2**: Categories are defined by the asset life cycle stage such as acquisition, construction, renewal, operation, maintenance, or end of life.
- **Level 3**: Groups are specific classifications of costs or carbon emissions in the project lifecycle, such as 'Demolition, site preparation, and formation', 'Substructure', or 'Services and equipment', and are used to consistently report and compare construction, renewal, maintenance, and operation costs and emissions.
- **Level 4**: Sub-groups are optional detailed classifications of costs or carbon emissions, such as 'Site survey and ground investigation' or 'Structural removal and alterations', allowing for more granular reporting. Transport for NSW has adopted Level 4 Sub-Groups in the *Engineering Cost and Carbon Library*.

Transport for NSW has defined three additional levels to their cost and carbon estimation framework.

- **Level 1a**: Global Strategic estimates provide broad strategic information on historic costs per unit of measurement that might be useful in preparing first strategic estimates.
- **Level 5**: Items are defined as distinct components or work packages of a project for which payment would be made to a contractor.
- **Level 6**: Resources refers to plant, labour, materials and fuels needed to deliver an item.

These levels of definition (*ICMS3* levels 1-4 and Transport for NSW levels 5-6) and classification are shown in Figure 2.7, along with examples and their unit rates.

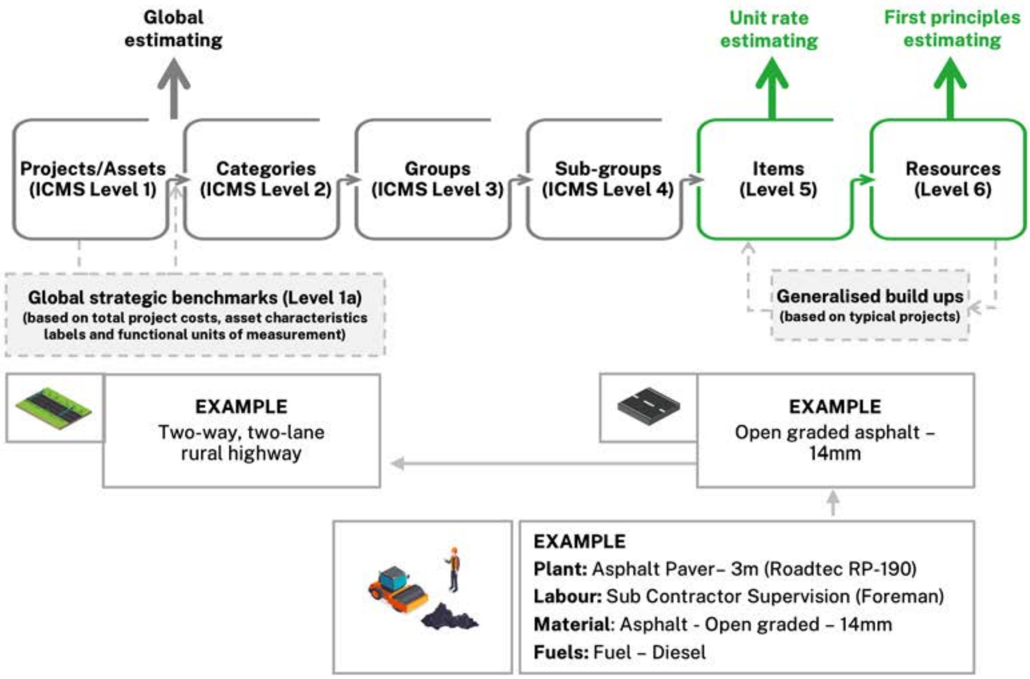
Figure 2.7 Level of cost and carbon estimates



	EXAMPLE	UNITS AND COST RATES	CARBON RATES
Projects/Assets (ICMS Level 1) *High level estimates of major components or segments of a project.*	Two-way, two-lane rural highway	$/lane-km	Units: tCO_2-e/lane-km or tCO_2-e/$
Categories (ICMS Level 2)	Construction	N/A	Units: N/A
Groups (ICMS Level 3)	Structure	$/km	Units: tCO_2-e/km or tCO_2-e/$
Sub-groups (ICMS Level 4)	Pavement	$/km	Units: tCO_2-e/km or tCO_2-e/$
Items (Level 5) *Distinct components or work packages of a project for which payment would be made to a contractor.*	Open-graded asphalt installation AC14	$/tonne	Units: tCO_2-e /tonne
Resources (Level 6) *Detailed estimates which break down items into the individual materials, labour and equipment needed.*	**Plant**: Asphalt Paver – 3m (Roadtec RP-190) **Labour**: Sub Contractor Supervision (Foreman) **Material**: Asphalt – Open graded – 14mm **Fuels**: Fuel – Diesel (on road)	**Plant**: $/day (hire) **Labour**: $/hour **Material**: $/tonne **Fuels**: $/litre	**Plant**: tCO_2-e /day **Labour**: tCO_2-e /hour **Material**: tCO_2-e /tonne **Fuels**: $/litre

Figure 2.8 demonstrates how these levels of classification align with the benchmark rates and methods of cost and carbon estimating.

Figure 2.8 Levels of classification required for each estimation type



The use of benchmark rates also relies on uniform data classification and consistent naming conventions for resources, items, and assets (Principle 3). This ensures that everyone refers to the same elements in the same way and allows for seamless integration with other classification systems such as those used in digital engineering or asset management.

Principle 3: Apply a uniform approach to data classification

The principle of uniformity in data classification is important, especially when comparing cost and carbon across different projects. The use of a consistent reporting taxonomy, such as the frameworks set out by *ICMS 3* and Transport for NSW, can streamline the process of classifying, defining, measuring, recording, analysing and presenting estimates.

The principle of uniformity should also extend to the units of measurement when undertaking quantity take-offs from digital models or scope and design inputs. Employing the same units of measurement across all data classifications maintains consistency and allows for uniform rates to be applied across projects, streamlining the cost and carbon estimation process. This is one of the key features of the *Engineering Cost & Carbon Library*, where quantity take-off in engineering design, also cost management is completely aligned, bringing these traditionally siloed processes together.

Consistency in baselines is also critical for accurate cost and carbon management (**Principle 4**).

Principle 4: Consistency in baselines and comparative assessment

Following *PAS2080:2023*, the development of baselines, for use in target setting or options analysis, should be directly related to a particular scope, function or level of service which quantifies the useful product or service delivered by the infrastructure. Table 2.1 provides examples of consistent and equivalent functional units.

Comparisons should be made between designs with an equivalent functional unit. Comparing cost or carbon outcomes of designs with vastly different scopes or functions does not provide meaningful insights and can lead to misguided decisions.

Table 2.1 Example purpose and functional units in baseline and comparative assessments

Purpose	Example functional units
For a comparison of transport modal options	Transportation of 10,000 passengers per day between Point A and Point B, which are 20 km apart, with a journey time of 1 hour, over a period of 60 years.
For comparing different rail track designs	1km of rail track designed to handle an annual traffic load of 60 million gross tonnes, with a service life of 60 years.

Source: adapted from Construction Leadership Council, Guidance Document for PAS2080

Note: In cases where options with differing scopes or functions need to be compared, such as during the Needs Analysis or Investment Decision phases, these differences should be clearly documented. Tools such as multi-criteria analysis or cost-benefit analysis should be used to quantify the impact of differing scopes in addition to the cost and carbon outcomes.

2.2.2. The Engineering Cost and Carbon Library

As projects progress through the life cycle, the level of definition increases, incorporating more detailed and precise information in the cost and carbon estimates. The Transport for NSW *Engineering Cost and Carbon Library* (summarised in Figure 2.9) provides assured benchmark data for costs and carbon emissions at a resource-level, item-level and global strategic-level. This enables practitioners to apply any of the three estimating methods throughout the project life cycle while maintaining a consistent set of underlying benchmarks for effective comparison. These benchmark rates are uniformly classified following the *ICMS 3* classification system shown in Concept 4 and are also mapped to other classification systems such as the Pay Item codes, which have been used by Transport for NSW for cost estimation, and the *Master Classification Library (MCL)* used in the Transport for NSW *Digital Engineering Framework*.

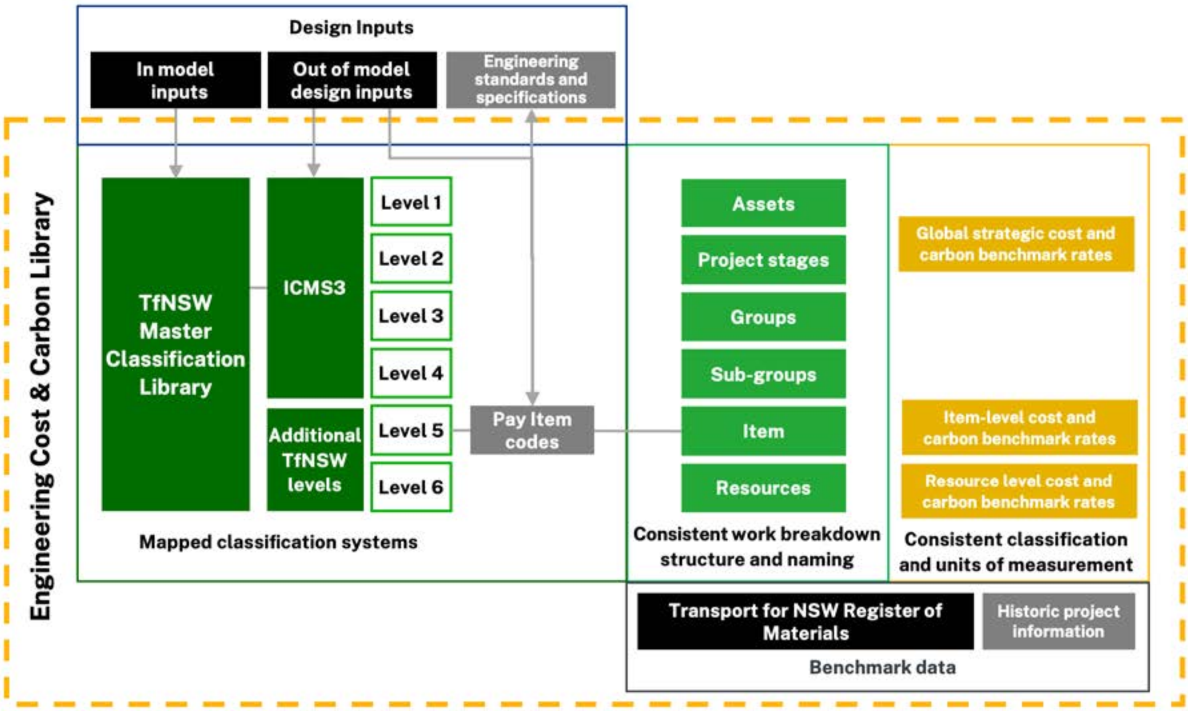
The resource-level benchmark rates are drawn from a database of historical projects and are aggregated using generalised build-ups to item-level benchmark rates. Global strategic rates are provided separately from asset-level benchmarks divided by relevant units of measurement and labelled according to the type of asset.

The first iteration of the *Engineering Cost and Carbon Library* covered A1-A5 emissions (upfront carbon). Transport for NSW has now also introduced B and C module emission rates at a resource level (level 6). For further details refer to Step 4 on quantification.

The *Engineering Cost and Carbon Library* was previously accessible through an Excel workbook that was shared with practitioners to assist with developing cost and carbon estimates at different levels of definition. Transport for NSW has since developed *Miraway* (see Section 2.2.3), a digital ecosystem with a web-based user interface that integrates the *Engineering Cost and Carbon Library* with other tools developed by Transport for NSW. As *Miraway* is deployed, it will become accessible by more members of the infrastructure value chain.

In *Miraway*, the *Engineering Cost and Carbon Library* is a live database which will be regularly updated as new project cost and carbon data is reported, thereby increasing the accuracy and relevance of the benchmarks.

Figure 2.9 Foundations of the Engineering Cost and Carbon Library



Currently, the *Engineering Cost and Carbon Library* uses the median unit price from available data points to establish benchmark unit costs for items and resources. As a result, unit prices do not currently vary for different quantity inputs. Transport for NSW is integrating cost curves (described in Concept 5) into *Miraway* (see Section 2.2.3) to address the relationship between unit prices and quantity procured and provide more accurate outputs for baseline cost estimation.

Practitioners should review the benchmark unit rates and ensure that they appropriately reflect the project's characteristics. Where project-specific unit prices are known for items or resources, practitioners should substitute the benchmark unit rates with the known prices.

Concept 5: The relationship between unit cost and quantity procured

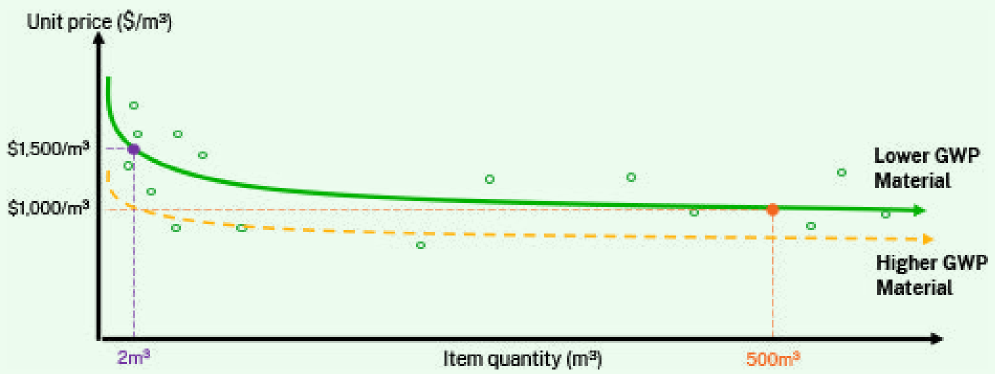
It is recognised that unit cost rates for items or resources will vary with the quantity of items or resources procured. For example, procuring 2m3 of concrete subgrade beam may incur a unit cost of $1,500/m3, but procuring 500m3 may incur a unit cost of $1000/m3. This change in the unit cost of the item or resource is reflective of economies of scale.

Cost curves show how resources or item unit costs change with the quantity procured, and an illustrative cost curve is presented in Figure 2.10 for a hypothetical project. The key components of a cost curve include:

- **Item/Resource quantity**: the horizontal axis represents the total amount of the item procured.
- **Unit cost rate**: the vertical axis represents the cost rate of the item procured.

Materials with lower Global Warming Potential (GWP) may have higher initial costs, but their unit price can decrease with economies of scale, making them more cost-competitive at larger procurement volumes.

Figure 2.10 Example of a cost curve



Case study: Linking carbon and cost (CESMM4 Carbon & Price Book, UK)[4]

In 2010 the Civil Engineering Standard Method of Measurement (CESMM4) Carbon & Price Book, published by the Institute of Civil Engineers, broke new ground in the civil construction industry by linking carbon values to cost measurement. The price book includes carbon values alongside the cost of materials and services. This data provides a valuable resource for contractors performing 'carbon accounting' for their projects to determine the overall carbon impact.

The *Engineering Cost & Carbon Library* adopts a similar approach. The library applies a classification system that maps to pay item codes used in the Transport for NSW *Standard Estimating Summary Sheet (SESS)* and the *Master Classification Library (MCL)* used in the Transport for NSW *Digital Engineering Framework*. Carbon values have been developed that also map to this classification system, allowing for the generation of carbon estimates in parallel to cost estimation and engineering design. This supports improved cost and carbon management through the ability to rapidly quantify cost and carbon impacts for a baseline scenario and potential options, enabling the ability to identify opportunities for cost and carbon savings.

2.2.3. Miraway

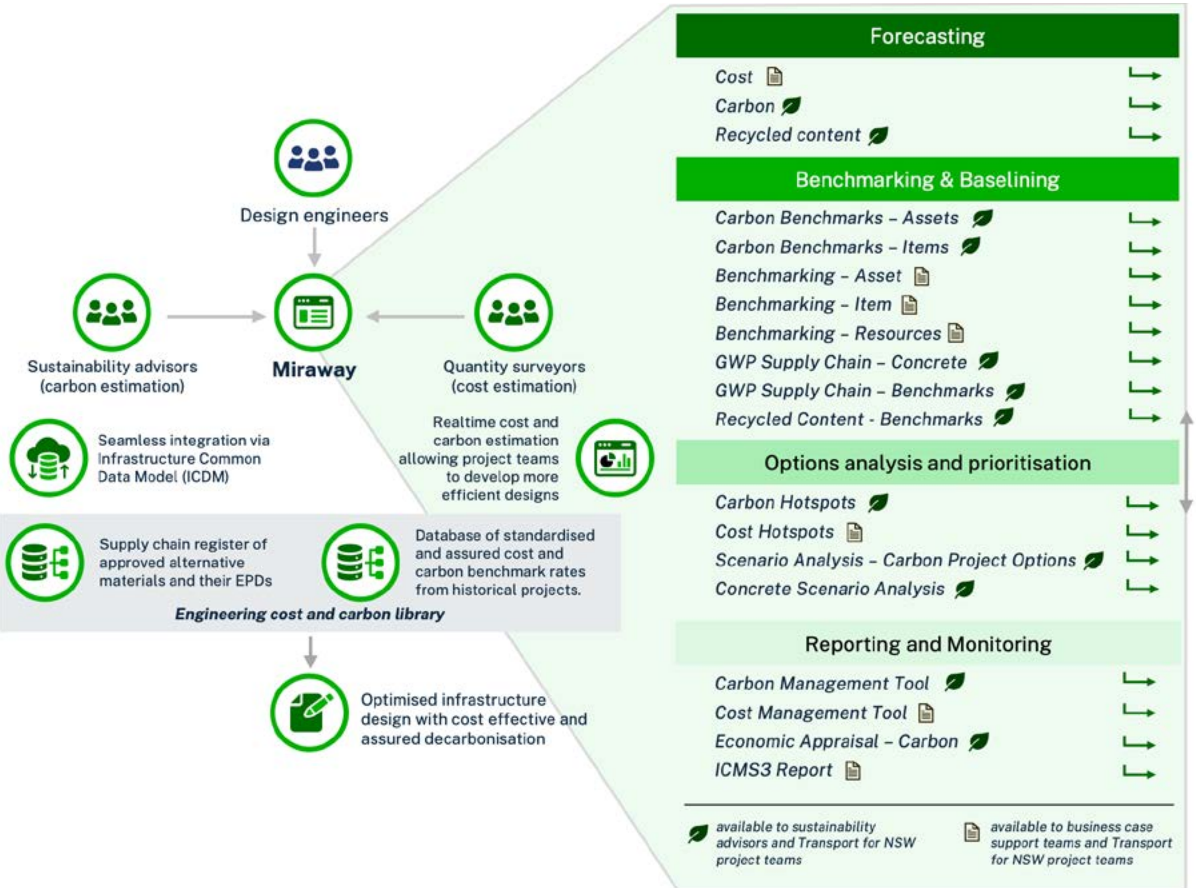
Miraway is a digital ecosystem designed to streamline how Transport for NSW plan, build, and manage infrastructure. It is a connected platform powered by the Transport for NSW *Infrastructure Common Data Model (ICDM)* and integrates several digital initiatives, including the *Engineering Cost and Carbon Library*, into a single source of truth and connection point for industry.

Miraway focuses on enhancing automation, transparency, traceability, and consistency across the value chain to deliver productivity gains. Government asset owners, constructors, designers, and small to medium enterprises will benefit.

The first *Miraway* module on integrated cost and carbon management will be embedded with industry throughout 2026. Future modules are under development to continue to improve productivity while delivering sustainable infrastructure.

Figure 2.11 presents an overview of *Miraway* and its cost and carbon module.

Figure 2.11 Overview of Miraway: A digital ecosystem for streamlined cost and carbon management in infrastructure



[4] Civil Engineering Standard Method of Measurement Carbon & Price Book

Source: Environmental Product Declaration (EPD) Portal

Transport for NSW is developing an EPD Portal within *Miraway* to allow contractors and product or material suppliers to share details on new and innovative low carbon products as they become commercially available. This EPD Portal will serve as a mechanism for new and conforming materials or resources with alternate carbon rates to be added to the *Engineering Cost and Carbon Library*, and subsequently for them to be used in cost and carbon estimation.

2.2.4. Estimating whole life carbon

As introduced in **Concept 1** and **Principle 1**, practitioners should consider whole life carbon under their control and influence. This includes upfront carbon (A1-A5), in-use and operational carbon from activities under their direct control (B1-B7), as well as activities which they have influence over such as asset user (enabled) carbon (B8), and end of life carbon (C1-C5). **Concept 6** further describes the difference between B6 and B8 emissions.

Concept 6: Operational carbon (B6-B7) and asset user (enabled) carbon (B8)

Operational carbon in projects is largely comprised of operational energy (B6), operational water (B7) and asset user (enabled) carbon (B8).

Operational carbon (B6-B7) refers to emissions associated with the energy and water used by the building or infrastructure assets. These emissions are within control of Transport for NSW and are a direct result of their activities and operations. Examples include:

- Carbon from public transport on the Transport for NSW network.
- Carbon from Transport for NSW office buildings.

This is distinct from asset (user) carbon (B8), which refers to activities that are enabled by use of the asset, however, are not in the direct control of the asset owner. Common examples include:

- Carbon from third party vehicles using roads or
- Third-party rolling stock on the rail network.

Both asset user enabled emissions and operational emissions represent two distinct concepts, which should be differentiated, however, it is important that they are both managed.

The *Engineering Cost and Carbon Library* contains assured benchmark rates for upfront carbon (A1-A5) and should be used to develop carbon estimates when benchmark rates are required.

The *Engineering Cost and Carbon Library* does not currently provide asset or item level benchmark rates for in-use carbon (B1-B5), operational carbon (B6-B7), asset user (enabled) carbon (B8) or end of life carbon (C1-C4), however, Transport for NSW is developing these for inclusion in future updates.

Operational carbon (B6 and B7) may be estimated following existing guidance as well as historical data and reporting. Transport for NSW has developed the ICDM, which powers *Miraway*, to improve the completeness and accuracy of reporting of operational emissions from the infrastructure that it commissions, including carbon associated with operational carbon (B6) (for example, emissions associated with public transport services). For vehicles and rolling stock, operational carbon can be estimated using ATAP fuel consumption parameters, which use vehicle specifications, speed and distance to estimate fuel usage for different vehicle types. This can then be used to estimate carbon emissions per litre of fuel. Similarly, for electric vehicles, electricity consumption and grid mix of different electricity generation can be used for determining carbon emissions. *ATAP Environmental Parameter Values PV5* provides information on carbon intensity of electricity generation in Australia.

Asset user (enabled) emissions (B8) form a large component of a project's whole life carbon, however, estimation of asset user (enabled) emissions can be challenging. For each type of project, practitioners should identify the asset users and the sources of emissions that they generate. Depending on the type of project, the number of users as well as changes to users can be determined from transport modelling. The economic analysis required for cost benefit analysis already relies on understanding transport users for benefits estimation. This same information can be leveraged to inform the estimation of carbon emissions. Practitioners should continue to use existing guidance and practices for calculating asset user enabled emissions, using emissions factors from sources such as those provided in *ATAP Road Parameter Values PV2*, the *Australian National Greenhouse Accounts Factors*, or from data sheets of known vehicle types.

2.2.5. Refining baselines over the project life cycle

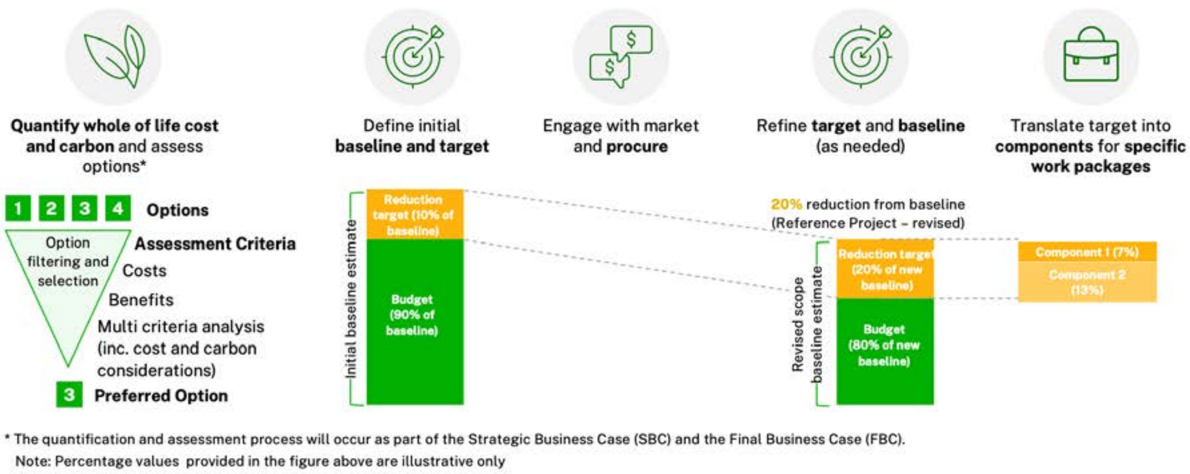
Developing and refining the baseline is an iterative process through the phases of project design and delivery. When comparing options to the baseline, the baseline should be updated to reflect:

- Changing project scope, function or service
- Changes in assumptions, quantities or scope alterations
- Changes in data sources and quality (for example, moving from item-level to resource-level or through increased detail of the design).

When using a baseline in projects with distinct contract packages, it may be beneficial to break it down into components for each contract. For example, the procurement strategy for a project or program of works may require individual components to be delivered by different designers or contractors. Each contract's scope should align with the relevant parts of the project baseline to facilitate effective progress monitoring and ensure that targets are achieved.

Figure 2.12 illustrates the refinement of baselines throughout project phases. Part B of this document provides more detailed representations for the process of updating and using baselines to assess performance of options for each phase of the project lifecycle.

Figure 2.12 Baseline and target setting, refining with date and scope certainty



Source: adapted from INSW Decarbonising Infrastructure Delivery Policy

2.3. Step 3: Set cost and carbon budgets (or targets)

To effectively monitor and control cost and carbon throughout the project life cycle, it is essential that the asset owner or manager set targets or budgets and use them to track performance. While cost budgeting is a well-established practice, carbon budgeting is still emerging. Typically, carbon management has relied on percentage-based emissions reduction targets relative to a defined baseline. Transport for NSW is undertaking work to derive 'bottom-up' portfolio carbon budgets based on forecast emissions associated with its existing and planned infrastructure pipeline. If NSW sector-based budgets are established, project level carbon budgets can also more easily be implemented in a manner consistent with the existing cost budgeting process.

2.3.1. Setting a cost budget

Cost budgets are determined based on the type of project. NSW Treasury has specific guidelines that government agencies must follow depending on:

- The type of project (such as capital project or recurrent expenditure)
- The size of the total project cost
- The level of risk associated with the project.

The process for developing a project budget and having it approved by Transport for NSW and NSW Treasury is summarised in Figure 2.13.

Figure 2.13 Process for developing a project budget

The development of a business case is required for both capital and recurrent expenditure. The level of detail in the business case varies depending on the project, but all types — whether long or short form, strategic or detailed — must include a cost-benefit analysis and a financial impact statement, with project costs accurately estimated and provided. These business cases inform NSW Treasury's expenditure decisions.

Business case submissions to NSW Treasury are part of the annual budget process, where budget decisions are made by the Expenditure Review Committee (ERC) of Cabinet. Treasury reviews each submission, verifying cost estimates and providing advice and recommendations on budget prioritisation. This review process by Treasury is distinct from the NSW Gateway process.

Transport for NSW has its own internal assurance process for business cases before they are submitted to NSW Treasury. The Economic Advisory team within the Investment and Assurance Branch conducts an Economic Concurrence Review, assessing the compliance and quality of cost-benefit analyses, including the accuracy of cost estimates.

In the future, as sector maturity increases, a similar budgeting process may be introduced for carbon, treating both financial and carbon resources as limited and streamlining decision-making accordingly. However, no such process is currently in place.

2.3.2. Setting carbon targets

Project-level carbon reduction targets provide a framework for driving emissions reductions throughout the project life cycle, ensuring alignment with strategic goals, policy requirements, and commitments.

When developing carbon reduction targets, it is crucial to clearly define the sources and boundaries of the emissions being addressed to enable effective measurement and tracking of reductions. Projects may utilise either carbon targets in percentage reduction terms, relative to a baseline, or in absolute terms (tCO2-e), also commonly referred to as carbon budgets (**Concept 7**).

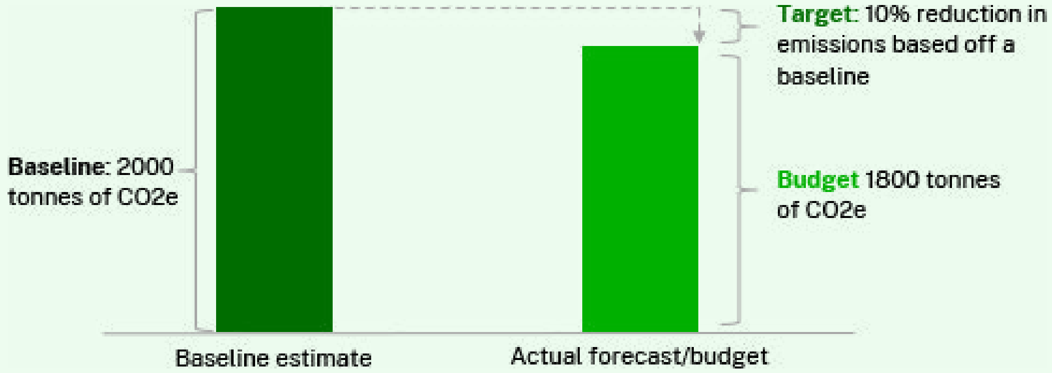
Concept 7: What is the difference between a carbon reduction target and a carbon budget?

Carbon reduction targets and carbon budgets are two key concepts in managing carbon performance. A carbon budget can be considered a type of target, as it sets an absolute tCO2-e limit to be achieved. Although they share a common goal, they differ in the following ways:

Carbon reduction target: This is typically expressed as a percentage reduction relative to a baseline of carbon emissions. In the context of an infrastructure project, it represents a specific goal to reduce carbon emissions across various phases or the entire project life cycle, compared to a baseline. Currently, this is the approach used by Transport for NSW, as the broader infrastructure portfolio level budget is still being derived in absolute amounts.

Carbon budget: This is usually presented as an absolute amount of carbon emissions (tonnes of CO2-e) that the project can produce while still aligning with organisational or broader economic emission targets. At the economy, sector, or organisational level, a carbon budget often applies to a specific time period (e.g., years), within which a certain amount of carbon (t CO2-e) can be emitted to remain on a pathway toward net zero. In other jurisdictions, such as the UK, sectoral carbon budgets have been established, allowing for top-down budgets to be set for projects within an agency's pipeline. Carbon budgets can also be derived using benchmark data or using a baseline and forecast estimate. Figure 2.14 illustrates the establishment of a carbon reduction target and budget using a carbon reduction baseline and a forecast estimate.

Figure 2.14 Carbon target and carbon budget



Note: In alignment with *PAS2080:2030* Clause 8, carbon targets/ budgets should relate to a defined outcome based on an equivalent functional or declared unit of measurement. The use of functional or declared unit of measurement in targets/budgets allows for easier comparability and allows the contribution to overall organisational or sector emissions to be assessed across the entire portfolio of projects.

A carbon emissions reduction target or budget should be set using a top-down approach, starting at the policy level. This process begins with the establishment of overarching carbon emissions targets or budgets aligned with broader climate goals. These targets or budgets are then cascaded down to portfolio and project levels. Further details on aligning carbon budgets with policy objectives are provided in **Principle 5**.

Carbon intensity caps are also an important mechanism that value chain members can use to drive emission reductions in line with targets and budgets, as discussed in **Concept 8**.

Principle 5: Align cost and carbon targets and budgets with policy objectives

Whether a project adopts carbon targets or budgets, they should be aligned with Transport for NSW and broader NSW Government strategic objectives and targets for the net zero transition. Transport for NSW has established a *Net Zero & Climate Change Policy* with ambitious carbon reduction goals that support the NSW Government's broader targets. Additionally, Transport for NSW is developing *Net Zero & Circular Economy Guidelines*, which will define the optimal pathway for achieving net zero across the following emission sources and targets:

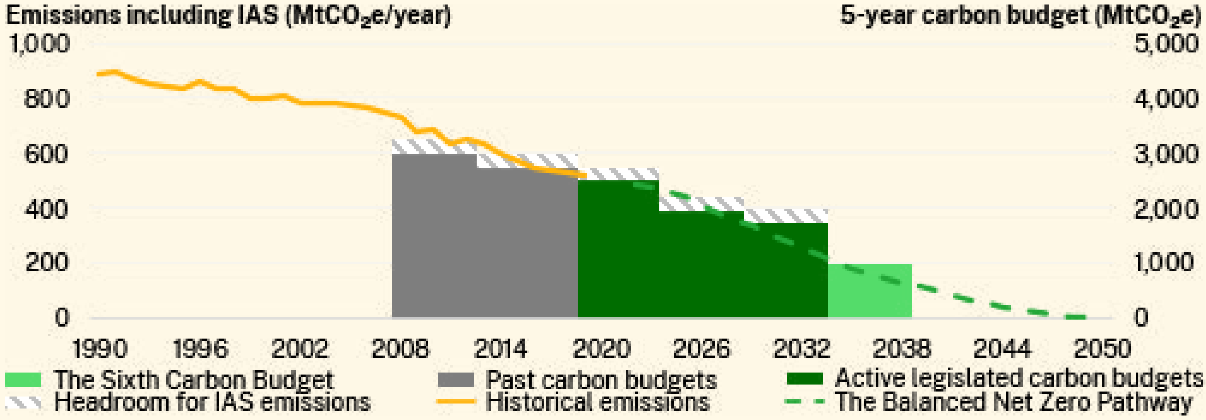
- Net Zero Transport Operations by 2035 (owned, leased and contracted facilities e.g. rail, buses, ferries, service facilities, office buildings)
- Net Zero Construction & Maintenance by 2045
- Net Zero wider transport network and asset users by 2050.

In line with PAS2080 Clause 8, carbon targets and budgets should align with targets established at the network or system-level. "Network" refers to the transportation system that Transport for NSW own and operate, while "system" refers to the broader NSW economy. This ensures project level targets and budgets are supporting the achievement of sector, state and national carbon reduction targets. The standard however acknowledges the limitations if network or system level carbon budgets have not been established, which is the case in Australia. However, Transport for NSW is undertaking efforts to establish their own portfolio-level budgets through the following methods:

- Estimating the relative reduction (%) from baseline carbon required, considering specific emission sources and the timing of project construction and operation. This may involve interpolation or extrapolation against Transport for NSW organisational baseline and targets.
- Forecasting the cumulative future emissions for the entire Transport for NSW portfolio and then allocating a share or 'budget' of carbon to each asset type based on a functional unit (e.g., lane.km of road, track.km of railway, m^2 of bridge deck). Transport for NSW is currently analysing the expected carbon emissions from its current and upcoming projects to inform the setting of carbon budgets across its infrastructure portfolio.

Figure 2.15 is adapted from the UK carbon budgets, which are established for five-year periods and set 12 years in advance. To align with local policy targets, specific carbon budgets for NSW will need to be developed.

Figure 2.15 UK Carbon budgets illustrative example



Concept 8: Carbon intensity targets

Carbon intensity targets can serve as normalised metrics for achieving carbon reductions by setting specific limits on the amount of carbon emissions per functional unit. These targets are typically based on established benchmarks and can be applied at various levels, such as the asset, item, or resource-level.

For instance, a carbon intensity target might be expressed as tCO_2-e per tonne of asphalt used. In some cases, these targets could be integrated into contract requirements, mandating reductions in emissions per unit of resource used.

Intensity targets can be an additional useful mechanism to drive emission reduction by setting an emission intensity limit/cap. Intensity targets may be particularly useful when it is challenging to set an absolute reduction target, for example carrying out maintenance work that may vary year to year.[5]

2.4. Step 4: Quantify cost and carbon outcomes for project options

Once a target is set against a baseline, value chain members can use *Miraway* to support quantification of the cost and carbon outcomes of their project options.

For cost estimates, this involves preparing estimates of asset, item or resource quantities in the Transport for NSW *Standard Estimating Summary Sheet (SESS)*, which is aligned with the *Engineering Cost and Carbon Library*'s classification system of assets, items and resources. In the SESS, cost estimates can be prepared using rates from quantity surveyors, contractors or product / material suppliers when project-specific information is available. In early project stages, cost estimates may be prepared using benchmark rates from *Miraways* Benchmarking Tool.

For carbon estimates, all projects should use the assured carbon benchmark rates from the *Engineering Cost and Carbon Library*. This will be done by uploading the SESS with quantity estimates to *Miraway*. Carbon estimates will be accessible in *Miraway*'s Carbon Management Tool. This tool will enable project teams to understand the carbon impact of a project when compared to the baseline and targets, allowing for targeted efforts to improve outcomes.

2.4.1. Sources of information for options and scenarios

Table 2.2 summarises the options that may be quantified and tested against a baseline at different phases of the life cycle for a typical design and construct project.

Table 2.2 Options tested across design and construct project phases

Phase	Baseline source of information	Options	Cost and carbon Rates Used
Needs Confirmation	Policy targets	N/A	Asset level benchmarks based on historical data
Need Analysis	Base case (as used in business case)	**Early phase**: Long-list of options. **Late phase**: Strategic design of shortlisted options	**Early phase**: Asset level benchmark rates **Late phase**: Item-level benchmark rates
Investment Decision	Redefined base case to reflect project scope	Concept design of preferred option(s) (with carbon improvements applied)	Item-level benchmark rates
Procure	Design provided to tenderers	Tendered design (with value engineering and carbon improvements)	• Resource-level benchmark rates, or • Tendered rates
	Detailed design	Detailed design (with value engineering and carbon improvements)	
Deliver & Initial Operations	Detailed design and as built documentation	Detailed design and as built documentation (with value engineering and carbon improvements applied)	• Contracted rates, or • Actual reported rates

[5] See www.ice.org.uk/media/vm0nwehp/2023-03-29-pas_2080_guidance_document_april_2023.pdf for more information

The Schedule of Rates (SoR) and Bill of Quantities (BoQ) form the basis for cost and carbon estimation, and consist of detailed measurements of items, materials, equipment and/or labour required for the project in a consistently classified manner. To generate a SoR or BoQ, practitioners must conduct quantity take-offs to extract asset, item or resource quantities from designs or project scopes. Quantity data for project and investment options can be sourced from various inputs depending on the stage of project development, including:

- project scope definitions,
- quantity takeoffs from 2D drawings,
- quantity takeoffs from 2D and 3D digital models, and/or
- material and cost estimates developed by quantity surveyors.

One or more of these inputs can be used to generate quantity estimates, which are then used to populate a SESS, which has been configured to align with the *Engineering Cost and Carbon Library*. As described above, *Miraway* enables the automated generation of carbon estimates.

Table 2.3 details common material quantity sources for each estimate type across the project life cycle. Leveraging digital models to inform cost and carbon estimates can assist in streamlining estimation, however, not all elements of the project will be 'in model' and will therefore require additional sources of information.

Table 2.3 Sources of project information to be used for cost and carbon estimates

Estimate type	Source of project information
Strategic	• Early project scope information • Asset characteristics and details from high-level project options (E.g. gross floor area, lane.km, km) • Industry guidance • Asset user information
Concept	• Quantity take-offs from the preferred option (from BIM, 3D models, engineering and architectural drawings) • Industry guidance • Asset user information (e.g. from Transport modelling) • Asset end of life recycling, reuse or circular economy strategies
Detailed	• Quantity take-offs from the detailed design (from BoQ, BIM, 3D models, engineering drawings) • Equipment schedule information (for resource-level estimation) • Industry guidance • Asset user information (e.g. from Transport modelling) • Asset end of life recycling, reuse or circular economy strategies
Tender	• Final design documents and model(s) • Detailed BoQ prepared by contractors • Industry guidance • Asset user information (e.g. from Transport modelling) • Asset end of life recycling, reuse or circular economy strategies
Post-tender	• Awarded contract documents (Construction methodology, schedules) • Updates to design drawings and models, including subcontractor designs and models • Finalised BoQ based on awarded contract • Industry guidance • Asset user information (e.g. from Transport modelling) • Asset end of life recycling, reuse or circular economy plans as tendered
Actuals	• As-built BIM models • As-built records of material and equipment quantities procured, and costs where practical • Actual asset user data • Actual recycling, reuse and circular economy implementations

Digital engineering software validation – future requirements

In future, Transport for NSW intends to enable connection between digital engineering software and the ICDM to allow for real-time cost and carbon estimation within design software and using the assured benchmark rates in the Engineering Cost and Carbon Library. For this, it is important that software align to RICS WLCA 2nd edition and ICMS3. If quantity takeoffs are undertaken from tools that are not aligned with RICS WLCA 2nd edition and ICMS3, the benchmark rates from the Engineering Cost & Carbon Library may not be compatible (see the cost and carbon assessment tools case study).

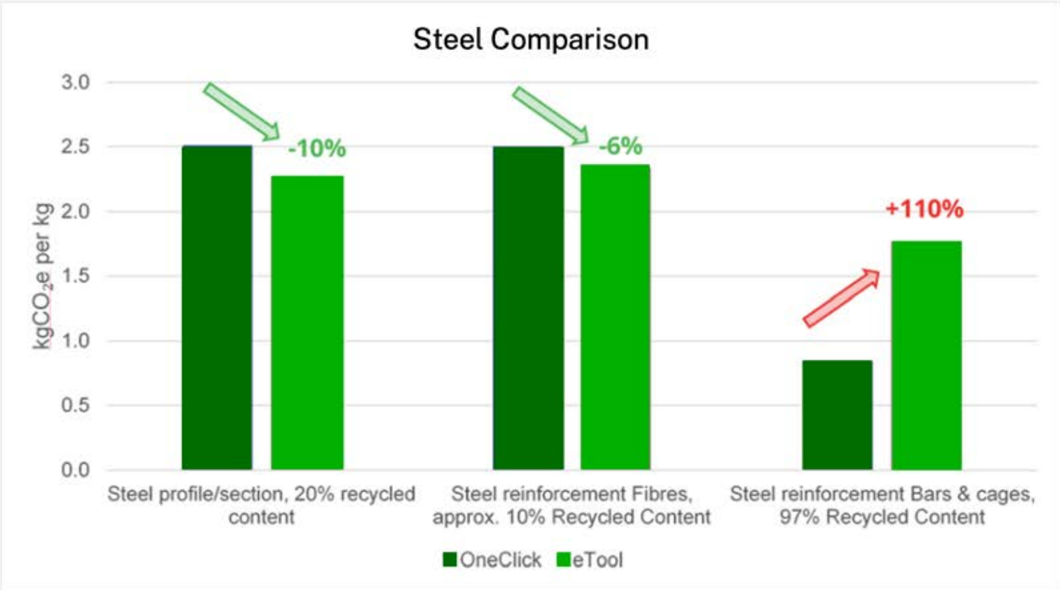
RICS is developing a software validation scheme, ensuring that the software receives inputs appropriately and performs calculations according to the mandatory requirements of RICS WLCA 2nd Edition, also ensuring that the software outputs are aligned with the WLCA reporting template in an acceptable digital format.

Case study: Cost and carbon assessment tools (HS2, UK)[6]

The HS2 project aims "to be the most sustainable high-speed rail network in the world" with a whole of life carbon reduction target of 50% against the project baseline. However, several research papers identified differences in estimates provided by lifecycle carbon assessment (LCA) tools, raising the issue of whether carbon estimates and reductions quantified during design are an accurate representation of actual emissions.

For the Euston station package the LCA was performed using 'OneClick' and 'eTool'. A comparison paper was subsequently developed to understand if the project emissions differed because of design choices, material specifications, or differences in the LCA methodologies. One of the key findings related to the difference in the A1 to A3 emission factors between the tools for concrete and steel reinforcement (see steel comparison below). With no change in design, just by switching tools, the LCA results substantially changed. This raised integrity issues with benchmark comparisons to previous LCA's including the baseline.

The use of *Miraway* and the *Engineering Cost and Carbon Library* standardises the approach to carbon estimation and scenario analysis. This reduces the risk of variability that may result from the use of different emissions factors, methodologies or assumptions. This will create consistency across projects and project stages.



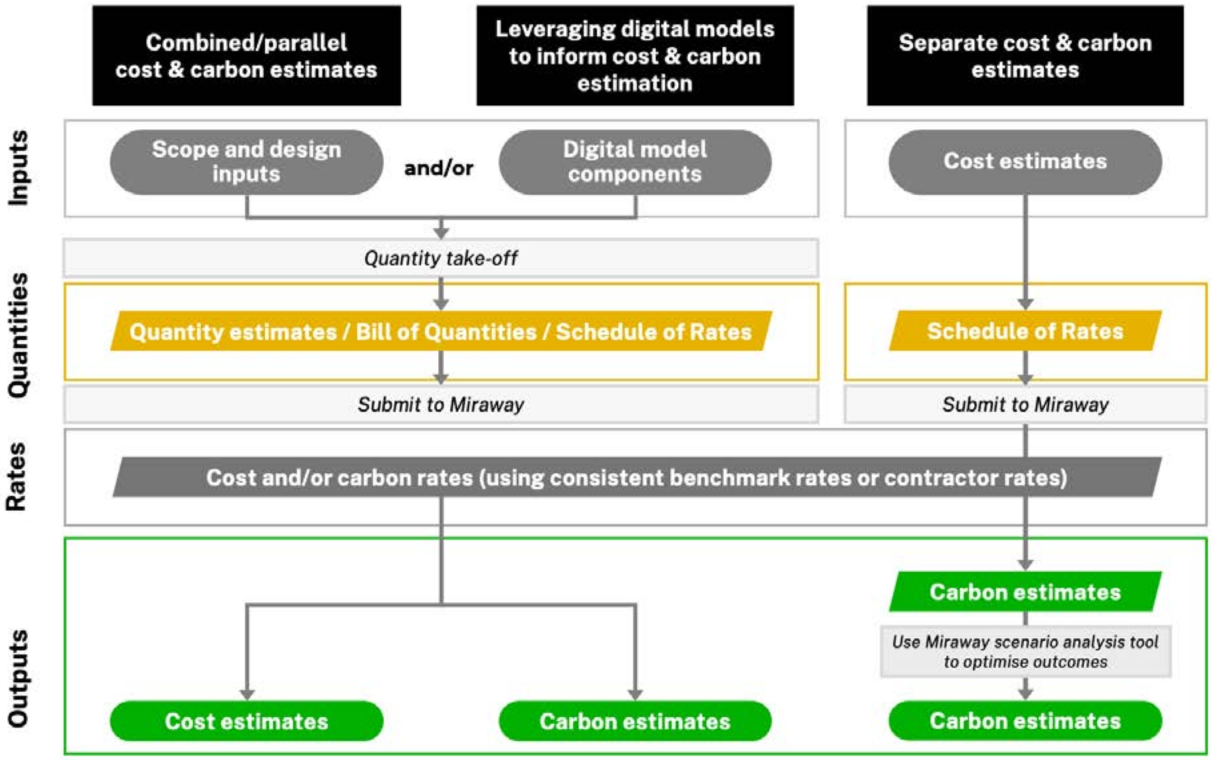
Source: HS2 learning legacy

[6] HS2 learning legacy

2.4.2. Estimating cost and carbon for options and scenarios

The process of converting quantity information to cost and carbon estimates (for A-A5 emissions) can take different routes depending on the type of data available, as shown in Figure 2.16 and the approaches to measuring carbon case study.

Figure 2.16 cost and carbon estimation process



Cost and carbon estimates may require adjustments to account for additional factors to ensure that the full boundary of assessment is captured in the estimates. This may include factors for contingency, escalation, or project overheads. **Principle 6** outlines the need to ensure that the data quality and coverage is appropriate for the project phase.

Case study: Approaches to measuring carbon (Carbon planning tool, UK)[7]

In 2013 the UK government recognised the link between cost and carbon savings in its Construction Industry Strategy and recommended that Government and industry clients collaborate to integrate carbon reduction requirements into programmes and projects by 2016. Supporting this recommendation, the Environment Agency (EA) for the UK released its carbon planning tool in 2016. The tool was designed to focus on the whole-of-life carbon emissions of a project and actively support the use of low-carbon solutions. This would result in cost savings due to less carbon intensive solutions, providing dual benefits. The tool consisted of two components:

- a top-down modelling tool used in early stages of a project to develop quick and simple carbon estimates
- a bottom-up carbon calculator for use during the delivery phase to measure actual carbon.

In 2022 this tool was updated, highlighting its ongoing use and benefits. While the carbon planning tool was not directly integrated, it aligned with the government's Project Cost Tool allowing both to be used in conjunction during a project.

The *Engineering Cost and Carbon Library* goes beyond the functionality of the two UK tools by directly integrating cost and carbon management within a single process, creating efficiencies and aligning the outputs.

[7] UK Environment Agency

Principle 6: Consider data quality, completeness, and uncertainty

Completeness

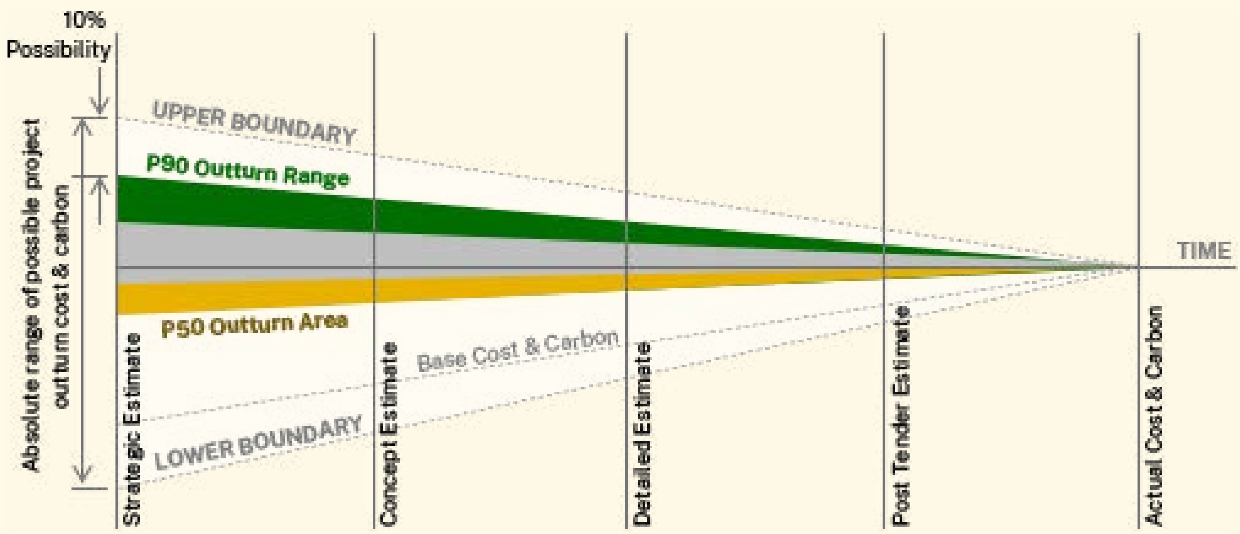
At later phases of project development, the availability of higher quality and more detailed data allows for more precise measurements and estimates. However, this is contingent on the project scope remaining consistent, as changes in the scope can impact the relevance and accuracy of the data. Maintaining data quality and coverage is crucial for decision-makers to better understand the risks associated with project outcomes, enabling them to make informed investment decisions. Projects should aim to include all project elements that impact cost or carbon outcomes for data completeness. However, it is recognised, particularly at the early stages of projects, this may not be possible. In these case, additional allowances to capture uncertainty should be included.

Uncertainty

Uncertainty in cost and carbon estimates arise from uncertainty in design elements, uncertainty in the cost or carbon rates data, and uncertainty in the material quantity data. To account for this, project estimates consist of a base estimate, calculated by applying cost and carbon rates to quantities, as well as a contingency. Contingency refers to an additional allowance of cost or carbon that is added to the base estimate to account for uncertainties. A P50 contingency represents an allowance that gives the total estimate a 50% probability of not being exceeded, while a P90 contingency provides a 90% probability of not being exceeded.

As projects move through their life cycle and the completeness and quality of data improve, the uncertainty in estimates decreases, as represented in Figure 2.17.

Figure 2.17 Spectrum of possible project outturn cost and carbon



Source: Transport for NSW Estimating Procedure

Escalation

Escalation is also applied to costs to reflect inflationary price increases of goods and services over time. Escalation should be applied to cost estimates in accordance with *Transport for NSW Estimating Procedure*.

2.4.3. Applying contingency to estimates

Contingencies can be determined through probabilistic or deterministic approaches.

- **Probabilistic approach**: Estimates the contingency by considering the probability distributions of various risk factors using quantitative methods, such as Monte Carlo simulations, that allow for a range of possible outcomes and associated probabilities.
- **Deterministic approach**: Sets a fixed contingency amount based on predefined criteria or expert judgment, without accounting for variability or uncertainty in the risk factors.

The appropriate approach to estimating contingency depends on the size and risk of the project, and the project's assurance requirements. Practitioners should refer to the relevant assurance requirements to determine which contingency estimation approach they can apply at their stage of project development.

Deterministic Contingency

The *Transport for NSW Estimating Procedure* indicates preference for probabilistic contingency where possible, however, in the absence of sufficient data points, a deterministic approach may be more suitable. Table 2.4 outlines the typical contingency ranges for cost and carbon estimates across the project development life cycle.

Table 2.4 Desired contingency ranges for cost and carbon estimates

Estimate type	Cost estimates P90 range	Cost estimates P50 range	Carbon estimates
Strategic	35-70%	60-85% of P90	15%
Concept	25-40%	75-90% of P90	**15%**
Detailed	15-25%	85-95% of P90	6%
Tender	No contingency to be allocated	No contingency to be allocated	–
Post-tender	10-20%	90-98% of P90	6%

Source: Transport for NSW Estimating Procedure (Cost estimates), RICS Whole life carbon assessment for the built environment 2nd edition (Carbon estimates)

For deterministic cost contingency, practitioners may refer to The Australian Government Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) *Guidance Note 3B – Deterministic Contingency estimation (2023)*, which sets a guideline and framework for estimating contingency using a deterministic approach.

Similarly, project teams should develop a justified breakdown for their relevant deterministic carbon contingencies. A similar framework may be adapted for estimating contingency for carbon, however, some factors such as scheduling risk may not be applicable.

Probabilistic contingency

Estimating probabilistic contingency requires a sufficiently advanced project scope and design, a detailed register of project risks, and typically requires a suitably qualified and experienced quantity surveyor that can model the project risk impacts on costs and carbon.

The DITRDCA Guidance Note 3A – Probabilistic Contingency Estimation provides guidance to practitioners on developing probabilistic cost estimates using a 3-point estimating method and tools such as @Risk.

Miraway is being developed to provide upper, central and lower bound estimates for carbon to enable a similar 3-point estimating approach to be used to estimate probabilistic contingencies for carbon. Transport for NSW is developing a technical direction on how practitioners should use these carbon data points for probabilistic contingency estimation, with expected publication in 2026.

Carbon contingency

RICS 2nd Edition Whole Life Carbon Assessments captures uncertainty through a composite factor consisting of three components that are applied across different project phases:

- **Contingency factor**: This factor addresses uncertainties in asset design, construction and material selection. It is applied across modules A, B1–B5, C and D throughout all project phases. The factor can be tailored to individual elements if uncertainties vary, and generally decreases as the project details are finalised.
- **Carbon data uncertainty factor**: This factor reflects the quality and representativeness of the carbon data used for materials. It is applied during the technical design, construction and post-completion phases. The value is higher when generic data are used and lower when data specific to the actual products is available. Calculation is based on an asset data confidence score derived from ten key datasets.
- **Quantities uncertainty factor**: This factor considers the accuracy of the material quantity data. It is similarly applied during the technical design, construction and post-completion phases. The factor is higher when estimates or benchmark data are used, and lower when measured quantities are available. It is calculated using the quantities uncertainty level from ten key datasets.

2.5. Step 5: Identify and assess opportunities to improve cost and carbon outcomes

Once project or investment options have been analysed against the baseline and targets, value chain members should pursue efforts to improve cost and carbon outcomes. This involves identifying priority or 'hotspot' areas for cost or carbon reduction using *Miraway*, identifying alternate solutions, implementing them in project scopes or designs, and testing them using the *Miraway* Scenario Analysis tool. This enables practitioners to seek continual improvement in cost and carbon performance (see **Principle 7**).

Principle 7: Continual Improvement of cost and carbon performance

Under *PAS2080:2023*, all members of the value chain are responsible for engaging in continual improvement of carbon management. This principle can also be applied to cost management.

Continual improvement is a fundamental aspect of the cost and carbon management process, enabling the application of lessons learned to improve the delivery of current and future projects or programmes. Ongoing efforts allow value chain members to develop cost and carbon management expertise and share knowledge on effective decarbonisation and cost management strategies. Detailed below are high level requirements for specific members of the value chain under *PAS2080:2023*.

Asset owner/manager requirements

- Annually review and improve cost and carbon management processes.
- Update procurement processes to incentivise carbon and cost reduction or efficiency.
- Adapt GHG assessment methods for accuracy.
- Develop a data inventory for baselines and emissions assessments.
- Ensure project baselines are current and accurate.

Designer requirements

- Provide input to owner/manager improvements and share carbon data.
- Assess and enhance internal skills for GHG assessments and low-carbon solutions.

Constructor requirements

- Share carbon data for owner/manager improvements.
- Enhance procurement to support carbon reduction.
- Capture as-built data to improve baselines.
- Evaluate and train for GHG assessments and low-carbon solutions.

Product/material supplier requirements

- Engage with value chain members to share and apply low carbon innovations.
- Evaluate and enhance skills for GHG assessments and low-carbon procurement.

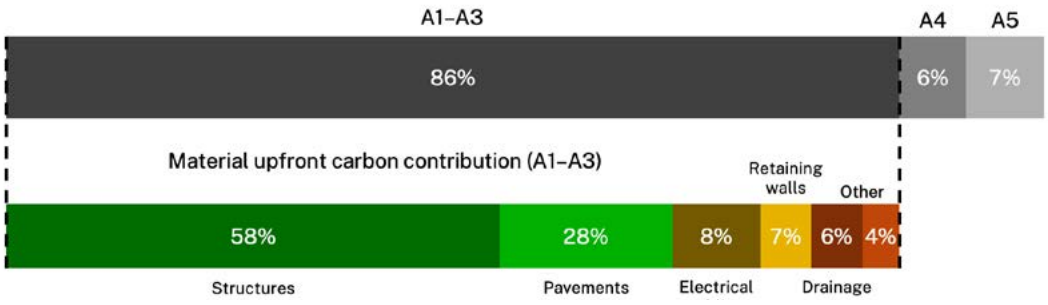
Contribution analysis

Contribution analysis is the process of identifying how different elements, processes, specific materials or life cycle phases influence cost or carbon outcomes, allowing for targeted efforts, focused on significant opportunities for improvement. Contribution analysis supports designers in:

- Identifying hotspots or drivers of carbon emissions and cost, such as materials or processes
- Focusing efforts on the most impactful opportunities to reduce cost and carbon
- Developing detailed and structured breakdown of results for future reference
- Supporting the future benchmarking of items and resources.

Figure 2.18 provides an example of contribution analysis for a road project

Figure 2.18 Contribution analysis of upfront carbon for an example road project



The Carbon Hotspots and Cost Hotspots tools in *Miraway* enable practitioners to understand the key drivers of costs and carbon in their projects and designs, and simplify the process of contribution analysis.

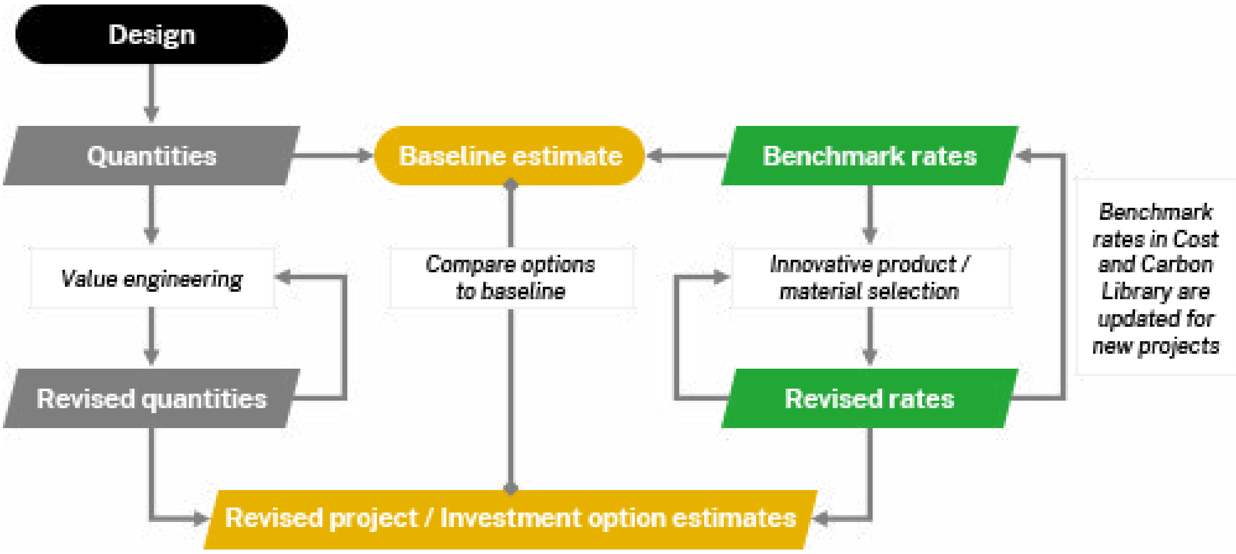
Value engineering

Cost and carbon estimates are functions of quantities, and the cost and carbon rates applied to those quantities. Value engineering refers to the iterative process of refining project designs to reduce cost. These cost reductions may come from reducing material quantities or selecting materials with lower prices (unit cost rates). This approach is summarised in Figure 2.19.

The process of value engineering and optimising designs for cost can be extended for carbon, where designers can identify opportunities to reduce material, plant or fuel quantities, or explore the use of innovative products which reduce the material, plant or fuel's carbon intensities (unit carbon rates), as shown in the EME2 case study. Relevant carbon rates from these innovative products should be sourced from Transport for NSW Conforming Material Registers which publicly disclose Global Warming Potential (GWP) or from respective Environmental Product Declarations (EPDs). This data is available in *Miraway* through the GWP Supply Chain tools.

Reducing both costs and carbon associated with a project or design can be challenging and may present conflicting objectives and require an analysis of tradeoffs. For this reason, the process of value engineering and design refinement for carbon reduction may be an iterative process that is repeated until the design, cost and carbon targets are achieved.

Figure 2.19 Value engineering and innovation processes



Case study: EME2 comparative study (Hume highway, NSW)

With the substantial growth in traffic loads, particularly on the major highways in NSW, Transport for NSW sought a cost effective and high-performance alternative to conventional Dense Grade Asphalt (DGA) that could provide a longer lasting and lower maintenance pavement while also lowering GHG during construction. Enrobés à Module Elevé Class 2 (EME2) is an asphalt mix produced using hard grade and high binder content bitumen, developed originally in France. International and domestic projects had shown a potential to reduce cost and carbon through pavement thickness reductions.

While the cost of EME2 per m2 was higher than DGA, the reduced thickness and number of layers meant less material was used and also reduced the time and use of plant and equipment during construction. A comparative analysis of the two pavement designs showed cost savings of 10% for material supply and up to 20% for the full design and construction. The study estimated material savings of 25%, a 31% reduction in construction time, and 27% fewer truck movements which helped to reduce carbon by 32%.

The use of *Miraway* and the *Engineering Cost & Carbon Library* will allow designers to rapidly compare and assess the use of different materials to select the best option in terms of both cost and carbon.

2.5.1. Identify opportunities

Once project teams have determined the hotspots for costs or carbon, they should identify opportunities for improving cost and carbon outcomes through targeted changes to the project scope or design, as appropriate in the relevant stage of the project. The cost and carbon impacts of these changes should then be quantified and assessed using decision-making frameworks to decide the best option(s) to proceed with. Practitioners may use the Scenario Analysis – Carbon Project Options tool in *Miraway* to support identification of opportunities.

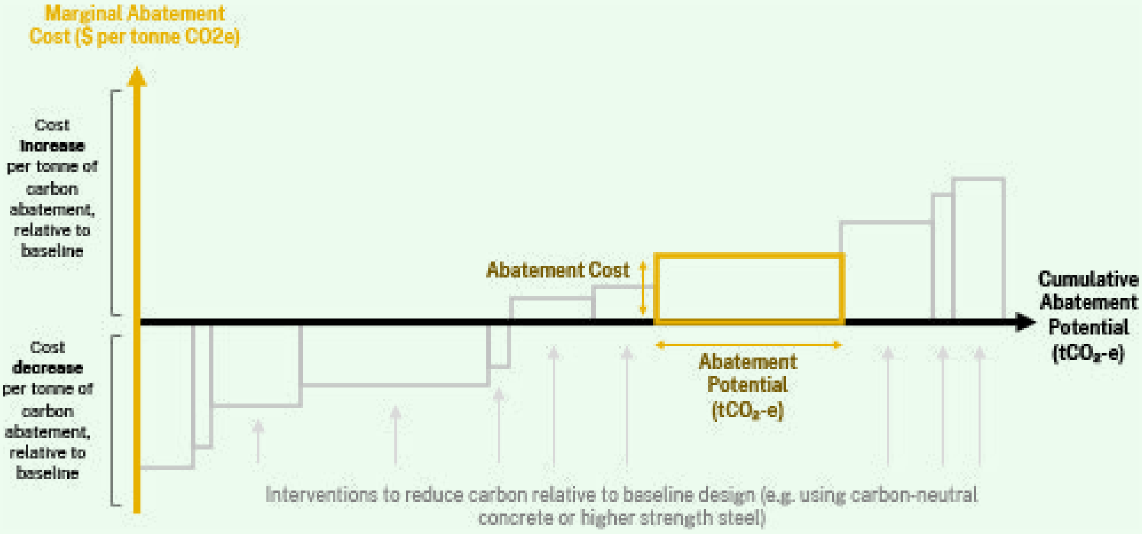
Recognising that making changes to project scopes or designs can be a lengthy and involved process, particularly in detailed design, practitioners should focus efforts on identifying targeted interventions which provide the greatest value in improving cost and carbon outcomes. Marginal abatement cost (MAC) curves are an example of a useful resource that practitioners can use to identify the highest impact and lowest cost interventions for carbon reduction (**Concept 9**).

Practitioners should collate potential opportunities into a longlist of options of interventions, and then consider which interventions would be feasible and worthwhile developing into sub-options. These sub-options can then be rapidly tested using benchmark rates from *Miraway* to estimate cost and carbon outcomes.

Concept 9: Marginal abatement cost (MAC) curves

A MAC curve is a graphical representation that ranks various carbon reduction measures based on their cost-effectiveness. It plots the cost per unit of carbon dioxide equivalent (CO2-e) reduced (vertical axis) against the potential amount of CO2-e that can be reduced (horizontal axis). Each initiative is represented by a bar, with the height of the bar indicating the cost (or savings) of the initiative relative to a baseline, and the width of the bar representing the carbon abated relative to the baseline. Figure 2.20 illustrates the key elements of a MAC curve

Figure 2.20 Illustrative MAC curve



MAC curves help designers identify which carbon reduction measures offer the greatest carbon savings for the lowest cost relative to their baseline designs. MAC curves may be developed at resource-level, item-level, global strategic-level, or even at sector levels. Several members of the value chain produce and publish MAC curves for assets, items and resources to illustrate and communicate opportunities for cost-effective carbon reduction to other members of the value chain. The process described below generalises how MAC curves can be developed and used to refine designs for cost and carbon.

Step 1: Define the bounds of the initiative and the level of definition of the MAC curve

Determine whether the design is at a global strategic level, item level, or resource level. Identify the function of the asset, item, or resource being substituted. This information dictates which initiatives or material substitutes should be included in the MAC curve.

Step 2: Locate relevant MAC curves or develop MAC curves from past representative projects

Locate published MAC curves from government agencies or material suppliers. Alternatively, use data from past projects and designs that incorporated material or design innovations for carbon reductions to develop your own MAC curves. Transport for NSW will develop a set of standardised MAC curves using the *Engineering Cost and Carbon Library* as part of future updates of *Miraway*.

Step 3: Apply the MAC curve

Identify the initiatives or material options with the lowest cost and highest carbon reduction potential from the MAC curve. Assess the feasibility of substituting these initiatives or material choices with the baseline design, taking into account technical feasibility, deliverability, and cost. Develop sub-options that incorporate various carbon reduction initiatives or material choices.

Step 4: Refine the design

Apply the value engineering process described below to iteratively refine the design until cost and carbon targets are met or exceeded.

2.5.2. Assess opportunities

The cost and carbon outcomes of project or design options should be compared to the respective functionally-equivalent baselines and targets. Some options may perform better in reducing carbon relative to the baseline but at a higher cost, while other options may achieve an overall lower cost with higher carbon estimates. To effectively balance this trade-off and determine which project or design option to proceed with, practitioners may need to rely on decision-making frameworks such as:

- **Multi-criteria analysis (MCA)**: a decision-making tool used to evaluate and compare alternatives based on multiple factors such as cost, environmental impact, and feasibility, risk and strategic alignment. It considers the relative importance of different factors by assigning weightings to the score.
- **Cost-benefit analysis**: a decision-making tool used to assess the economic value of project or design options by comparing the total expected costs against the total expected benefits, expressed in monetary terms. It helps determine whether the benefits outweigh the costs and provides a clear basis for comparing alternatives.

Depending on the decision-making framework used, practitioners may also need to rely on guidance documents relating to sustainable investment decision making and valuing carbon, such as the:

- *Transport for NSW Valuing Sustainable Outcomes Technical Guidance*
- *Transport for NSW Cost-Benefit Analysis Guide*
- *Infrastructure Australia Guide to Multi-Criteria Analysis*

Decision-making requirements on the trade-offs between carbon and cost are being embedded in to key project development and delivery practices through documents such as the *NSW Government Business Case Guidelines* and the Sustainable Procurement in Infrastructure Standard.

2.6. Step 6: Report and monitor outcomes

The final step is to report and monitor cost and carbon outcomes, and take the necessary actions to ensure future baselines, targets, and investments align with policy objectives. To effectively manage cost and carbon, assessing and reporting should be initiated early in the project life cycle. According to the *RICS Cost Prediction Professional Statement*, these assessments should continue throughout the design, procurement, construction and post-construction phases. Initially, cost and carbon assessments rely on forecasts, which are later updated with actual data at the end of a project.

As a government agency, asset owner, and manager, NSW Government and Transport for NSW provide guidance on cost estimating procedures, cost concurrence requirements, business case development, procurement, and benefits realisation. Members of the value chain should follow existing and emerging guidance from Transport for NSW and the INSW IIAF on how to report cost and carbon outcomes across the project lifecycle. Value chain members may also develop and follow their own internal guidance documents to dictate internal reporting and monitoring requirements, while also satisfying the necessary requirements of value chain members with whom they interface.

One of the key features of the *Engineering Cost & Carbon Library* is the identical reporting structure for cost and carbon which is aligned to *ICMS3* and *RICS 2nd* Edition. Reporting may occur at differing levels depending on the project phase, however it is consistent from the top of the asset down to construction resources.

For costs, practitioners should follow the guidance and specifications provided in the:

- *Transport for NSW Estimating Procedure*
- *Transport for NSW PS291 Estimating and Quantity Survey specification*
- *Transport for NSW PS295 Quantity Survey* specification

In alignment with these procedures and specifications, practitioners should use the best-available and project-specific quantity and price information, and not rely solely on the benchmark cost rates in the *Engineering Cost and Carbon Library* when developing final cost estimates for projects or designs.

For carbon estimation however, the automated method through *Miraway* relies on the assured benchmark carbon rates in the *Engineering Cost and Carbon Library* for global strategic and item level estimates. Benchmark rates should only be substituted for materials in the Transport for NSW register of conforming materials, and this should be done using the tools embedded in *Miraway*.

2.6.1. Defining roles and responsibilities

Establishing a defined governance structure and clear accountability is crucial for ensuring that targets are met across all relevant value chain members (**Principle 8**). This includes both internal governance for individual value chain members and governance between these members.

Principle 8: Implement appropriate governance to manage cost and carbon

Effective governance is required to ensure cost and carbon management is prioritised in decision making. The following points should be an integral element of project delivery and governance.

All value chain members should develop and enforce internal governance structures to:

- Define roles and responsibilities for effective carbon management to achieve decarbonisation goals.
- Align investment decisions with policy targets and apply the cost and carbon hierarchy.
- Include whole life carbon in business and management processes alongside cost, time, and risk.
- Establish roles for engaging with value chain members and stakeholders to manage system-wide opportunities and risks.
- Allocate resources (human and financial) to support carbon management efforts.
- Establish processes to measure GHG emissions, identify reduction opportunities, and implement them in projects.
- Ensure management supports all major decisions affecting cost and carbon management.
- Maintain records to support carbon management monitoring and reporting.

External governance responsibilities ensure effective communication and collaboration across the value chain. Each member of the value chain has different external governance requirements.

An asset owner and manager should:

- Develop targets for cost and carbon, and track performance against these targets at an asset level. Ensure these targets are part of a proactive reporting system that is shared across the value chain.
- Design governance structures to ensure targets are met.
- Encourage and incentivise innovation from designers, constructors and suppliers.
- Maintain sufficient communication with all members of the value chain.

Designers should implement governance to identify and promote whole life cost and carbon reduction opportunities within an asset's design.

Constructors should maintain clear communication with asset owners, managers and designers about tracking performance.

Product Suppliers should ensure alignment with the carbon reduction goals and collaborate effectively with other value chain members.

Cost and carbon governance should align with organisational processes that span all portfolios in the organisation, including commercial and quality strategies.

The section below provides an overview of cost and carbon reporting and monitoring requirements for value chain members that work with Transport for NSW. Further details on reporting requirements at each phase of the project life cycle are provided in Part B of this guidance.

2.6.2. Reporting and monitoring requirements for Transport for NSW

Consistent reporting of cost and carbon outcomes should be undertaken throughout the project life cycle to inform decision-making. This should be in the form of:

- Frequent and iterative reporting within the project team through project development and delivery, for example as part of considering options in design, procurement and construction
- Milestone reporting from project teams to a portfolio level, at a minimum at the end of every project phase, which will support organisational reporting and development of benchmarks.

When working with Transport for NSW as an asset owner or manager, the reporting format that projects use should also align with the *Transport for NSW Estimating Procedure* for cost, and carbon reporting should be aligned with *ICMS: Global Consistency in Presenting Construction Life Cycle Costs and Carbon Emissions 3rd edition* for consistency in reporting. Example cost and carbon reporting templates are provided in Appendix G and H of the standard.

The *Transport for NSW Estimating Procedure* governs cost reporting and monitoring, specifying deliverables including the SESS, Benchmarking Summary Sheet, and Risk Outputs for comprehensive reporting of project costs and estimates. The Bill of Quantities, which itemises the quantities of resources and items required for a project is a critical component of the cost reporting and monitoring process and must comply with the Transport for NSW specifications, providing auditable and consistent documentation. The Work Breakdown Structure (WBS) in the SESS standardises cost breakdowns to align classification of assets, items and resources with the *Engineering Cost and Carbon Library* for consistent tracking, facilitating accurate monitoring and reporting throughout the project life cycle.

To enable reporting from projects to be aggregated, validated, and used for central reporting and the development of benchmarks, the following is considered in the *Engineering Cost & Carbon Library*:

- Consistent data format across all projects aligned with *ICMS3* and *RICS 2nd* Edition
- Breakdown by assets or project components that can be reported by a functional or declared unit that is scalable and related to the function or service of the asset
- Breakdown by significant emission sources in line with an appropriate classification system or WBS, to show where emissions are originating which will support targeted reduction efforts
- Separation of biogenic carbon emissions, e.g. from land clearing or significant sources of timber
- Separate reporting of emissions and removals, as well as total emissions

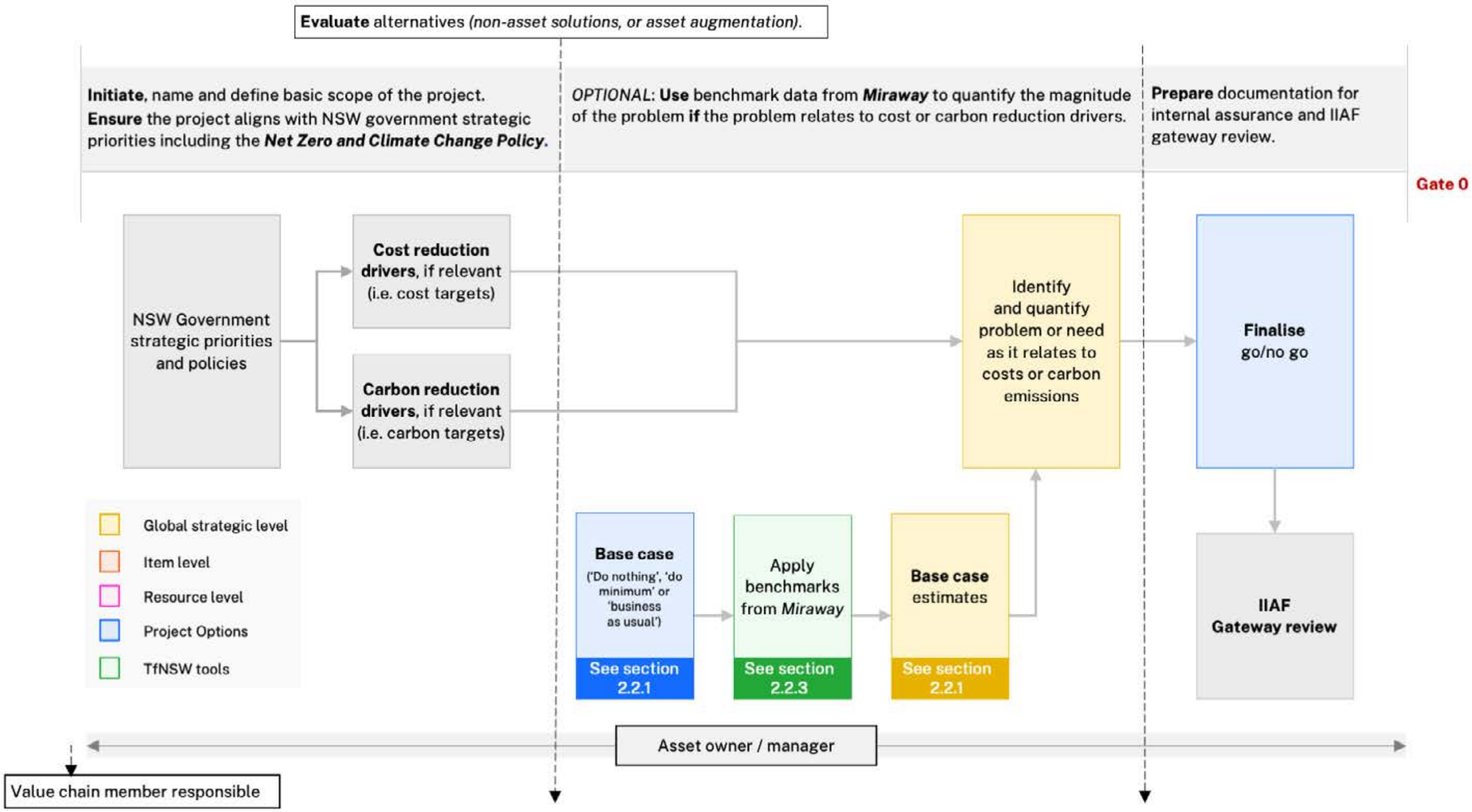
Part B

The following sections provide illustrative workflows for each project stage. It should also be noted that workflows presented in this section may vary depending on the specific nature of each project and contract arrangement.

Part B does not represent a comprehensive statement of all requirements applicable to projects under the Transport for NSW Cost Estimating Procedure or the Project Management Framework, and should instead be read in conjunction with other applicable project requirements.

Cost & Carbon Management in the Project Life Cycle

3. Phase 1 – Needs Confirmation (Mandatory for Tier 1–3 projects)



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3.1. Overview

3.1.1. Initiate, name and define project scope

The beginning of the Needs Confirmation phase occurs when a project is initiated, named and the initial scope is defined. This phase formally recognises the project and identifies a clear problem or service need that the project will address. In alignment with the INSW IIAF, the gateway review deliverable should provide evidence of the existence of the problem or service need, demonstrate its alignment with government strategic priorities, highlight the urgency or criticality of addressing the problem or service need, and include documentation related to strategic asset management planning.

In some cases, the problem may be driven by a need to reduce costs or carbon emissions associated with existing infrastructure. In these cases, project teams may need data to support the quantification of the problem. Cost or carbon reduction drivers should be derived from government strategies, policies, and frameworks to ensure alignment with whole of government targets (see section 1.1). This includes, but is not limited to, the *NSW Government Climate Change (Net Zero Future) Act 2023*, I*NSW Decarbonising Infrastructure Delivery Policy*, and the *Transport for NSW Net Zero and Climate Change Policy*.

In some cases, the primary problem may not be driven by cost or carbon reduction drivers, and instead be related to service delivery needs. In these cases, *Miraway*'s cost and carbon modules are unlikely to support the quantification of the size of the primary problem, but may still be used to demonstrate opportunities for cost and carbon reduction.

Evaluate alternatives

In evaluating the project scope, the asset owner should thoroughly consider alternatives to new project development, including non-asset options and the potential augmentation of existing assets and apply the carbon reduction hierarchy as per Principle 2. At the needs confirmation phase the agency should assess:

- **Non- asset solutions: this includes exploring the use of existing assets, implementing demand management strategies, responding operationally to the problem or service need and evaluating policy alternatives.**
- **Integration or Augmentation: this includes exploring opportunities to integrate or enhance existing assets or investment programs, potentially improving efficiency and effectiveness without necessitating entirely new assets.**
- **Digital and technological solutions: this includes considering the role of digital solutions and technical innovations in addressing the problem.**

3.1.2. Use Miraway for high level benchmarks of the base case

Once the project is initiated and strategic alignment is confirmed, the asset owner may define a base case representing a 'do-minimum' scenario if the problem remains unaddressed (see section 2.2). To quantify the extent of the problem or service need, the base case costs or carbon emissions may be quantified using global strategic benchmark rates presented in *Miraway* (see section 2.2.2). Reviewing the cost and carbon estimates of inaction can further reinforce the need for the project and support the go/no-go review.

3.1.3. Prepare documentation for gateway review

In preparation of documents for the INSW IIAF Gateway Review, the process described above may support the development of:

- Registration Record of the project from the Reporting and Assurance Portal
- Completed Gate 0 Project Justification template (included in the Gate 0 suite of documents) or equivalent Delivery Agency document.
- Relevant asset management framework or asset and service planning document extract.

3.2. Case study

Case study: Carbon in the planning stage (Geokalykl, Sweden)

There is a preconception within the construction industry that carbon is not a measurable or manageable value until the later stages of the design process, after investigations have provided a clear picture of site conditions and design elements have been developed in greater detail. This can impact how a project need is developed, as the problem cost and carbon may not be properly quantified. Similarly, the drivers of the project may be misunderstood as the true impacts of the problems are not fully understood. By the time impacts are quantified it may be too late to explore low-carbon and low-cost alternative options.

In the case of a new transport link, the cost and carbon impacts of some enabling works may not be known during the route selection phase, where designers have other competing priorities. Once the full impact of the required construction activities is understood, and therefore the cost and carbon of the solution in comparison to the problem, it may be too late to change the route as work is already underway, and designers must work within the constraints of the preferred design. This can reinforce the preconception that these impacts were unavoidable and could only be accounted for once detailed design had begun following geotechnical investigations.

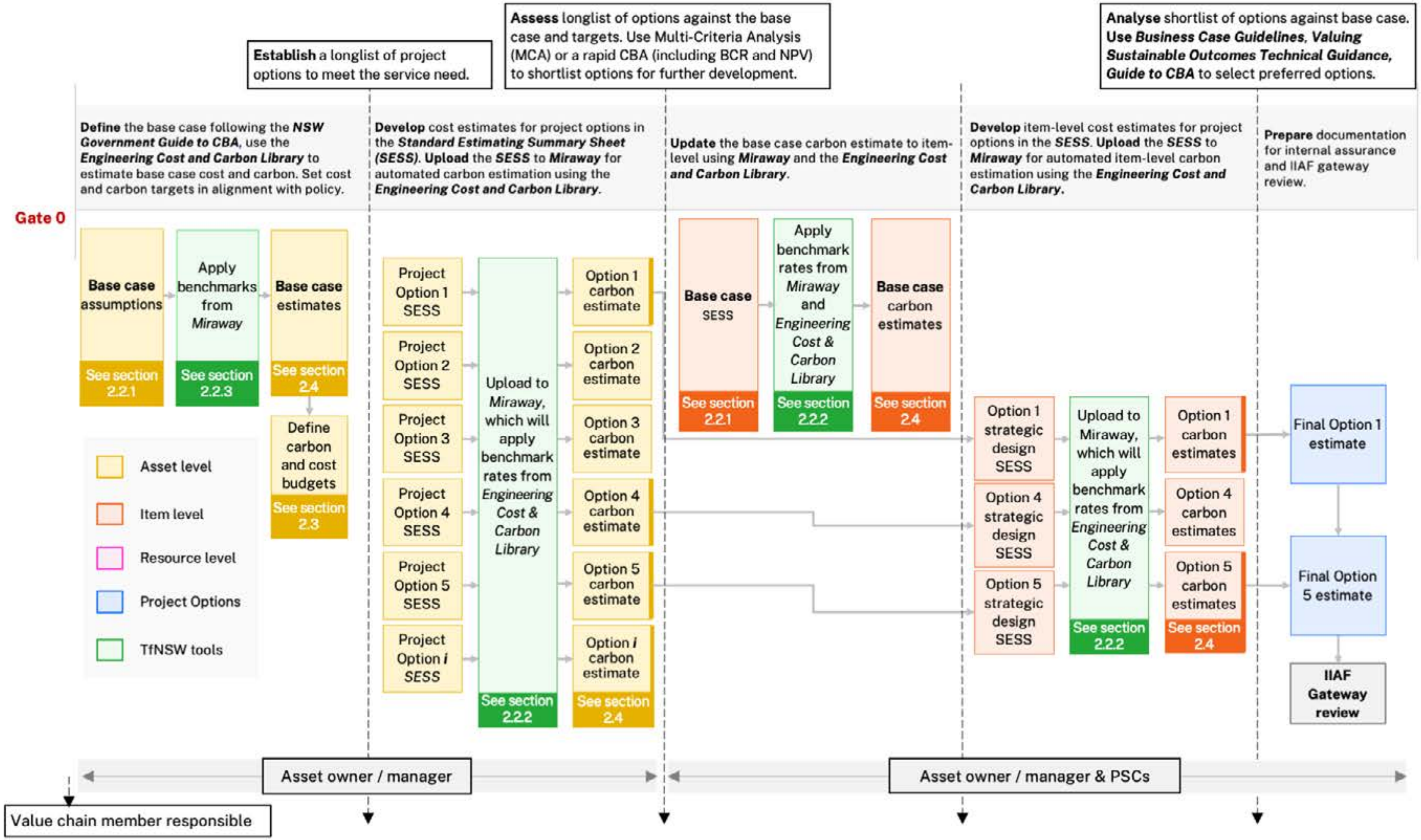
However, by understanding the relationship between cost and carbon and the ability to adopt cost and carbon benchmark rates derived from a large data set of historical projects that is continually being refined, it is possible to estimate the carbon impact of a project at any stage where the cost can be considered. This means that problem identification, and its influence on option design, can play a critical role in determining a project's carbon impact prior to any detailed design or ground investigations. The Geokalykl GIS tool, developed for the Swedish Transport Administration, applies this relationship in the early stage of the design process once the need to deliver a long-distance connection between two points has been clearly identified. Geokalykl is a supporting GIS tool, which can ingest a GIS environment containing key information such as:

- Alternate route options
- No-go and must-go areas
- Foundation reinforcements
- Material transport distances
- Corridor combinations.

Geokalykl then outputs high-level estimates of the cost, carbon impact, and construction energy consumption for each option based on internal benchmark rates, as well as identifying cost and carbon 'hotspots'. These outputs can help designers to quickly evaluate how different route elements will impact the project's final costs and total carbon, determine appropriate geotechnical investigations, and explore how they can minimise cost and carbon by working around high-intensity areas to optimise the project's outcomes.

While Geokalykl is most relevant for a 'needs analysis' assessment, its functionality shows how the cost and carbon relationship can be applied early in the project lifecycle, prior to detailed designs, to understand these impacts. In the same manner the *Engineering Cost and Carbon Library* can be applied to the base case to better understand the problem and explore the feasibility of alternative options at a high level.

4. Phase 2 – Needs Analysis (Mandatory for Tier 1&2 projects, optional for Tier 3 projects)



4.1. Define the base case and set cost and carbon targets

After the Needs Confirmation phase, the project scope must be redefined to detail what will be included and excluded from the analysis. A whole-of-life approach should be adopted to capture the full project lifecycle, ensuring that both cost and carbon impacts are considered comprehensively (see section 2.1).

At this early stage, project teams may not yet have a fully detailed view of potential options, and instead a longlist of options may only be defined at a global strategic-level, focusing on assets or sub-assets. The targets set for cost and carbon reductions should reflect this level of definition, acknowledging that more detailed information and target-setting will emerge later in the process (see Principle 4). To enable this, the base case should also be defined at a global strategic (asset or sub-asset) level, outlining what is required for the project under a 'do-minimum' condition (see section 2.2). Benchmark rates from *Miraway* and The *Engineering Cost and Carbon Library* should be applied to the base case to generate initial cost and carbon estimates, which will serve as the reference point for evaluating project options.

Once the base case is established, high level cost and carbon budgets should be outlined in line with relevant policy and strategic objectives (See section 2.3). This approach ensures that the project's development follows a boundary for cost and carbon expenditure and aligns with broader sustainability goals from the outset.

4.2. Develop estimates for project options using *Miraway*

The longlist of project options should be defined at a global strategic-level. This means that basic dimensions and properties of the project options should be quantified. Practitioners can apply the benchmark rates from *Miraway* and the *Engineering Cost and Carbon Library* to calculate cost and carbon estimates for each option at a global strategic-level.

Assess the longlist of options against the base case

Prior to proceeding, the longlist of options should be assessed relative to the base case in a Multi-Criteria Analysis (MCA) format, or by applying a rapid CBA where necessary, to refine to a shortlist of options. Cost and carbon outcomes will form part of the inputs to this process, but other factors such as the ability to meet service need, strategic alignment, risk and other sustainability outcomes should also be considered in line with the NSW Government Guide to Cost Benefit Analysis and Transport for NSW Cost Benefit Analysis Guide.

4.3. Update the base case estimate

Strategic designs will need to be developed for each project option in a more detailed, itemised format. In alignment with **Principle 2**, the base case should be refined to the same level of detail to allow for effective comparative assessment. This requires quantifying the relevant items under the base case. For most projects, a 'do-minimum' scenario will involve limited items, primarily related to the maintenance of existing assets. New infrastructure should only be included if it falls within the defined scope of the base case. The cost estimate should be developed for the base case in the *Standard Estimating Summary Sheet (SESS)* at an item level. The SESS should then be uploaded to *Miraway* to determine base case carbon estimates.

4.4. Develop item-level estimates for project options

Asset owners or managers may engage professional service contractors (PSCs) or designers to develop strategic designs for shortlisted project options, following established practices. This process often involves a combination of digitally modelled components, 2D designs, and out-of-model information, which define the scope of each option (see section 2.4.1).

To develop cost estimates, PSCs can extract data from these designs and produce a bill of quantities. Cost estimates should follow the *Transport for NSW Estimating Procedure*, with PSCs using benchmark rates to reflect project costs. These estimates should be prepared in the SESS. The SESS can subsequently be uploaded to *Miraway* to generate automatic carbon estimates.

Analyse the shortlist of options against the base case

The shortlist of options should be analysed against the base case using the Business Case Guidelines (TPP18-06), the NSW Government Guide to Cost-Benefit Analysis (TPG23-08), and the Transport for NSW Valuing Sustainable Outcomes Technical Guidance. These frameworks will guide the options analysis, helping to define the benefits sought, risk management, impacts, and affordability assessment, ultimately selecting one or two options to proceed to the Final Business Case stage.

4.5. Prepare documentation for assurance reviews

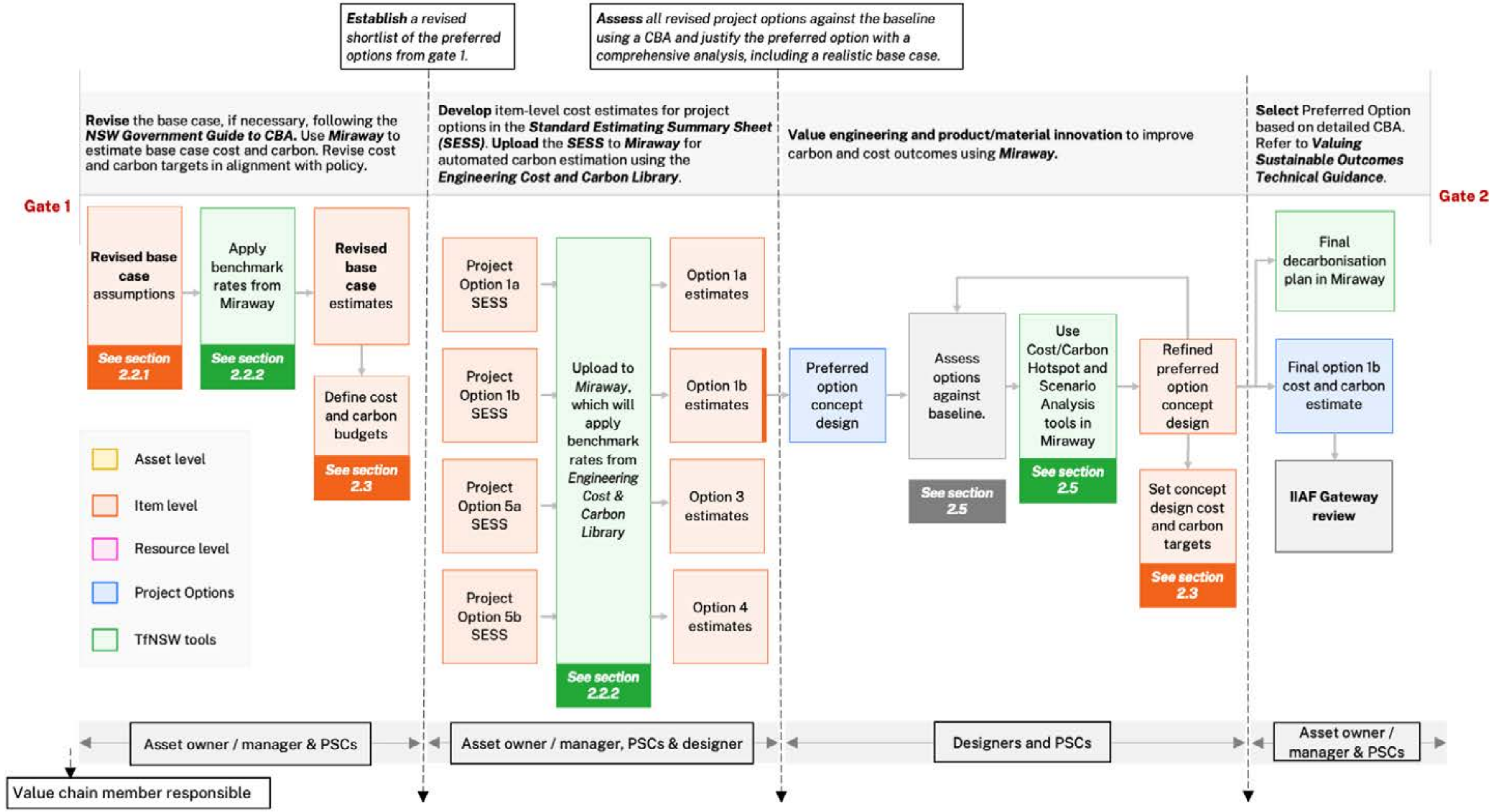
Following the selection of preferred options, if strategic designs are further refined, the cost and carbon estimates should also be updated. In preparation of documents for the INSW IIAF Gateway Review, the process described in the sections above may support the development of a:

- Options analysis report
- Document presenting the option(s) to be taken through to Final Business Case

4.6. Case study

Case study: Western Sydney International Airport Precinct
The *Engineering Carbon and Cost Library* was used during the strategic stage for one of Australia's largest infrastructure and city-shaping programs, the 11,200ha Western Sydney International Airport Precinct. Transport has identified seven road corridors that could constitute the Western Sydney International Airport Precinct Road Network. There is a proposed multi-billion-dollar program of works currently at the strategic business case stage, with delivery dates proposed for 2030/2040. Integrated carbon & cost management was executed on the project at the strategic stage. Cost was 'mirrored' by baseline carbon through applying the *Engineering Carbon and Cost Library*, which enables automation of baseline carbon estimates as part of the existing cost estimation process. The ECCL is configured to the Royal Institute of Chartered Surveyors (RICS) Whole Life Carbon Assessment (WLCA) 2nd Edition and the National Embodied Carbon Measurement Guidance. Several decarbonised options were derived from key carbon hotspots across roads and bridges, with the marginal cost of abatement established. The seven corridors were analysed and compared for cost and carbon using the International Cost Management Standard 3 (*ICMS3*) and benchmarks Transport has developed as part of the 'Global Estimating' approach. The project has helped to inform the development of this guideline. A back analysis of the Cost Benefit Analysis (CBA) was completed to account for embodied emissions. Including embodied emissions and marginal abatement costs did not materially affect the CBA results. Embodied emissions accounted for less than 1% of total benefits (in absolute value terms) while marginal costs represent less than 1% of total costs.

5. Phase 3 – Investment Decision (Mandatory for Tier 1&2 projects, optional for Tier 3 projects)



5.1. Overview of phase

5.1.1. Revise the base case and set cost and carbon targets using Miraway

Following Phase 2 Needs Analysis, the outcomes of the Strategic Business Case (SBC) should be revisited and confirmed. If the scope of the project has changed, the base case definition may need to be revised, and a new base case estimate may be developed using benchmark rates in *Miraway* and the *Engineering Cost and Carbon Library*. Cost and carbon targets may also be revised if the scope has changed.

5.1.2. Develop estimates for a revised shortlist of options using Miraway

One or more preferred options may be carried from the SBC to FBC. Within these SBC preferred options, a new shortlist of options may be developed to include variations of the SBC preferred options (for example Option 1a and Option 1b in the flowchart presented above are variations of SBC Option 1). At the FBC stage, concept designs for each of these shortlisted options should be developed, and from these designs, an itemised bill of quantities may be extracted (see section 2.4.1)

At the FBC stage, asset owners or managers may engage professional service contractors (PSCs) or designers to develop concept designs for the preferred project option, following established procedures. These concept designs typically include digitally modelled elements, 2D sketches, and supporting documentation to outline the scope of the project (refer to section 2.4.1).

For concept estimates, PSCs can use these design outputs to produce a bill of quantities, which serve as the foundation for cost estimation. The cost estimates should align with the *Transport for NSW Estimating Procedure* and be prepared in the SESS. The SESS can then be uploaded to *Miraway* to automatically produce carbon estimates.

Assess the longlist of options against the base case

Before proceeding, the shortlist of options should be evaluated against the base case through a detailed CBA and outcomes of this analysis alongside other strategic considerations should be documented in the Final Business Case in line with existing guidance. Cost and carbon outcomes will be key inputs in the selection of a final preferred option, but other factors such as the ability to meet service needs, strategic alignment, risk, and additional sustainability outcomes, should also be considered in line with the NSW Government Guide to Cost Benefit Analysis and the Transport for NSW Cost Benefit Analysis Guide.

5.1.3. Apply value engineering or product and material innovation to improve cost and carbon outcomes

If any further refinements are made to the design of the preferred option following its selection, a new estimate for cost should be developed using the SESS and uploading it to *Miraway* for an updated carbon estimate at the item-level. These estimates will serve as a baseline for any further design refinements targeted at improving value for money (e.g. through cost reduction) or further reducing carbon.

To further refine and iterate on the design of the preferred option, a value engineering process should be applied, as well as an investigation of product or material innovations that could be substituted in to the baseline design. This involves systematically reviewing and adjusting various design elements — such as exploring quantities and types of materials, construction processes, or other specific features (see Section 2.5.3).

Miraway will streamline this value engineering and scenario analysis process, allowing cost and carbon estimates to be easily developed and compared using a consistent set of benchmark rates, and providing asset owners and designers with a clear understanding of the cost or carbon trade-offs of any design changes. Following this process, a final preferred design sub-options may again be selected for progression to detailed design.

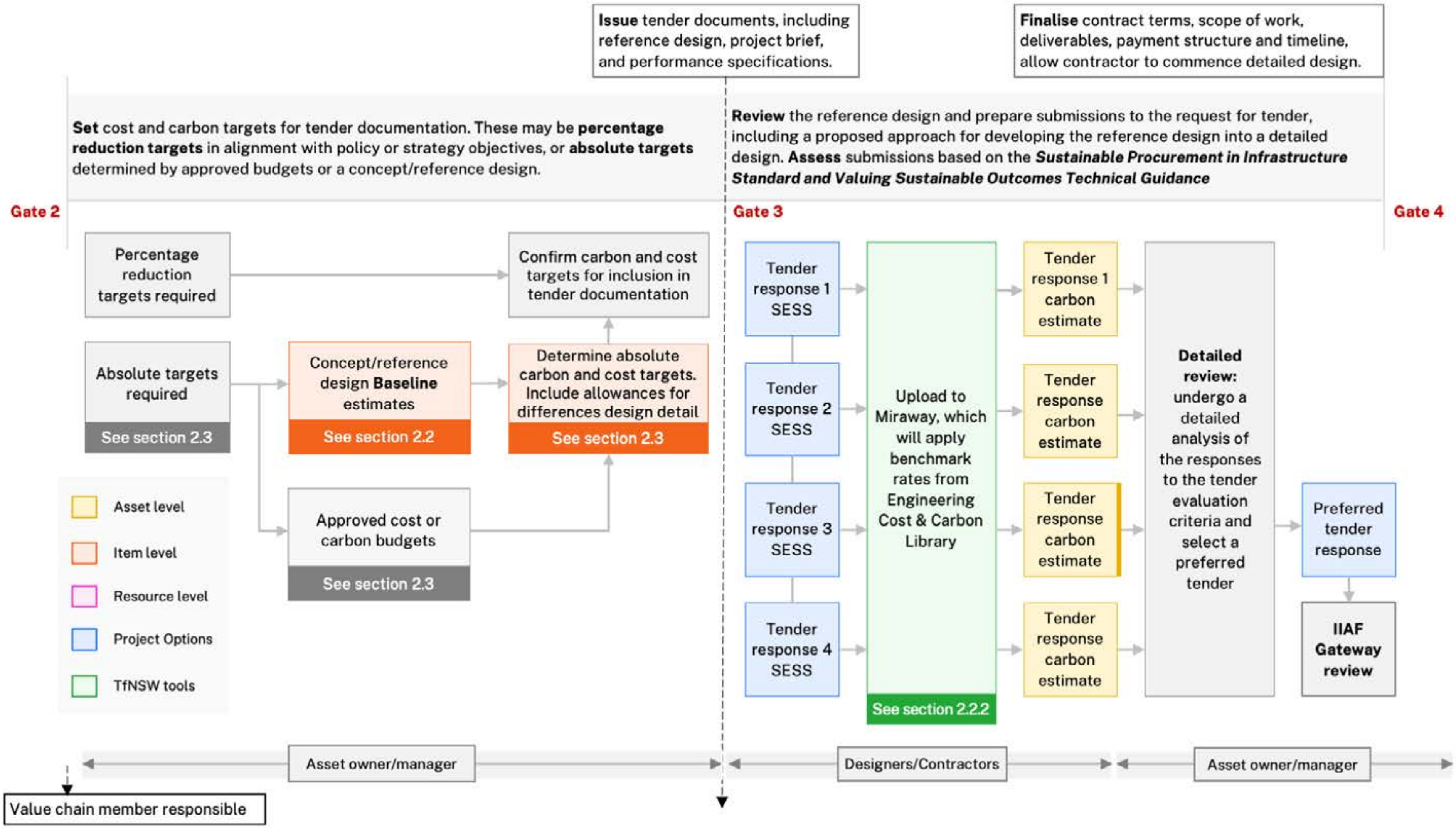
5.2. Prepare documentation for assurance reviews

Following the selection of preferred options, if concept designs are further refined, the cost and carbon estimates should also be updated. In alignment with the INSW IIAF, the Gate 2 deliverable should provide evidence of the project's readiness for funding approval and procurement. The FBC should align with the *NSW Government Business Case Guidelines* and include a thorough analysis of the preferred option, a clearly defined delivery strategy and contracting methodology, alongside a comprehensive CBA.

In preparation of documents for the INSW IIAF Gateway Review, the process described in the sections above may support the development of a:

- Project presentation providing an executive overview of the project
- Final Business Case
- Cost-Benefit Analysis with Benefit-Cost Ratio (BCR) and Net Present Value (NPV)
- Benefits Realisation Management Plan or Evaluation Plan • Detailed risk register or matrix
- Detailed cost plan
- Cost Data Collection Template

6. Phase 4 – Procure (Mandatory for Tier 1 projects, optional for Tier 2&3 projects)



6.1. Overview

The procedure for procurement and subsequent development of a detail design only, or design and, is dependent on the procurement approach selected by the project. This section describes the workflow for using *Miraway* to develop cost and carbon estimates under a design only, or design and construct procurement approach.

6.1.1. Set a target and initial baseline

Before the release of tender documentation, asset owners and managers will need to quantify and include cost and carbon targets. The process for setting these targets will vary by project and may be presented in different forms (see section 2.3.2). The process for setting cost targets is well established, and typically follows the cost budgeting process described in section 2.3.1. However, for carbon these may be in the form of:

- **Percentage reduction targets** – describe the percentage reduction in emissions that the detailed design must achieve relative to a baseline estimate. This baseline estimate may be the first iteration of the detailed design for which cost, and carbon outcomes are estimates.
- **Absolute targets** – set an absolute amount of carbon emissions (tonnes of CO2-e) that the project can produce while still aligning with organisational or broader economic emission targets. These absolute targets may be set as a predetermined percentage reduction relative to a concept or reference design estimate or follow an approved cost or carbon budget.

Issue tender documentation

When issuing tender documentation, include the reference design, project brief and performance specifications to guide tender responses. Ensure cost and carbon targets are clearly defined, enabling contractors to integrate value engineering, and cost and carbon reduction strategies, while ensuring compliance with project technical specifications.

6.1.2. Submission and assessment of tender responses

Once tender documentation is issued, interested contractors may review the reference design and submit responses to the request for tender with their proposed approach to developing the reference design into a detailed design. During the development of their tenders, designers may use *Miraway* at the global strategic-level to estimate carbon outcomes from their designs. Tenderers should describe how their detailed design will meet or exceed the targets set in the tender documentation, as this will inform how cost and carbon targets are set in the contract terms for the preferred tenderer.

Depending on size and scale of the project, tenderers may be required to propose **Sustainable Innovation Options (SIOs)** aimed at enhancing sustainability outcomes of the project. These options should consider any associated costs and program impacts. Tenderers are also expected to submit Carbon Intensity Options (CIOs), which concentrate on carbon abatement opportunities while accounting for cost and program implications. Tenderers may be expected to submit cost estimates in the SESS format, so that it can be uploaded to *Miraway* for automated carbon baselining.

Shortlisted submissions should undergo a detailed technical review to evaluate their alignment with the FBC, ensuring they capture the project scope and deliver the required service outcomes. Submissions should also be assessed using the SPIS and the Transport for NSW Submission Evaluation Procedure. The terms of the negotiated agreed final contract will dictate the ultimate cost and carbon targets that are set for the detailed design in the subsequent phase.

6.1.3. Prepare documentation for gateway review

In preparation of documents for the INSW IIAF Gateway Review, the process described in the sections above may support the development of a:

- Project presentation providing an executive overview of the project
- Tender Evaluation Plan
- Cost Data Collection Template

6.2. Case study

Case study: Integrating carbon into procurement (Motorway A6, Netherlands)[8]

To achieve its emissions reduction targets, in 2010 the Dutch House of Commons set a target of 100% sustainable procurement by 2015. In 2015 Rijkswaterstaat, the Department of Public Works within the Dutch Ministry of Infrastructure and the Environment, released a Design, Build, Maintain and Finance (DBMF) contract for Motorway A6 covering a 13km stretch of road. The maintenance period of the project covered 20 years and formed part of a wider range of improvements along the corridor targeting traffic flow and capacity.

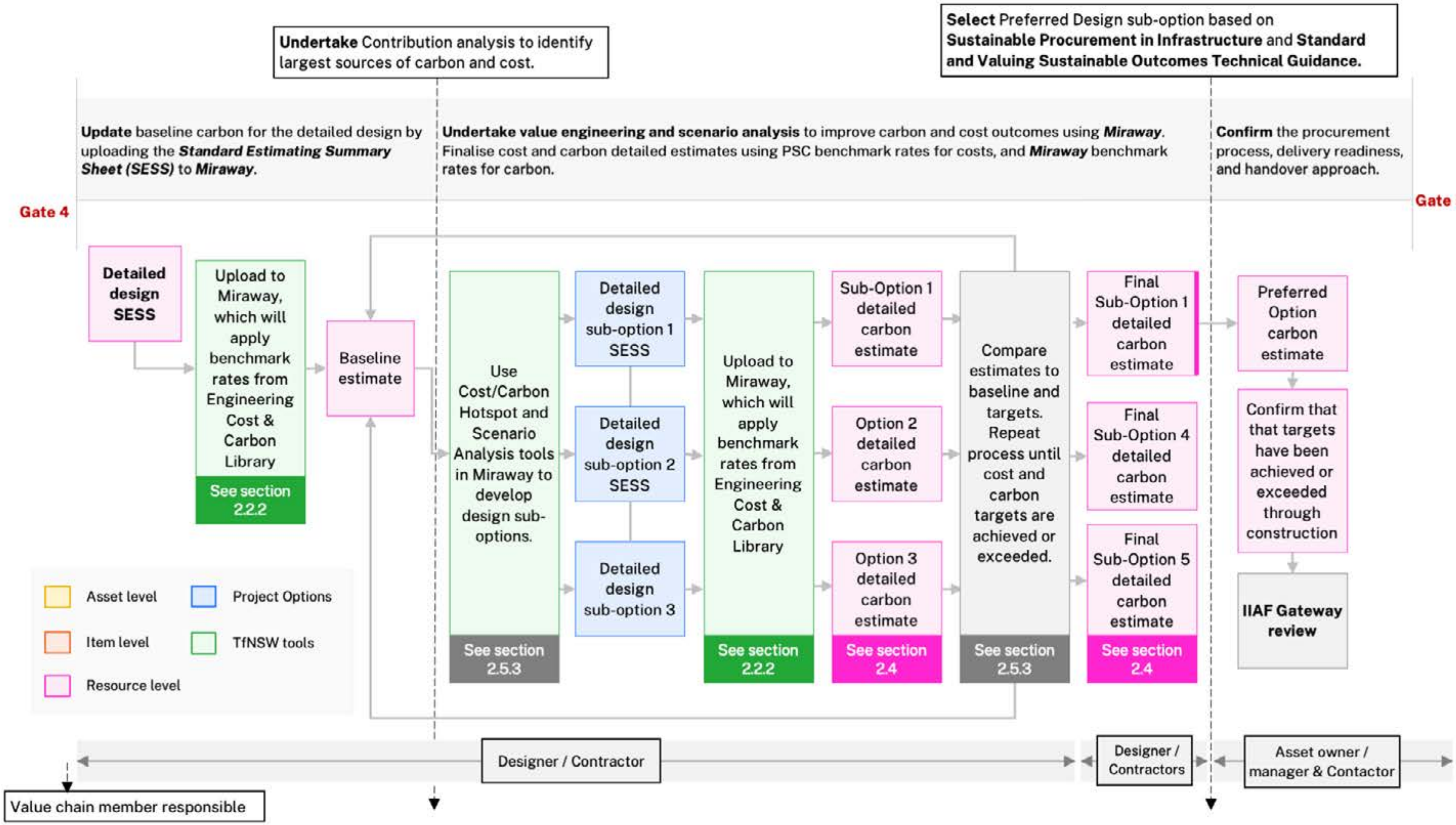
To align with the sustainable procurement requirements, the procurement process featured two additional elements:

- The CO2e Performance Ladder: By showing how the bidder reduced its own CO2 emissions, across other projects, or its supply chain, it could earn a discount rate that would be applied to its proposed fee.
- DuboCalc: A LCA tool which calculated an Environmental Cost Indicator (ECI) based on material and design sustainability drawing on standardised values from the National Environment Database. This allowed bidders to test their designs to optimise sustainability prior to submission. Bids that scored an ECI below a set threshold earned a cost reduction applied to their fee purely for scoring purposes.

These elements together led to strong innovation by bidders, and the successful tenderer put forward a competitive score which achieved the highest CO2e Performance Ladder discount and was below the ECI threshold. This equated to a carbon savings of 52,800 tonnes of CO2e emissions overall or annual savings of 1,056 CO2e/year over the life of the DBMF contract.

The use of *Miraway* will allow tenders to rapidly quantify carbon estimates and assess different options and include results in the tender submissions. This will enable Transport for NSW to incorporate carbon into infrastructure tender scoring criteria across a wider range of projects and include incentives in contracts. This will streamline the onboarding of new suppliers, highlight the importance of carbon reduction throughout the design process and encourage innovation to achieve cost and carbon savings.

7. Phase 5 – Delivery & Initial Operations (Mandatory for Tier 1 projects, optional for Tier 2&3 projects)



7.1. Overview

This phase considers the development of an initial detailed design, and its subsequent refinement to meet or exceed the targets set under the tender documentation. It is conceptual and applicable to different delivery models and contracting approaches depending on circumstances .

7.1.1. Develop a baseline

In this phase, the initial detailed design serves as the reference point for setting a baseline. The baseline quantity information should be extracted from the detailed design at a resource-level (see Section 2.4.1) in the Transport for NSW SESS format. The SESS should be uploaded to *Miraway* to estimate baseline carbon. The cost and carbon targets should remain as per the agreed contract terms and should only be modified if the scope of the detailed design changes post award.

Undertake contribution analysis on the detailed design and identify opportunities to reduce cost and carbon

After comparing the baseline estimate to the targets, designers should perform a contribution analysis to identify the key drivers of whole life cost and carbon (refer to Section 2.5). Simultaneously, MAC curves and cost curves can be used to pinpoint opportunities for design improvements, such as incorporating lower carbon materials, reducing material costs, or further reducing material usage where appropriate.

7.1.2. Undertake a value engineering exercise to optimise for cost and carbon outcomes

Designers should develop feasible sub-options for the detailed design based on the contribution analysis and identified opportunities to reduce cost and carbon (see Section 2.5). This may involve reviewing representative past projects or new product innovations to identify the most impactful and cost-effective initiatives to reduce carbon (e.g. reduction in materials, or use of innovative low carbon materials).

Once sub-options are developed and incorporated into the detailed design, an updated SESS should be produced and uploaded to *Miraway* for automated carbon estimation for each sub-option at a resource-level. These estimates should be compared against the targets established contract during the previous phase. This comparison will support in understanding how each sub-option improves or deviates from the original detailed design's cost and carbon and the impacts on risk or deliverability should also be considered. To further refine and iterate on the sub-option designs, value engineering should be applied to further optimise each sub-option. This process of systematically reviewing and adjusting aspects of the design such as materials, processes, or specific design elements should be repeated until the cost and carbon targets are achieved or reasonably exceeded.

The preferred design sub-option should be assessed using the *Valuing Sustainable Outcomes Technical Guidance* alongside other existing assessment frameworks before proceeding to the next design milestone, and any cost or carbon reduction relative to the baseline should be recorded in absolute terms (dollars or tCO2-e). As the design progresses through milestones and is refined in the level of detail (e.g. increasing levels of LOD, or moving from 50% design to 80% design), practitioners will need to re-baseline and develop new baseline estimates reflecting the higher level of detail. Recording cost or carbon changes from previous design decisions in absolute terms is therefore important to ensure that cost carbon improvements can be effectively tracked relative to the contractual targets.

7.1.3. Prepare documentation for gateway review

In preparation of documents for the INSW IIAF Gateway Review, the process described in the sections above may support the development of a:

- Summary presentation of the project, including scope, location and purpose
- Final detailed design documentation
- Benefits Realisation Plan (or similar)
- Any agency project evaluation documentation
- Final project reports from the completion of the project

7.2. Case study

Case Study: Exploring low-carbon options during detailed design (HS2, UK)[9]

The Skanska Costain Strabag JV developed an innovative method for quantifying cost and carbon simultaneously for the High Speed Two (HS2) project in the UK through the use of a 5D+ integrated workflow. The five dimensions of this project included:

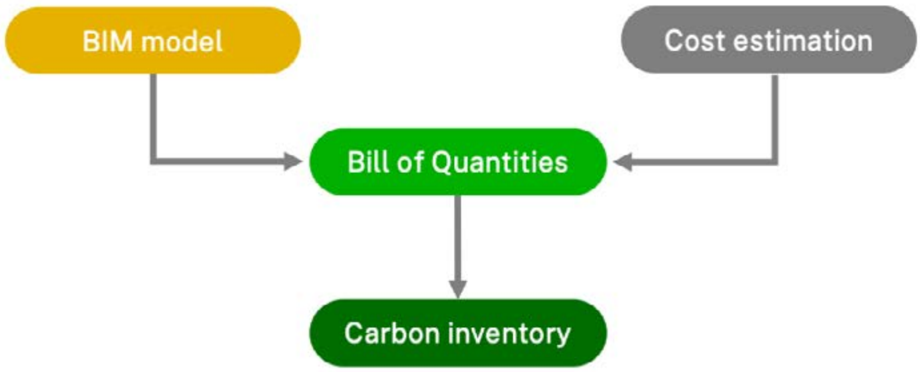
- the 3D design model
- the time/scheduling layer applied within the BIM model
- the cost and carbon layer applied outside of the model.

Accurate quantity take-offs were extracted from the project's BIM model and structured into a bill of quantities (BoQ). Cost and carbon values were then mapped to the BoQ and could be summed to estimate the design's cumulative value. A single data management platform was developed to perform all required tasks, enabling consistent and replicable outputs that could quickly be updated following any changes. The 5D+ integration accelerated the platform's calculation speed and minimised data transformations and movements, reducing the number of errors.

This approach linked cost and carbon through a simple logic, "whatever is designed will be priced, whatever is priced will be measured and scoped in the BoQ". This provided confidence that all aspects of the project that had a cost were captured in the BoQ, and therefore all carbon producing elements were also captured. The 5D+ approach had an added benefit of allowing the project to track any changes in cost and carbon impacts throughout the optioneering process and into detailed design, providing an additional layer of consistency in outputs.

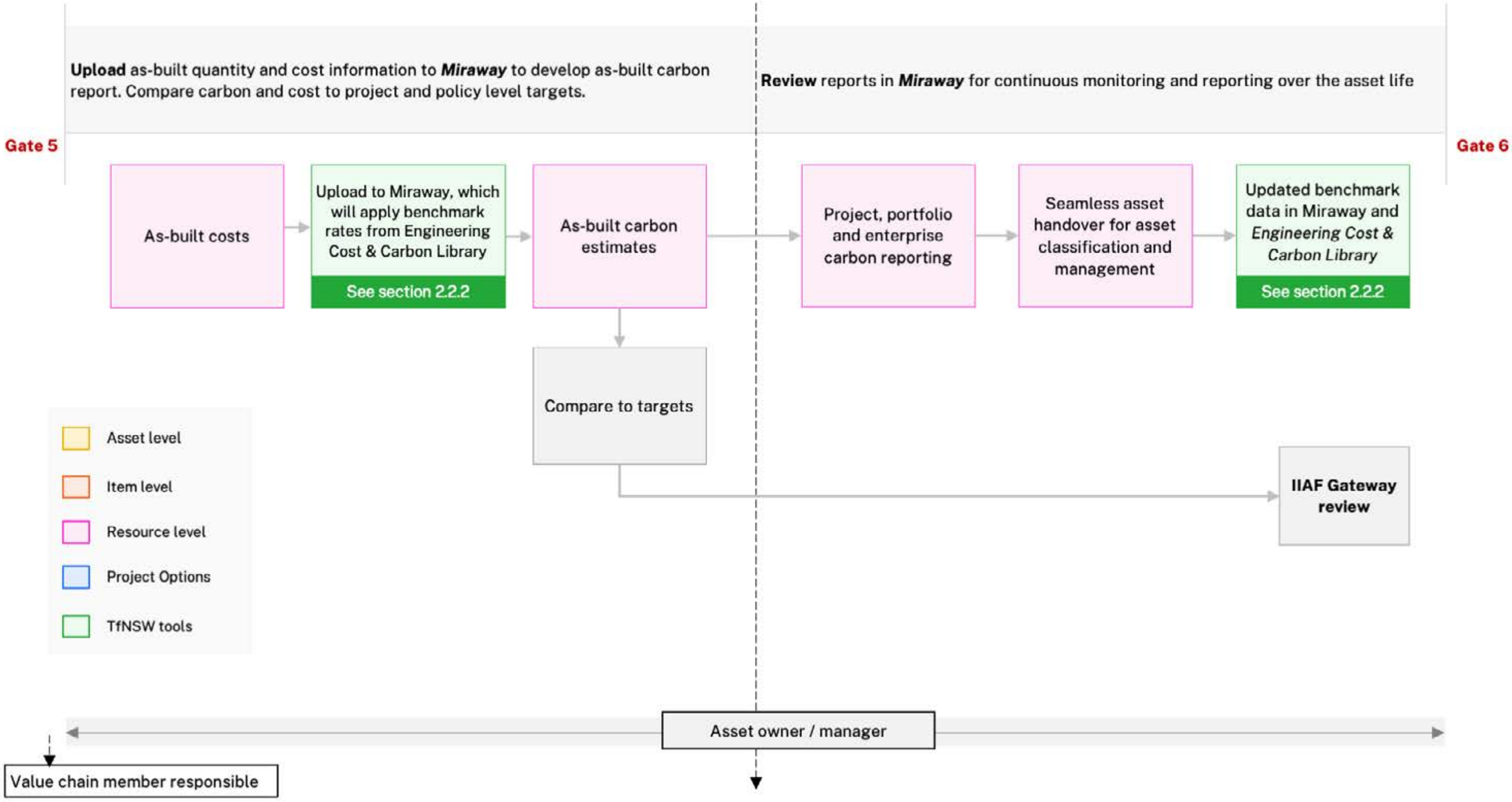
Miraway operates in a similar manner, ingesting data from a standard template form, the Standard Estimating Summary Sheet, which the user can fill in based on information extracted from their design/model, then performs the required data transformations, and outputs the carbon estimate. In future, Transport for NSW may enable connection between digital engineering software and the ICDM to allow for real-time cost and carbon estimation to occur within the design software and using the assured benchmark rates in the *Engineering Cost and Carbon Library*.

Integrated Cost and Carbon model



[9] The Green Construction Board

8. Phase 6 – Benefits Realisation (Mandatory for Tier 1 projects, optional for Tier 2&3 projects)



8.1. Overview

8.1.1. Use as-built quantity and cost information to develop a final estimate for carbon

Benefits realisation typically occurs 4-8 months after an asset begins operation, providing sufficient time to assess its functionality and key benefits. During this period, the asset owner should report as-built costs and quantities in line with existing guidance and frameworks, ensuring that quantities and costs are detailed at a resource-level.

The ICDM developed by Transport for NSW will streamline this reporting process, integrating it with asset management frameworks. For carbon reporting, the as-built BoQ, prepared in the SESS format, should be uploaded to *Miraway*. The Carbon Management Tool in *Miraway* will present the carbon reports, supporting comprehensive project, portfolio and enterprise-level cost and carbon reporting.

The final as-built cost reports and carbon estimates should be compared to the targets set during the detailed design phase. This comparison will identify any deviations from the original estimates and offer insights into necessary mitigation measures, as well as lessons for improving cost and carbon management in future projects.

Miraway will also ingest the as-built data to dynamically update the *Engineering Cost and Carbon Library* benchmarks for future projects, improving the accuracy in cost and carbon outcomes across the organisation.

8.1.2. Prepare documentation for gateway review

In preparation of documents for the INSW IIAF Gateway Review, the process described in the sections above may support the development of a:

- Project presentation providing an executive overview of the project
- Operational Readiness Plan

8.2. Case study

Case study: Measuring the economic carbon impacts of projects (Glasgow Airport Investment Area, UK)[10]

The Glasgow Airport Investment Area (GAIA) scheme formed part of the larger Renfrewshire City Deal in the UK. The GAIA scheme included the design and construction of new roads, realigning existing roads, substantial earthworks, structures and several bridges, including a new opening bridge across the River Clyde. These were packaged up into two major infrastructure projects, with a total value of approximately £130M ($261M AUD). The project team incorporated carbon management into the procurement cycle from the prequalification stage of the tendering process as part of their PAS 2080 application. This included the supplier's ability to deliver a lower carbon solution forming 5% of the scoring criteria, and suppliers being challenged to present how they would achieve a 2,000-tonne reduction in carbon footprint at the tender stage.

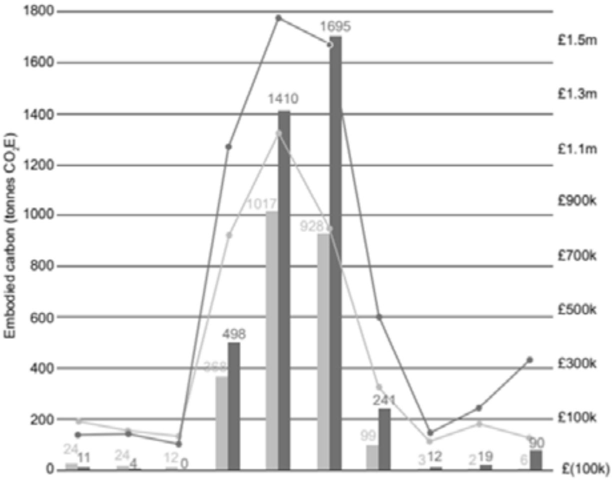
By incorporating carbon reductions from the onset, the project team established the importance of carbon reductions within the project, and the necessary commitment from the preferred supplier to achieve carbon reductions through all elements of the supply chain. Carbon reduction targets were established based on solutions provided during the tendering stage and embedded within the tender requirements for the successful tenderer.

This commitment to emissions reduction paid off twofold for the GAIA scheme, as not only did the project see significant carbon savings across both the design and construction phases, these translated into cost savings through the exploration of non-or low-infrastructure options, as shown in the graph. Carbon savings that led to cost savings included:

- 5,000 tonnes of carbon were saved by reconsidering the need for a gateway road
- 900 tonnes were saved by replacing a pedestrian bridge with a large, signalised pedestrian crossing.

The design consultant utilised its international reach, collaborating with colleagues in its Swedish business, to investigate the relationship between cost and carbon and identify further emission reduction opportunities, with an expected 7,900 tonne reduction in carbon compared to the baseline. The savings from this process are demonstrated in the provided graph, with both cost and carbon values much lower across the project despite some minor increases in the early stages of the project.

The asset, item, and resource levels built into the *Engineering Cost and Carbon Library* allow tracking of a project's cost and carbon impacts from the quantification of the problem all the way through to the actual materials and services used in the final asset and/or infrastructure. This enables the cost and carbon benefits of the project to be directly compared to the proposed savings by the supplier during the tendering phase and any further saving options developed during the design process. This removes ambiguity in actual savings and supports Transport for NSW in achieving its emission reduction outcomes through the realisation of benefits



Source: The Green Construction Board

[9] The Green Construction Board

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9. Future developments to this document

The workflows outlined above provide a foundational understanding of how existing processes in design, option development, and cost estimation can be integrated with carbon management practices using the *Engineering Cost and Carbon Library* and *Miraway*. These workflows are expected to evolve as Transport for NSW continues to refine and enhance the capabilities of both the *Engineering Cost and Carbon Library* and *Miraway*.

In parallel, Transport for NSW is working to update relevant guidance, standards, and specifications across areas such as design, digital engineering, quantity surveying, cost estimation, and business cases. These updates will reflect the streamlined approach to cost and carbon management outlined in this document. Future revisions of this document will incorporate technical direction aligned with these broader updates.