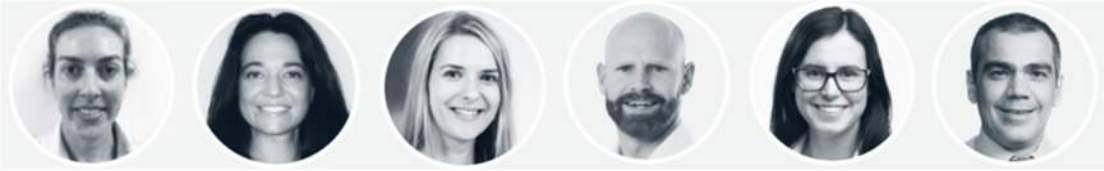
Roads Australia Fellowship Group Project 2022

RESEARCH PAPER

14th October 2022

GROUP ONE – SUSTAINABILITY IN DESIGN
NEW SOUTH WALES



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EXECUTIVE SUMMARY

The Australian Government adopted a target of "Net Zero" emissions by 2050 and a 26 – 28% reduction of emissions below 2005 levels by 2030. RA Fellowship Group 1, self-titled "Sustainability in Design", acknowledges the great work undertaken across the transport infrastructure sector to alter the way in which we delivery projects and the outcomes achieved towards mitigating climate change.

Through exploration of our transport industry network's current understanding of sustainable delivery practices, we explore the feedback received and how it could be utilised to further improve existing methods. We sought to understand how consideration to sustainability impacts could be greater focused upon in the design phase of the lifecycle of transport infrastructure assets.

Detailed analysis of existing procurement models and sustainability frameworks was undertaken to explore what is done well and potential areas for improvement in the next stages of industry innovation.

WHAT DOES OUR INDUSTRY NETWORK UNDERSTAND ABOUT CURRENT PROCESS?

INDUSTRY NETWORK PERCEPTIONS

- *There is strong support for a greater emphasis on sustainability*
- *Sustainability frameworks need to be easy to use*
- *Adoption needs to be client driven*

HOW ARE CURRENT PROJECT CONTRACTING METHODS REWARDING GOOD PRACTICES TOWARDS SUSTAINABLE DELIVERY?

INSPECTING PROCUREMENT MODELS

- *Assessment of sustainability outcomes achieved by a Tenderers solution should be mandatory*
- *Non-price evaluation to include at least one sustainable delivery focused tender returnable schedule*
- *Price adjustment should be considered during evaluation*
- *An established sustainability framework should form part of the mandatory delivery requirements*
- *Independent verification of applied frameworks should be mandatory*
- *Monitoring of 'planned' sustainability initiatives versus 'actual' achieved outcomes is necessary*

WHAT LESSONS CAN WE TAKE FROM EXISTING SUSTAINABILITY FRAMEWORKS AND HOW COULD THESE APPLY TO FUTURE INNOVATION?

AN IDEALISED FRAMEWORK

- *It is imperative that early assessment of project outcomes related to sustainable delivery becomes mandatory in strategic design and during the preparation of business cases*
- *Frameworks should capture as much of the Use Phase emissions as practically possible*
- *Methodology should avoid disproportionate effort for low percentage outcomes*
- *Focus attention on environmental impacts initially, particularly embodied carbon and GHG*
- *Government agencies need to invest in further research and development towards the measurement of social and financial impacts*

HOW CAN EFFICIENCY AND CONSISTENCY BE ACHIEVED IN SUSTAINABLE PROJECT DELIVERY ACROSS AUSTRALIA'S TRANSPORT INFRASTRUCTURE SECTOR?

APPLIED CONSISTENCY AND EASE OF USE

- *Industry should adopt a single source of emissions factors*
- *Standardise the approach adopted across the nation*
- *Government agencies must invest to make the unified framework free*
- *Guidance documentation, training and support resources must underpin the unified framework*
- *Establish an easy to use, intuitive, user interface*
- *Provide an industry accreditation scheme*
- *Include visual representation of sustainability performance on deliverables*

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GLOSSARY OF TERMS

Term	Definition
BAU	Business as Usual
Embodied carbon	Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and construction processes throughout the whole lifecycle of an infrastructure asset.
Emissions factor	Emissions factor is a coefficient that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned).
Environmental Cost Indicator (ECI)	Adds all the relevant environmental effects that occur during the life cycle of a product and displays them in one indicator.
Environmental Product Declaration (EPD)	An independently verified and registered document that communicates transparent and comparable data and other relevant environmental information about the life-cycle environmental impact of a product.
Environmental Sustainability	Responsible interaction with the environment to avoid degradation or depletion of natural resources and ecosystems; mitigation of the climate crisis.
Financial Sustainability	Investment decisions that consider the environmental and social externalities, and whole of life cost.
Greenhouse gases (GHG)	Includes all greenhouse gases (CO_2 e – which is a measure created by the United Nations' Intergovernmental Panel on Climate Change in order to make the effects of different greenhouse gases comparable, because every gas has a different global warming potential: carbon dioxide, methane, nitrous dioxide, etc.) which describes the global warming potential of all greenhouse gases. In other words, the impact of different greenhouse gases is expressed in terms of the amount of CO_2 that would result in the same amount of warming. Kilma, 2021)
IS Enviropoints v2.0	Seven environmental impact categories that make up the single score result: ▪ Global warming ▪ Ozone depletion ▪ Acidification ▪ Eutrophication ▪ Photochemical smog ▪ Abiotic resource depletion – elements ▪ Abiotic resource depletion – fossil fuels
Life Cycle Assessment (LCA)	The systematic analysis of the potential environmental impacts of products or services during their entire life.
Life Cycle Cost (LCC)	The costs that will be incurred during the lifetime of the product, work or service: purchase price and all associated costs (delivery, installation, insurance, etc.) operating costs, including energy, fuel and water use, spares, and maintenance.
Life Cycle Impact Assessment (LCIA)	All relevant inputs from the environment (e.g., ores and crude oil, water, land use) as well as emissions into air, water and soil (e.g., carbon dioxide and nitrogen oxides).
Net Present Value (NPV)	Used to calculate the current value of a future stream of payments from a company, project, or investment.
PSC	Professional Services Contractor engaged via contract for the delivery of professional services.
Scope 1 emissions ***Scope 2 emissions*** ***Scope 3 emissions***	GHG emissions are categorized into three scope areas: ▪ Scope 1 greenhouse gas emissions are the emissions released to the atmosphere as a direct result of an activity, or series of activities ▪ Scope 2 greenhouse gas emissions are the emissions released to the atmosphere from the indirect consumption of an energy commodity. ▪ Scope 3 emissions are indirect greenhouse gas emissions other than scope 2 emissions that are generated in the wider economy. Some examples are extraction and production of purchased materials, transportation of purchased fuels, use of sold products and services, and flying on a commercial airline by a person from another business. (Australian Government Clean Energy Regulator, 2021)
Social Sustainability	Identification and management of impacts, both positive and negative, on people and quality of life.

Term	Definition
Sustainability	In 1987, the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." With the increasing threat of climate change, efforts must be made to ensure development today does not negatively affect future generations. (United Nations, n.d.)
System Boundary	A description of the activities within the product's life cycle phases that are included and excluded from consideration.
Whole-of-life cost	Whole-of-life cost includes purchase and installation, design and building costs, operating costs, maintenance, associated financing costs, depreciation, and disposal costs.

1 Introduction

It is becoming imperative that the transport industry operates in a more sustainable manner to meet the challenges that climate change presents. The Australian Government adopted a target of "Net Zero" emissions by 2050 and a 26 – 28% reduction of emissions below 2005 levels by 2030 (Australian Government Department of Climate Change, Energy, the Environment and Water, 2021). Nationwide, it is estimated that infrastructure contributes around 70% of national emissions, with around 15% directly contributed through the delivery and operation of that infrastructure (Australian Constructors Association, Consult Australia, Infrastructure Sustainability Council, Autodesk, 2022).

Roads Australia recognises that transport infrastructure impacts the environment and contributes to climate change, and that a strong partnership between governments and industry is required to meet national and global sustainability goals and community expectations (Roads Australia, 2022).

Construction of transport infrastructure involves the use of large quantities of engineered materials. These embody a large amount of energy required for their extraction, processing, placement, and end-of-life disposal. Recent Australian data is lacking, however globally the construction sector is estimated to cause up to 25% of industrial emissions.

Production of steel, cement and asphalt are especially emission intensive, as shown in Figure 1.

Adoption of best practice could halve road-construction greenhouse gas emissions (Engineers Australia, 2022).

To contribute to the united effort necessary to achieve the above, the Roads Australia (RA) annual Fellowship Program has tasked the 2022 Fellows with the research topic detailed below.

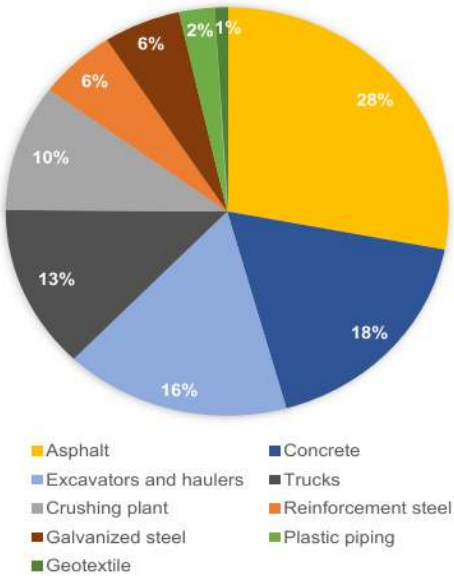


Figure 1: Estimated Greenhouse Gas (GHG) from a typical road project (Ida Karlsson, 2020)

1.1 Research topic

How are transport infrastructure sectors evolving to meet climate change challenges?

Research and respond to the topic in collaboration with the business you have selected. Your response could include answering the following questions:

1. Identify some of the **climate change challenges that your business is facing** in the delivery and operation of transport infrastructure. **Select a challenge** and work to research and propose a change which could be implemented.
2. What **risks and opportunities** have you identified and how are you planning to address/capitalize on these?

1.2 Our research objectives

To understand the full extent of embodied carbon in transport infrastructure, consideration must be given to the entire project life cycle of assets, not just the materials used to construct, operate, and maintain the assets. The objective of our research is to understand the current status quo in the Transport Industry in implementing **analysis processes at the design stage of transport infrastructure projects to reduce embodied carbon**.

1.3 Project goal

We aim to develop a **holistic design optioneering framework** for transport infrastructure projects to inform design decisions by **embedding environmental, social and financial sustainability assessment** into the design stage of the asset. As with most processes used to inform design changes, the earlier in the lifecycle they are introduced, the more influential they can be and at a greatly reduced implementation cost. We want sustainable engineering to be upfront during strategic and concept design stages, and not a tick-box exercise left to the detailed design.

Figure 2: The typical stages of an infrastructure asset lifecycle

One objective for influencing behaviours to consider sustainability earlier in the infrastructure asset lifecycle is to provide a visual output which can be clearly shown on design drawings, providing sustainability metrics and enabling like-for-like, whole-of-life assessment of various design options. The provision of these metrics would enable informed decision-making regarding sustainability impacts and decarbonization of each design option being presented.

The framework proposed in this report largely focuses on pavement design options, however suggestions for broadening this framework to other civil infrastructure elements have also been provided.

Consideration has also been given to how various infrastructure delivery agencies can introduce the proposed framework into their procurement models.

1.4 Partnership with Arcadis

Arcadis has been developing an innovative approach to assessing sustainability impacts of pavement design options. Our group partnered with Arcadis to incorporate their approach into the proposed holistic design optioneering framework and to identify challenges associated with the implementation at the design stage of an asset.

1.5 Research road map

The research scope and methodology include five primary themes as outlined in Table 1 below. We devised a strategy of research components within each workstream and set out to investigate the current practices for sustainable procurement, measurement of emissions, integration of sustainability for project delivery, and the opportunities that may exist to improve current practices in the delivery and operation of transport infrastructure.

Table 1: Research 'road map'

Themes	Team approach	Ref
Investigate how sustainability is currently assessed during the project planning and design stages	▪ Develop and conduct a survey to obtain feedback from our project group entities and industry contacts on attitudes toward and understanding of sustainability, existing sustainability measures and approaches, as well as comments to guide our proposed framework ▪ Summarise findings from the survey	**Section 2**
	▪ Analyse the incentivisation of sustainable project delivery in the procurement phase of past projects: o What requirements are placed on contractors during tender development and planning? o How are tenderers evaluated for sustainable practices? o What obligations are necessitated for project delivery? o What variance exists due to contract model, project size, client, etc? ▪ Summarise findings from the analysis	**Section 3**
Understand the breadth of sustainability assessments across project life cycle and asset life cycle stages	▪ Research current literature on sustainability impact assessments applied to the life cycle of a project ▪ Review the timing of 'business as usual' sustainability impacts review in the project Design and Planning stage ▪ Research 'system boundaries' applied to the breadth of sustainability assessment across the project lifecycle stages	**Section 4**
Investigate industry best practices for approaches to quantifying embodied carbon and greenhouse gases and assess existing sustainability frameworks	▪ Review existing methodologies for quantifying embodied carbon and greenhouse gases ▪ Look at sustainability performance indicators through the lens of environmental, social, political and financial impacts ▪ Analyse and compare the existing sustainability assessment frameworks applied within the transport industry ▪ Summarise findings from the analysis	**Section 5**
Develop an Idealised Framework for sustainability assessments that could maximise return on investment and further drive sustainable innovation	▪ Summarise improvements that could be made during the creation of an industry wide framework based on the learnings from Section 2 to 5. o Timing of application in the lifecycle of an asset o Breadth and system boundaries o Methodology o Implementation ▪ Adopt lessons learned from analysis of the strengths and weaknesses of past project procurement models ▪ Adopt lessons learned from analysis of the strengths and weaknesses of existing sustainability frameworks	**Section 6**
Partner with Arcadis to share learnings from their sustainable pavement design innovations and how their model may be improved or extended on the basis of our research	▪ Work with Arcadis to understand the key findings from their research on the assessment of sustainability impacts focused on pavement design options ▪ Learn about the standard operating procedures (SOP) applied to sustainable pavement design option selection and any barriers faced during implementation ▪ Trial the Arcadis process for a project case study to gain any added first-hand lessons – inputs & outputs, time investment, ease of use, gaps etc. ▪ Apply key learnings from the development of the Idealised Framework that could provide improvement to Arcadis' SOP.	**Section 7 & 8**

2 Industry Network Survey

In this section, we explore the wider experiences of our industry network – general knowledge and understanding of sustainability, perception of project delivery requirements, and expectations for improvement.

2.1 Survey Structure

To determine the wider experiences of the transport industry, the Team conducted a survey of our colleagues and other contacts working within the transport industry, including designers, consultants, and contractors.

The purpose was to obtain industry feedback on:

- The personal importance of sustainability and its various facets to individuals working within the transport industry.
- Level of understanding of sustainability within the transport industry.
- How often sustainability was considered in contracts and at which stage of the project lifecycle.
- Barriers to consideration of sustainability in the design process.
- Interest in a framework to measure sustainability of a design.
- Factors that would incentivise the adoption of a framework to assess the sustainability impacts of a design by industry.
- Priorities for elements of a design that should be assessed in the framework.

The survey was created using Microsoft Forms and distributed via email. A copy of the email and survey questions is provided in Appendix A.

2.2 Survey Responses

The survey ran over two weeks, from the 4th to the 19th of August 2022. During this period, we received 82 responses. A copy of the responses in included in Appendix B.

As shown in the figures below, we had a good spread of respondents across designers, consultants and contractors. Company size appears to be typical of the industry in Australia, with the market dominated by small and medium-sized enterprises (SMEs) and large multinational corporations. We also had a relatively even spread across age and experience categories, and a wide variety of roles.

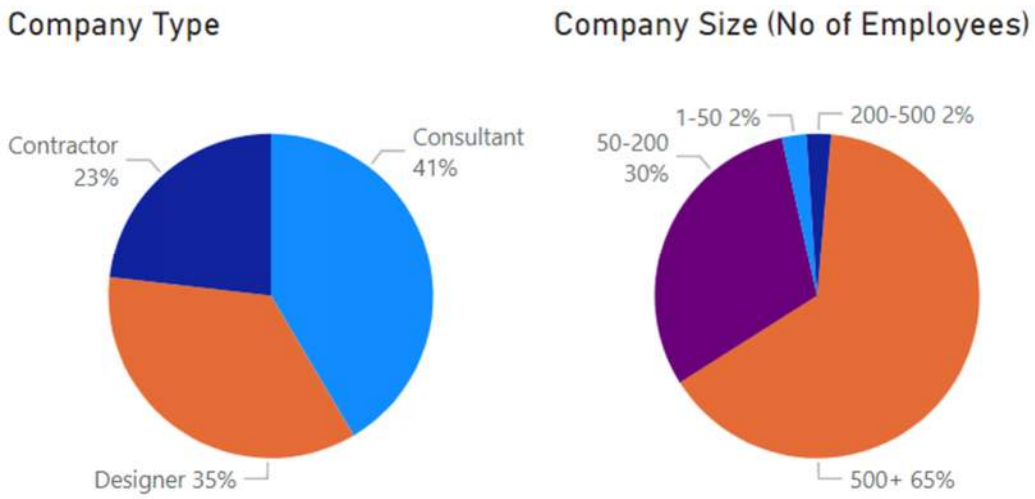


Figure 3: Industry role and company size of respondents

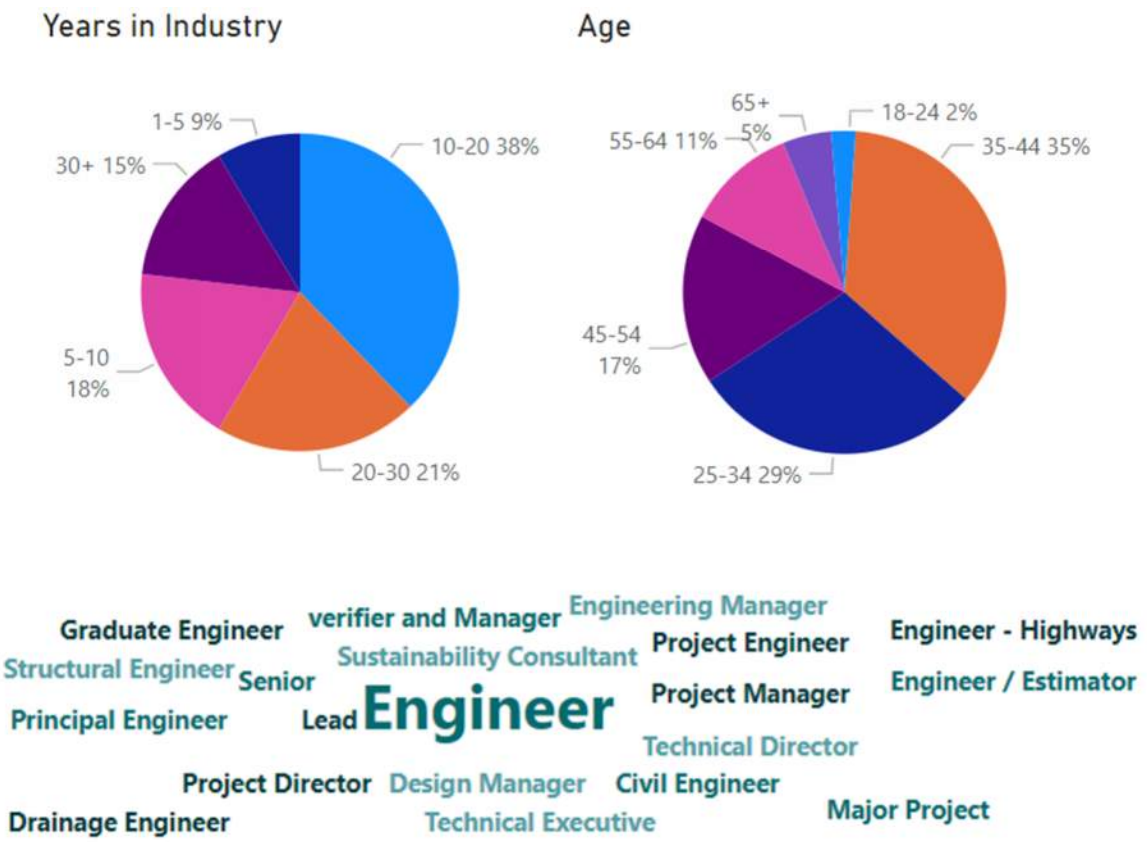


Figure 4: Demographic of respondents to the Survey

Only 20% of respondents identified as female. This is consistent with ABS data, with women making up 27.4% of Australia's transport industry across road, rail, sea and air, dropping to 20% for land transport only (Roads Australia, 2022).

Most respondents were based in Sydney, which is reflective of the fact that our team, and therefore our professional networks, are all based in NSW. This may bias the survey results.

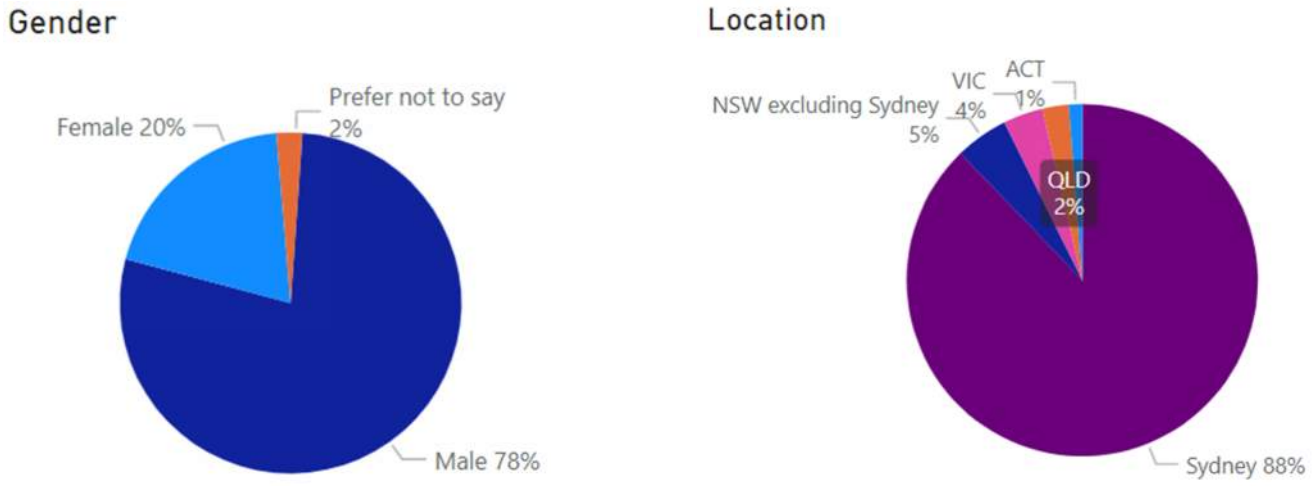


Figure 5: Gender and location of survey respondents

2.3 Survey Outcomes

98% of respondents agreed that they would like to see a greater emphasis on sustainability across the construction industry.

90% of respondents stated that if there was a process or framework to measure the sustainability of a design, they would use it or review the results of it, reinforcing our team's view on the value of such a framework.

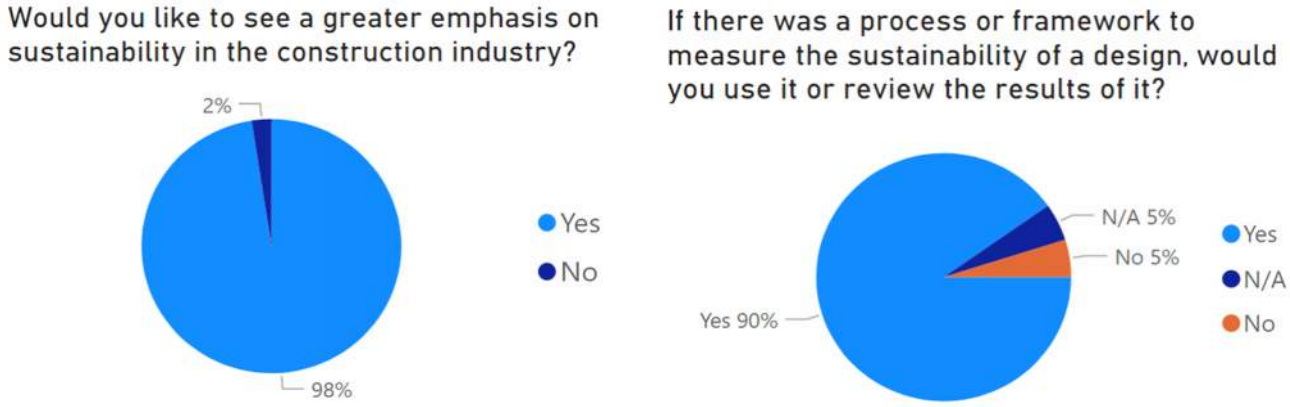


Figure 6: Appetite for sustainability in industry

The top three barriers identified by respondents regarding applying sustainability considerations more broadly in the design process were lack of knowledge, cost and lack of client incentive.

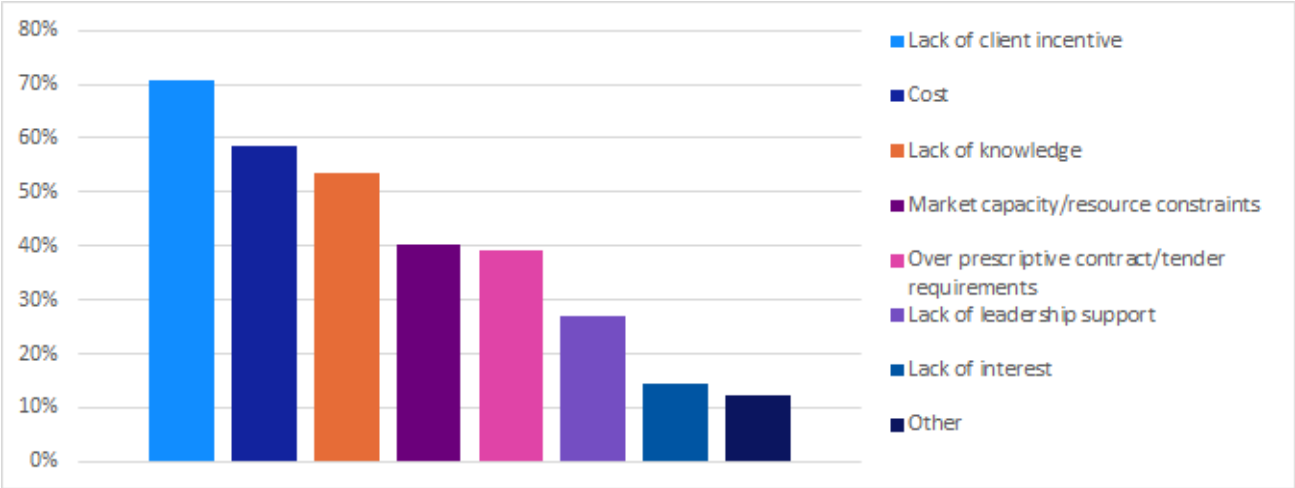


Figure 7: Barriers to applying sustainability considerations more broadly in the design process

Other barriers identified by respondents include:

- Lack of legislation or political commitment.
- Difficulty in getting innovations or non-conforming elements approved due to design specifications or lack of long-term performance record.
- Lack of time, often due to political commitments to delivery timeframes.
- Existing frameworks, such as the IS Rating process, being too resource intensive for small and medium projects.

Respondents were also asked to rank the elements listed below based on their perception of their contribution to greenhouse gas emissions on a transport infrastructure project. This was compared to data on typical CO_2 emissions on road projects in the UK (National Highways UK, 2021).

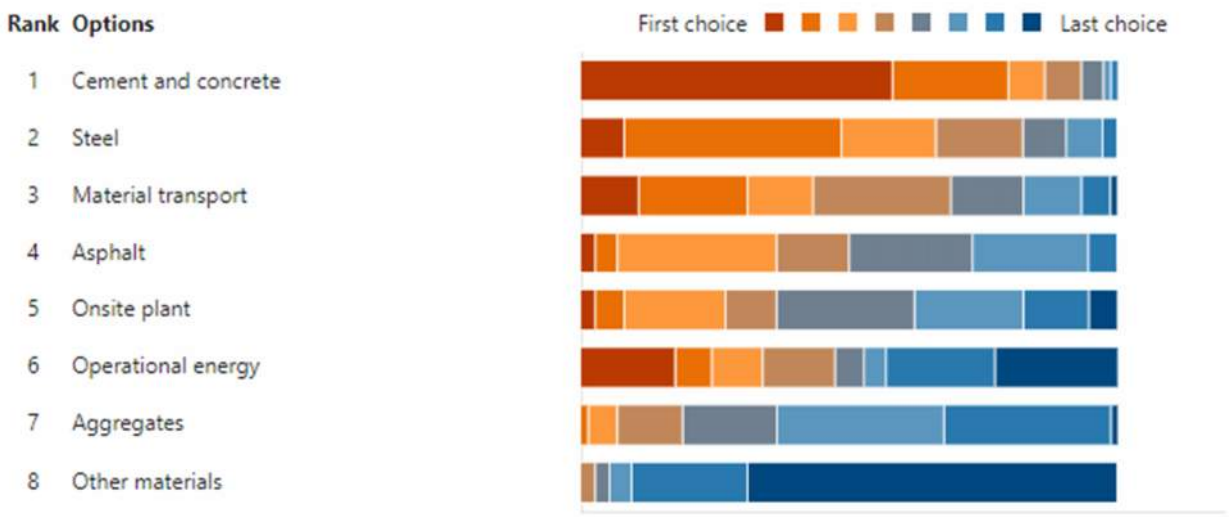


Figure 8: Industry knowledge of primary contributors to greenhouse gas emissions

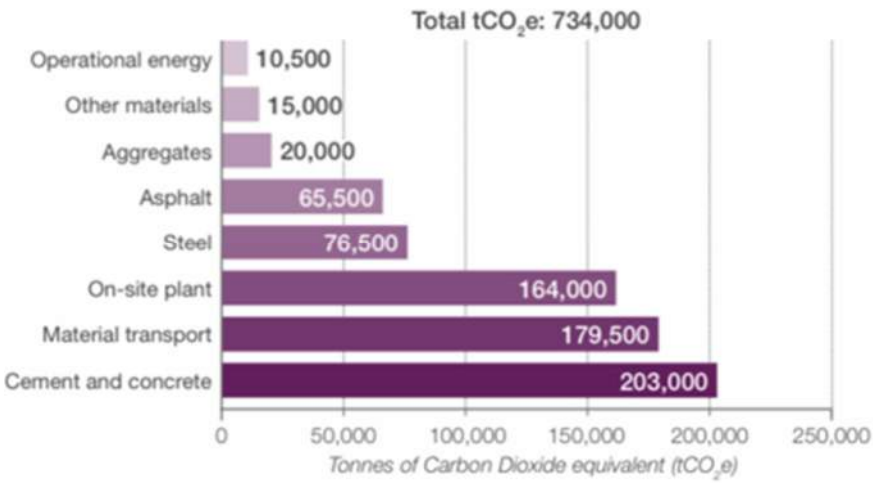


Figure 9: Typical CO_2 emissions on road projects in the UK (National Highways UK, 2021)

As a collective, respondents underestimated the contribution on-site plant has to CO_2 emissions on a road project and overestimated the contribution of steel. This may be because:

- Steel has a high embodied carbon but makes up a relatively low percentage of material usage on a road infrastructure project.
- We are conditioned to focus on material use rather than the consumption of fuel by construction plant.

To address the identified barrier "lack of knowledge", education and training on sustainability is an important part of the industry's response to climate change for several reasons, including:

- Giving individuals the confidence to champion sustainability.
- Helping people identify and focus their effort on areas that will have the biggest impact.

3 Review of Sustainability Incentivisation during Procurement

In this section, we explore the personal experiences of our team in the delivery of a handful of transport infrastructure projects in NSW, primarily focused on government procurement.

3.1 Procurement via Tendering

When NSW government agencies procure large infrastructure projects, they have a fundamental objective to ensure the procurement achieves value for money. Efficiency and effectiveness, probity and equity, and effective competition are key principles underpinning the Policy Framework (NSW Government, 2005).

During tender planning, the Request for Tender (RFT) documents are developed ahead of inviting tenderers. These will generally comprise the following components:

- Conditions of tendering.
- Tender form and/or pricing schedule(s).
- Returnable schedules of information.
- Standard and special conditions of the contract/deed.
- Technical specifications (functional or performance).
- Drawings or other information documents.

The RFT documents prescribe the evaluation criteria and broad weightings on which the assessment of the tenderers, and their submissions, will be based.

3.2 Opportunities to incentivise sustainability

The agency procuring the work and completing the evaluation of tenders has an influential position in driving projects to achieve certain objectives.

If the transport industry plans to achieve Net Zero, there is an obligation for the supporting agencies to value sustainability and reward tenderers that commit to achieving positive outcomes in this space.

Competitive tendering drives project cost reduction through the intrinsic nature of the competitive environment. But a reduction in cost alone may not achieve a 'value-for-money' outcome for a project. The determination of 'value' on this balancing scale is highly subjective and depends on the criteria used to measure how much value is provided, how much weight each criterion holds relative to each other, and the personal opinion(s) of those making the assessment.

To achieve Net Zero, measuring the positive and negative outcomes for sustainability must be part of the balancing scale equation. This extends in the same manner to a benefit versus cost assessment and preparation of a business case – i.e., the argument for whether or not the project is worth doing, either in part or in whole, should include consideration of how sustainably it can be delivered.

The preparation of an RFT package provides the agency with several opportunities to incentivise sustainability as a core objective. Some of these include:

1. Incorporating a discrete assessment criterion for sustainability initiatives:
    - Price evaluation – for example, a sustainability cost estimate for greenhouse gas emissions over the project life, applied as a cost incentive if we have a positive sustainability outcome.
    - Non-price evaluation – for example, tenderer's proposed sustainability resources, sustainability processes, past-experience in sustainability delivery.
2. Requesting tenderers to document their actual or planned processes for driving excellent sustainability outcomes in the delivery phase of the works. For example, requiring a tender Returnable Schedule – draft Sustainability Action Plan.

3. Requiring tenderers undertake a sustainability rating assessment, e.g., IS rating or similar, often as a comparison against a baseline assessment established prior to tender.
4. Including incentives within the commercial model such as defined Key Performance Areas and Indicators (KRA/KPI's) with financial reward, or conversely, penalties.

Industry feedback from the survey indicates that there is significant room for improvement when it comes to incentivising sustainability, with only 16% of respondents stating that their organisation's project contracts always include a focus, assessment or incentive relating to sustainability. There was also a clear trend in the frequency of an incentive based on the size of the organization, with SMEs' contracts significantly less likely to include an incentive than large organisations of 500+ people.

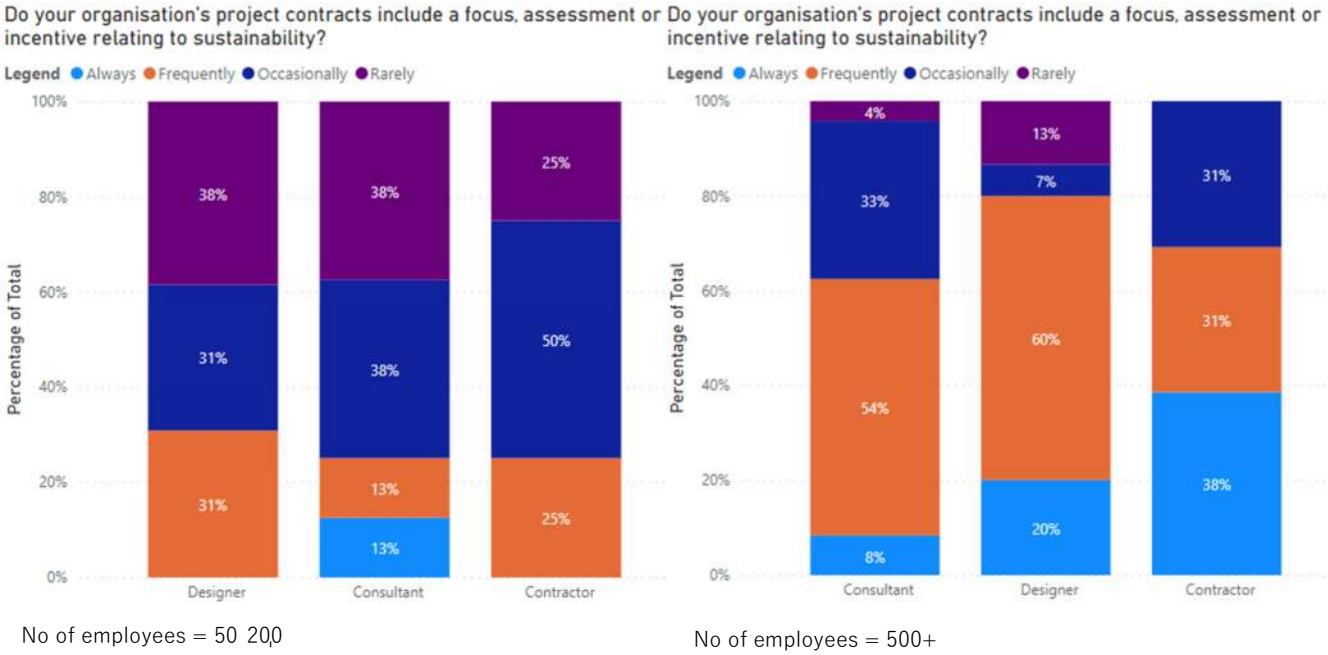


Figure 10: Sustainability incentivisation by company size

3.3 Past project reviews

We have reviewed several projects that our team of design consultants and construction contractors were exposed to in the last five years. This review focused primarily on projects procured by New South Wales government and sub-agencies.

We intentionally shortlisted projects with a variety of; Contract type; CAPEX; Procurement design stage; Client; Scope of works. The Contract type has a significant impact on the ability for all involved parties to influence the outcomes of the project and hence, further explanation of this category has been provided.

NSW Government's *Construction procurement guide; contract systems* (NSW Government, 2008) outlines some key and relevant types of contracts used to deliver construction projects which are further explained in Section 3.3.1 to Section 3.3.6.

Figure 11 demonstrates the flexibility of the Contractor to influence the design solution through each of the key contract types.

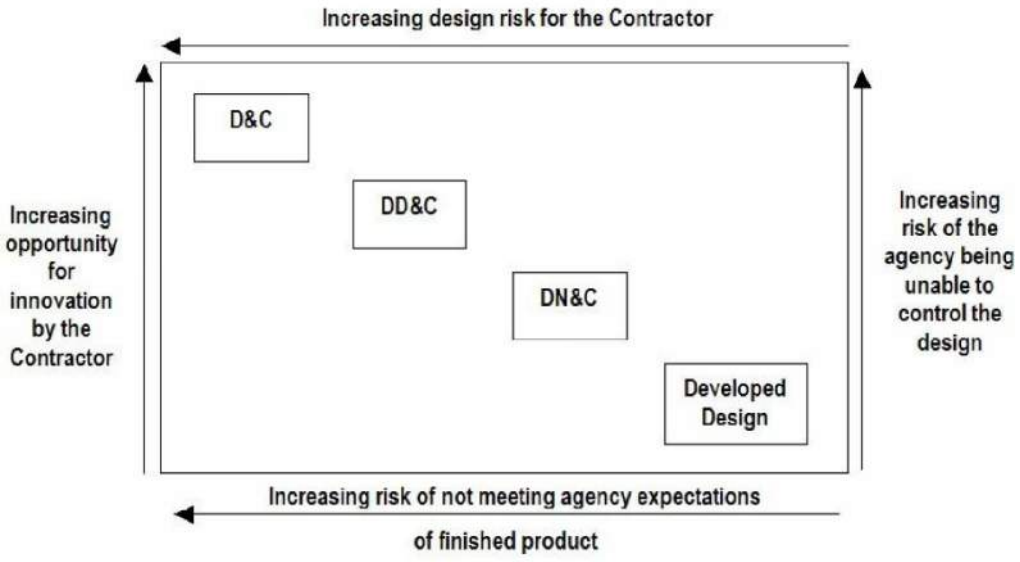


Figure 11: Traditional construction contracts and allocation of design control/risk (Government, 2008)

3.3.1 Documented design, also known as 'construct only'

Design process and construction contractor procurement are largely separated, maximizing the procuring agencies' control over the design, but minimizing innovation the construction contractor can bring to the design solution.

3.3.2 Design development and construct (DD&C)

Early phase design (e.g., concept design) developed with construction input allowing for D&C style solutions earlier in the project lifecycle.

3.3.3 Design, novate and construct (DN&C)

As above, with novation involving signing over the contractual relationship between the designer and procuring agency to create a contractual relationship on the same terms between the designer and construction contractor. This provides continuity of designer's involvement.

3.3.4 Design and construct (D&C)

Finalisation of the design and construction documentation occurs in parallel, enabling construction methodology and design solutions to be integrated. This form of contract provides flexibility in incorporating innovations and increasing value-for-money outcomes.

3.3.5 Design, construct and maintain (DCM)

As per D&C, with a maintenance contractor involved to maintain the assets for a specified period. This incentivises the construction contractor to produce a higher quality product in order to minimise maintenance costs.

3.3.6 Alliance

An agreement between two or more entities to undertake the work cooperatively and through joint decision making. Designed to remove contractual barriers and maximise contributions by all participants.

Table 2: Analysis of Tender and Delivery Requirements for past projects

Projects Analysis	Road Tunnelling	Freeway Upgrade	Rail Tunnelling	Regional Road Remediation	Urban Arterial Road Upgrade	Urban State, Regional and Local Road Upgrades	Urban/Rural Arterial Road Upgrade
General Project Details							
Contract type	Design development & construct (DD&C)	Design development and construct (DD&C)	Design development and construct (DD&C)	Design, novate and construct (DN&C)	Alliance	Documented Design (Construct only)	Documented Design (Construct only)
Contract Principal	Government formed delivery authority	NSW Government	Government formed delivery authority	Council	NSW Government	NSW Government	NSW Government
Estimated CAPEX	$4.35B	$1.18B	2.16B	Not awarded – Est. $250M	Not awarded – Est. $200M	$200M	Not awarded – Est. $40M
Design status	Tender Design and Detailed Design	Tender Design and Detailed Design	Tender Design and Detailed Design	Detailed Design	Detailed Design	Concept Design and Detailed Design	Detailed Design
Procurement year	2015	2020	2021	2022	2021	2018	2022
Project description	▪ 9 kms of twin road tunnels constructed with road headers ▪ Construction of a major and complex above ground intersection over a remediated landfill site ▪ 10 bridges ▪ 5 Motorway operation complex sites	▪ Upgrade of 4km of Freeway ▪ Two major interchanges ▪ Relocation of road and shared user bridges ▪ Provision for future tunnelling connections ▪ Other operational infrastructure, including surface drainage, utilities, signage, tolling, lighting, CCTV and other traffic management systems.	▪ Twin 9km tunnels constructed with tunnel boring machines (TBM) ▪ TBM launch site temporary works ▪ Tunnel portal, dive excavation and spur tunnels connecting to a surface Maintenance Facility ▪ Earthworks, retaining structures, drainage and utilities corridor for the Maintenance Facility ▪ Excavation and civil works for underground railway stations ▪ A segment manufacturing facility for TBM tunnelling support	▪ Disaster recovery works along a 45km stretch of regional roads ▪ Road reinstatements due to landslips ▪ 240x slope failures requiring re-stabilisation ▪ Upgrade of drainage/culverts ▪ Isolated upgrades at discrete sections for safety improvement	▪ Widening approximately 1km of urban arterial road in Western Sydney ▪ Providing active transport and public transport improvements ▪ Decommissioning a grade separated private access to commercial property ▪ Upgrade of motorway exit ramps ▪ Noise walls and property adjustments ▪ Utility adjustments	▪ Road widening along key roads in and around a business precinct ▪ Conversion of 2 roundabouts to signalised intersections ▪ Upgrade of 6 other signalised sites ▪ Property adjustments and interface with adjacent developers ▪ Substantial utility relocations and protections ▪ Bus infrastructure upgrades and relocations	▪ 3.6km shoulder widening along the arterial road ▪ 0.4km section of road realignment on approach to an upgraded major intersection ▪ Two roundabout upgrades ▪ Construction of a new bridge over a creek and minor creek realignment ▪ Drainage upgrades ▪ Utility relocations
Sustainability Incentivisation							
Tender Design Mandatory tender requirements for Sustainability	▪ Appointment of a Sustainability Representative (min. 5yr exp.) ▪ Calculate the interim IS 'Design' rating	▪ Calculate interim IS Design Rating ▪ Calculate interim IS As-Built Rating ▪ Nominate Rating / % recycled materials against 24 measurable items	▪ Key Personnel - Sustainability Manager ▪ Calculate IS Design Rating ▪ Preliminary assessment of tender design outcomes on sustainability performance targets	▪ N/A – tender design not required for Early Contractor Involvement bid	▪ No requirement for sustainable design evident in the tender process	▪ No requirement for sustainable design evident in the tender process	▪ ***C73 Request for Tender*** document did not require any sustainability initiatives to be included in the tender (albeit a Documented Design engagement)
Tender Evaluation Price based	▪ Redacted files	▪ Client undertakes assessment of Tenderer's Target Cost and adjust for; conformance, risk, whole of life costs	▪ No evidence of Price evaluation benefit for sustainability initiatives	▪ No evidence of Price evaluation benefit for sustainability initiatives	▪ No evidence of Price evaluation benefit for sustainability initiatives in the Target Outturn Cost	▪ No evidence of Price evaluation benefit for sustainability initiatives in the submitted Price.	▪ No evidence of Price evaluation benefit for sustainability initiatives in the submitted Price.
Tender Evaluation Non-Price based	▪ Redacted files	▪ Volume 4G – demonstrate how Tenderer will achieve workforce development for Sustainability reps ▪ Volume 4H – 15-page response on how Tenderer will achieve or improve on sustainability targets in Appendix D.5	▪ Requirement 3.2B(1) – Tenderer's Design Report containing incorporation of sustainability ▪ Requirement 3.3G – Spoil Disposal Strategy and Management ▪ Requirement 3.5B – Sustainability submissions outlining how the tenderer will achieve the targets	▪ Sub-section of Understanding of Project Requirements focused on 'meeting sustainability objectives'. This provides a general statement that Council will 'consider selection of products or services that maximise sustainability outcomes'	▪ No specific tender returnable schedule focused on Sustainability – actual outcomes achieved during tender or planned activities during delivery	▪ No specific tender returnable schedule focused on Sustainability – actual outcomes achieved during tender or planned activities during delivery	▪ No specific tender returnable schedule focused on Sustainability – actual outcomes achieved during tender or planned activities during delivery

Projects Analysis	Road Tunnelling	Freeway Upgrade	Rail Tunnelling	Regional Road Remediation	Urban Arterial Road Upgrade	Urban State, Regional and Local Road Upgrades	Urban/Rural Arterial Road Upgrade
Delivery Req's Mandatory Sustainability frameworks / processes	**SWTC Appendix D.5 – Sustainability** ▪ Comply with the Delivery Authority sustainability commitments ▪ Register project with ISCA and demonstrate how the IS ratings will be achieved, min = 55 points ▪ Implement and maintain a sustainability assurance framework to track compliance ▪ Develop and maintain a Sustainability Plan ▪ Quarterly sustainability reporting	**SWTC Appendix D.5 – Sustainability** ▪ Comply with sustainability vision and policy detailed in Planning Approval ▪ Register project with ISCA and demonstrate how the IS ratings will be achieved, min = 60 points ▪ Appointment of ISCA accredited professional to the project delivery team ▪ Implement and maintain a sustainability assurance framework to track compliance ▪ Develop and maintain a Sustainability Plan	**Volume 4A – General Specification** ▪ Tunnelling Contractor must ensure sustainability is addressed through the performance of the Project Works ▪ Register project with ISCA and demonstrate how the IS ratings will be achieved, min = 75 points ▪ Participate in sustainability forums hosted by the Principal on a quarterly basis ▪ Develop and maintain a Sustainability Management Plan ▪ Quarterly sustainability reporting **Volume 4B –Particular Specification** ▪ Produce a Sustainable Design Report at completion of Stage 2/3 milestone	▪ Reference to Council's Procurement Policy document.	**Project Brief Appendix C.1 – Plan Req's** ▪ Sustainability Action Plan noting how the non-owner participant (NOP) will manage and meet requirements of Appendix D.2 **Project Brief Appendix D.2 – Enviro Req's** ▪ Construction Sustainability Management Plan (CSMP) developed with consideration of ISC rating tools ▪ CSMP developed to align with client sustainability objectives within client's operating strategy document – Sustainability in Infrastructure Design and Construction ▪ Identification of personnel responsible for developing, implementing and monitoring the CSMP for the Works	**PS201/PS301 Professional Services for Concept/Detailed Design** ▪ Lists one of client's values being 'Solutions' – deliver sustainable, innovative, value for money and fit for purpose solutions to NSW's transport needs. **PS251/PS351 Road Design** ▪ Includes statement that Street Lighting should provide a cost effective and sustainable energy efficient lighting scheme. **PS271/PS371 Drainage Design** ▪ Includes considering the effects of climate change in modelling. **PS361 Structures Design** ▪ Requires proposals for designs to consider aspects relating to sustainability.	**PS301 Professional Services for Detailed Design** ▪ Includes bespoke text regarding Sustainability requirements in delivery. ▪ Overview statement to consider social, environmental and economic matters to ensure the project is consistent with sustainability principles. ▪ Implementation of initiatives described in the REF, submissions and preferred infrastructure reports and from client's operating strategy document. ▪ Sustainability Management Plan to be produced at the outset of Detailed Design to establish project governance related to Sustainability.
Delivery Requirements Climate Change	▪ Climate change risk assessment	▪ Climate change risk assessment	▪ Climate Change Impact Assessment Report in accordance with client's guidelines ▪ Greenhouse Gas Inventory Report	▪ Nothing specific required by the project documents	▪ Defers to client's overarching sustainability objectives ▪ Nothing specific required by the project documents.	▪ PS271/PS371 states the PSC is to undertake flood modelling – issues to be addressed include *"The potential effect arising from climatic change"*	▪ PS301 includes bespoke text regarding Climate Change Risk Assessment in accordance with client's guidelines ▪ Risks to be integrated to project risk register
Delivery Requirements Energy and Carbon	▪ Energy Efficiency and Greenhouse Gas Emissions Strategy and Management Plan ▪ Demonstrate opportunities to maximise operational energy efficiency have been investigated ▪ Demonstrate opportunities to maximise construction energy efficiency have been investigated ▪ Monitor and record energy use during construction	▪ Energy Efficiency and Greenhouse Gas Emissions Strategy and Management Plan ▪ Demonstrate opportunities to maximise operational energy efficiency have been investigated ▪ Demonstrate opportunities to maximise construction energy efficiency have been investigated ▪ Monitor and record energy use	▪ Undertake greenhouse gas assessment and reporting in accordance with client's requirements and using client's tool ▪ Assessments and reports to be provided on a six-monthly basis ▪ Tunnelling Contractor must offset at least 25% of all Scope 1/Scope 2 emissions defined in National Greenhouse and Energy Reporting ▪ Must implement all opportunities for onsite sources of renewable energy which achieve a BCR ≥ 1	▪ Nothing specific required by the project documents	▪ Nothing specific required by the project documents	▪ Nothing specific required by the project documents	▪ Nothing specific required by the project documents
Delivery Requirements Materials and Waste	▪ Demonstrate opportunities to reduce material use have been investigated ▪ 100% of all timber products to be reused/recycled timber products ▪ Quantity monitoring – material use, waste, recycled	▪ Demonstrate opportunities to reduce material use have been investigated ▪ 100% of all timber products to be reused/recycled timber products ▪ Quantity monitoring – material use, waste, recycled	▪ Identify and implement waste minimisation tactics and material selection strategies to minimise embodied carbon ▪ At least 95% of inert and non-hazardous construction waste (excl. spoil) and 60% of office waste is recycled/reused ▪ Use compostable/reusable temp erosion control devices where practicable ▪ Undertake life-cycle assessment in accordance with ISO 14044 in selection of low-impact materials ▪ Demonstrate a minimum 15% reduction (against BAU case) in environmental footprint of the materials used ▪ Reduce material use through avoidance/reduction strategies from design refinement, construction planning and methodology	▪ Nothing specific required by the project documents	▪ Reuse on site or recycle off site a minimum of 90% of usable spoil ▪ Reuse on site or recycle off site a minimum of 85% of construction and demolition generated materials ▪ Monitor waste management, take-back, and recycling during construction and report to Principal during reporting	▪ Standard clauses for Whole of Life assessment in decision making of pavement selection.	▪ Standard clauses for Whole of Life assessment in decision making of pavement selection.

Projects Analysis	Road Tunnelling	Freeway Upgrade	Rail Tunnelling	Regional Road Remediation	Urban Arterial Road Upgrade	Urban State, Regional and Local Road Upgrades	Urban/Rural Arterial Road Upgrade
Delivery Requirements Water Efficiency	▪ Undertake water balance study to estimate quantities of potable/non-potable water use ▪ Demonstrate opportunities to reduce water use have been investigated ▪ Quantity monitoring – water use, water reuse, treatment, harvesting	▪ Undertake water balance study to estimate quantities of potable/non-potable water use ▪ Demonstrate opportunities to reduce water use have been investigated ▪ Quantity monitoring – water use, water reuse, treatment, harvesting	▪ Undertake water balance study to estimate quantities of potable/non-potable water use ▪ Meter water supplied for construction from both recycled water networks and potable sources and report against targets in the specifications	▪ Nothing specific required by the project documents	▪ Source at least 15% of non-potable water use from non-potable sources	▪ Nothing specific required by the project documents	▪ Nothing specific required by the project documents
Delivery Requirements Biodiversity Conservation	▪ Nothing specific required by the project documents	▪ Nothing specific required by the project documents	▪ Tunnelling Contractor must identify and implement initiatives for biodiversity enhancement and habitat connectivity ▪ Minimise clearing of vegetation, particularly native vegetation ▪ Undertake landscaping and revegetation as soon as possible	▪ Nothing specific required by the project documents	▪ Prepare a Flora and Fauna management sub-plan in accordance with client's quality assurance and environmental specification	▪ Nothing specific required by the project documents. ▪ PS211/311 Environmental Design and Compliance not provided as part of the project specifications	▪ Sensitive Area Mapping to identify threatened species and areas of biodiversity conservation significance. ▪ Water quality management to avoid impact on sensitive threated species habitat, EECs, or other identified areas of biodiversity conservation significance.
Summary							
Positives	▪ Mandatory to adopt a specific framework for sustainability ▪ Quantitative minimum targets prescribed in Appendix D.5 ▪ Monitoring of successful implementation of framework via quarterly reports ▪ Quantitative demonstration of efficiency in Materials and Waste management, Energy and Carbon and Water use - specific and measurable. ▪ The delivery authorities Sustainability Policy outlines the value areas and specific objectives relating to four pillars – People, Planet, Places and Partnerships.	▪ Mandatory to adopt a specific framework for sustainability ▪ Quantitative minimum targets prescribed in Appendix D.5 ▪ Appointment of a suitably qualified person to fulfill the role of compliance with the Sustainability Management Plan ▪ Independent sustainability review ▪ Quantitative demonstration of efficiency in Materials and Waste management, Energy and Carbon and Water use - specific and measurable.	▪ Mandatory to adopt a specific framework for sustainability ▪ Quantitative minimum targets prescribed in returnable schedule 3.5B and submission (could motivate design change during tender) ▪ Nomination of Sustainability Manager in Key Personnel for tender evaluation ▪ Quantitative demonstration of efficiency in Materials and Waste management, Energy and Carbon and Water use - specific and measurable.	▪ Tender returnable schedules afforded space for a response to sustainability objectives	▪ Sustainability Action Plan is required for the delivery phase of the project. ▪ Some quantitative targets listed in Appendix D.2 ▪ Representative to be nominated and responsible for implementation of CSMP during delivery. ▪ Reporting on outcomes from actual achieved site outcomes required	▪ Design to consider the effects of climate change included in flooding/drainage.	▪ Design to consider the effects of climate change included in flooding/drainage. ▪ Bespoke requirements for a Sustainability Management Plan added to the standard template specification. ▪ Climate change risk assessment to feed into the overall project risk register for visibility and traceability.
Areas for improvement	▪ Behaviours of IS rating tool will be to meet the target of the tender design, not necessarily better it, i.e., innovation stops at award ▪ Price based evaluation of embodied carbon/emissions	▪ Behaviours of IS rating tool will be to meet the target of the tender design, not necessarily better it, i.e., innovation stops at award ▪ Price based evaluation of embodied carbon/emissions	▪ Price based evaluation of embodied carbon/emissions	▪ Price based evaluation of embodied carbon/emissions ▪ Tender evaluation could include a specific sustainability focused returnable schedule ▪ Delivery phase obligations are vague and do not follow a framework for implementation	▪ Alliance model afforded the opportunity to include sustainability focused key result areas; however, only tree impacts were included ▪ No sustainability management plan required in tender submission ▪ Quantitative assessment of achieved outcomes not required during tender phase which does not provide for comparable assessment between tenderers ▪ Key Personnel to include Sustainability focused role for tender assessment	▪ Documented Design procurement method did not require construction management plan development during tender or during detailed design. There could be some up-front planning placed on the designer related to materials, water use, energy and carbon. ▪ Price based evaluation of embodied carbon/emissions ▪ Non-price evaluation of strategies to be undertaken by the PSC during the concept and detailed design. ▪ Include mandatory requirement for implementation of a sustainability framework during design development.	▪ Price based evaluation of embodied carbon/emissions ▪ Non-price evaluation of strategies to be undertaken by the PSC during the concept and detailed design. ▪ Include mandatory requirement for implementation of a sustainability framework during design development.

3.4 Overview of past projects

3.4.1 Project size and procurement contract type

It is apparent from the synopsis provided in Table 2, that for DD&C projects with significant CAPEX (+$1B), more rigour in the sustainability requirements were established. Commonly, the Infrastructure Sustainability Council (ISC) framework was referenced in all three projects and similar bid phase and delivery phase responsibilities were placed directly on the Contractor, and therefore, indirectly on the Designer.

The smaller projects reviewed (<$1B) did not mandate the implementation of a specific sustainability framework such as ISC. Some initiative was taken in the development of the delivery documents to include a Sustainability Action Plan and climate change risk assessment in the tender returnables. Mandatory requirements for sustainable delivery were scarcely included in the documents, and the inclusion lacked specificity and ability to measure performance objectively.

The Alliance project model affords a great opportunity to include a Key Result Area around sustainable delivery, and a contractual model that would facilitate the collaboration to achieve these goals, but the sample project did not grasp this opportunity. However, the delivery requirements did include sustainability management and governance, a plus for this example.

3.4.2 Positive observations

Where a special purpose Delivery Authority was formed for project delivery an enhanced focus on Sustainability was evident through a project specific Sustainability Policy. This outlined overarching objectives across four pillars – People, Planet, Places and Partnerships. This document provided a high-level vision for project sustainability outcomes and reinforced them as important objectives determining project success.

Tender documents that specified a mandatory framework/policy for sustainable delivery avoid subjectivity for tenderers in what the intended requirements are.

Establishing suitable project governance for sustainability was done well on the DD&C projects, requiring commitments to be documented through processes in the management plan and established at the outset of the project. Project performance updates for sustainability outcomes were also mandatory in quarterly reporting which avoids a 'set and forget' mentality and fosters continual monitoring and improvement.

3.4.3 Potential improvements

Setting some measurable targets on a variety of key sustainability criteria is a good strategy for compliance. However, the challenge is to work away from a pass/fail process and instead look to maximise the achieved outcomes by setting acceptable and desirable targets.

It was very rare for tender evaluation criteria to include non-price submissions. If tender returnable schedules requested this, the opportunity would arise for the tender submission to be assessed on its sustainability impacts.

There was no evidence of sustainability outcomes being financially estimated and included in the project Price. For example, a quantitative assessment of embodied carbon / emissions of the project could be used to determine a project cost reduction if outcomes were positive against a baseline, or conversely cost added as a penalty if outcomes were negative against a baseline.

3.5 Key Learnings for Sustainable Procurement

The cross-section of the sample projects and their RFT Documents has highlighted some positive observations and areas for improvement. Table 3 provides a summary of actions that could be undertaken in the development of RFT packages, and some potential benefits that could be realised from these strategies.

Table 3: Observations and improvements for project procurement documentation

Observation	Advice to Improve	Potential Benefits
Tender design development *All projects lacked incentives for improving sustainability outcomes during the tender design stage*	▪ Require tenderers to undertake a baseline assessment of key sustainability impacts of the project – embodied carbon, emissions etc. ▪ Include mandatory requirement for tenderers to challenge the Reference Design for improved sustainability outcomes on the project. ▪ Procuring Agency to have established the base case for the project and communicate this to Tenderers within the RFT documents.	▪ Estimate of the project sustainability impacts sets the baseline. ▪ Tenderers incentivised to implement changes during competitive tendering – additional motivation. ▪ Client ownership of IP results in collection of all ideas to be passed on to the awarded contractor for the next stage. ▪ Less resistance to change and contract variation by implementing design changes prior to award.
Tender Evaluation – Non-price *Rarely did the tender documents include a non-price submission on Sustainability*	▪ Include non-price evaluation tender returnable on the proposed approach to project delivery – who, when, what initiatives will you undertake? ▪ Establish minimum and desirable criteria covering specific elements of Sustainability – Key Personnel experience, Climate Change, Energy and Carbon, Materials and Waste, Water Efficiency, Biodiversity.	▪ Planning and commitment for the requirements are established during the bid phase. ▪ Key roles related to sustainability requirements are fulfilled. ▪ Tenderer striving for best possible project outcomes against the criteria during competitive process. ▪ Evaluation of preferred tenderer is weighted by sustainability performance.
Tender Evaluation – Price *No projects included Price criteria related to Sustainability (penalty or bonus)*	▪ Include an assessment of emissions or embodied carbon in the tenderer's Price as a credit or penalty on the bottom-line Price. ▪ Incentive payment for delivery team for the achievement of sustainability key performance indicators.	▪ Price is typically a heavily weighted evaluation criterion. Providing a monetary bonus/tax on the Price will further drive the Tenderer to make concerted effort against Sustainability outcomes. ▪ Tangible result for delivery team.
Project Delivery *Projects referencing a specific Sustainability framework are less subjective and more rigorous*	▪ The procuring agency should decide on a specific sustainability framework to include in the project delivery phase. ▪ Sustainability planning and governance should be mandatory on all projects. ▪ Specific and measurable targets for sustainability across variety of project elements in the control of the Contractor should be included. ▪ Project delivery should include independent verification of achieved outcomes.	▪ Leaning on a developed framework will provide industry familiarisation and experience with a set process – over time reducing the cost to include. ▪ Frameworks are more specific in the process, quantification, inclusions/exclusions and will boost consistency when undertaken by multiple tenderers. ▪ Establishing governance for how the project will plan, execute, monitor, adjust and record outcomes enforces continued input and improvement. ▪ Setting measurable criteria will showcase project performance in transparent manner. ▪ Independent verification of results will aid in removing subjectivity of measurements for any quantitative calculations or qualitative statements.

4 Principles for Developing a Sustainability in Design Framework

4.1 Adoption of a framework

Survey results suggest that there is high level of interest in using a Sustainability Framework within industry, with over 90% of respondents indicating that they would use such comparison framework or review its results.

Ease of use in terms of simplicity and flexibility was indicated as the key factor that would incentivise practitioners to use such framework, followed by client requirements (refer Figure 12).

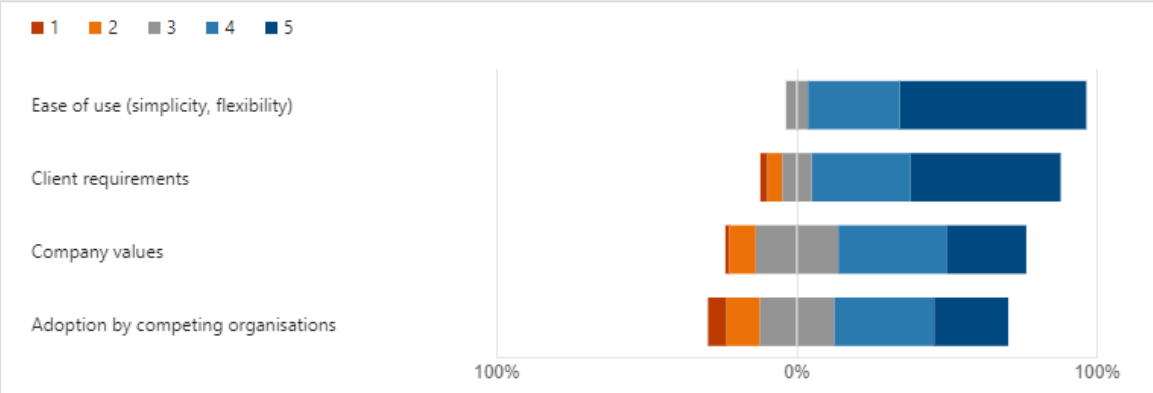


Figure 12: Relative importance of factors that would incentivise practitioners to use the design options comparison framework (1 = least important; 5 = most important)

Note: The chart shows percentage of respondents that indicated a particular level of importance for each of the indicated criteria (e.g., ease of use was scored 5 by 62% of respondents, 4 – by 31% and 3 – by 7%)

There are many existing frameworks for measuring sustainability and agencies are adopting inconsistent approaches to sustainability, as observed in Section 3. Procuring agencies need to take ownership and provide the regulation to standardise the process and drive adoption. Businesses are unlikely to commit resources to learning and adopting a framework if there is no certainty around the approach being adopted by their clients.

4.2 Integrating sustainability at earlier project stages

A key issue identified in the infrastructure sector on the pathway to better sustainability and incentivisation is that most of the embodied carbon from constructing a project is determined during the early planning and design phases of the project (Infrastructure Partnerships Australia, 2022). To have the largest impact, sustainability considerations therefore need to be integrated as early as possible in the infrastructure project lifecycle.

As we saw in Figure 11, the ability to influence outcomes diminishes through the project lifecycle. The survey conducted as part of this research project indicated that sustainability received greater consideration in the later design stages, being 10% higher for the detailed design stage compared to the strategic design stage (see Figure 13). There is room to improve the timing of sustainability considerations during the design and planning stage and front-loading more work to the earlier project lifecycle stages.

However, a barrier to undertaking sustainability impact assessments earlier in the design and planning stage is the less matured design and construction understanding. Therefore, the framework would need to include flexibility for what is considered at any given time of assessment, based on the best available information at the time of conducting. As an example, when undertaking a Sustainability in Design assessment of a strategic design pavement option, the construction duration may be unknown.

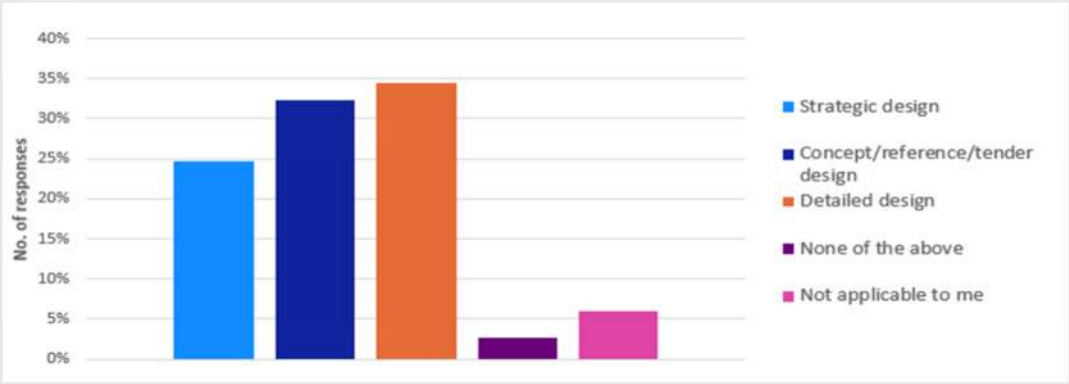


Figure 13: Number of respondents that consider sustainability during the various stages of the design process

4.2.1 Barriers to decarbonisation of construction materials at different lifecycle stages

There are several different levels at which carbon needs to be considered and abatement measures taken, starting from the policy arena outside of any individual project, moving through project planning, to design and construction. Much can be done before the actual construction phase is initiated. Reducing capital carbon requires involvement from different stakeholders on different levels, both on an overarching societal level to change behaviour and to set the framework and rulebook for the transport industry, and within each project to implement the changes.

Figure 14 shows an indicative systems diagram on how to consider decarbonisation through the project life cycle. The diagram identifies some of the existing barriers the construction industry currently faces in driving embodied carbon that should be the delivery focus of transport infrastructure projects. These are discussed in Table 4 below.

Table 4: Barriers to decarbonization of construction materials during lifecycle stages

Lifecycle Stage	Barrier	Discussion
Project conception	Capital Expenditure	▪ CAPEX is often at the top of the priorities when major infrastructure projects are being planned and financed, particularly when funded through government. ▪ As low-carbon practices become business-as-usual, the cost to sustainably deliver infrastructure projects will reduce – knowledge will be wider spread; materials will be manufactured more efficiently at a larger scale; and construction methodologies will be tried and tested.
Pre-design	Conservatism	▪ Sticking to what is known is a well-recognised barrier to change. ▪ Engineers (including construction teams) can be risk-averse which can lead to a reluctance to consider alternative materials and methods. This approach, in addition to keeping costs low, stifles innovation.
Tender Stage and Design Development	Procurement Practices	▪ Procurement policies, practices and models are recycled without uptake of innovations. ▪ Probity issues during competitive tendering can also prevent collaboration between suppliers, designers and clients prior to award, becoming difficult to adjust in delivery as the contract and particulars have been agreed.
Value Engineering	Inertia	▪ Value Engineering essentially challenges the current solution, inadvertently leading to additional effort and delay. ▪ Resistance to change is often encountered as program delay from loss of inertia is perceived as too high of a risk.
Final Design and Construction	Site Practices and Skills	▪ Skill levels of the major infrastructure delivery teams can prevent change due to a preference for what is known and can be done easily. ▪ Identifying, implementing, and testing new materials, changing practices and up-skilling takes time and money.

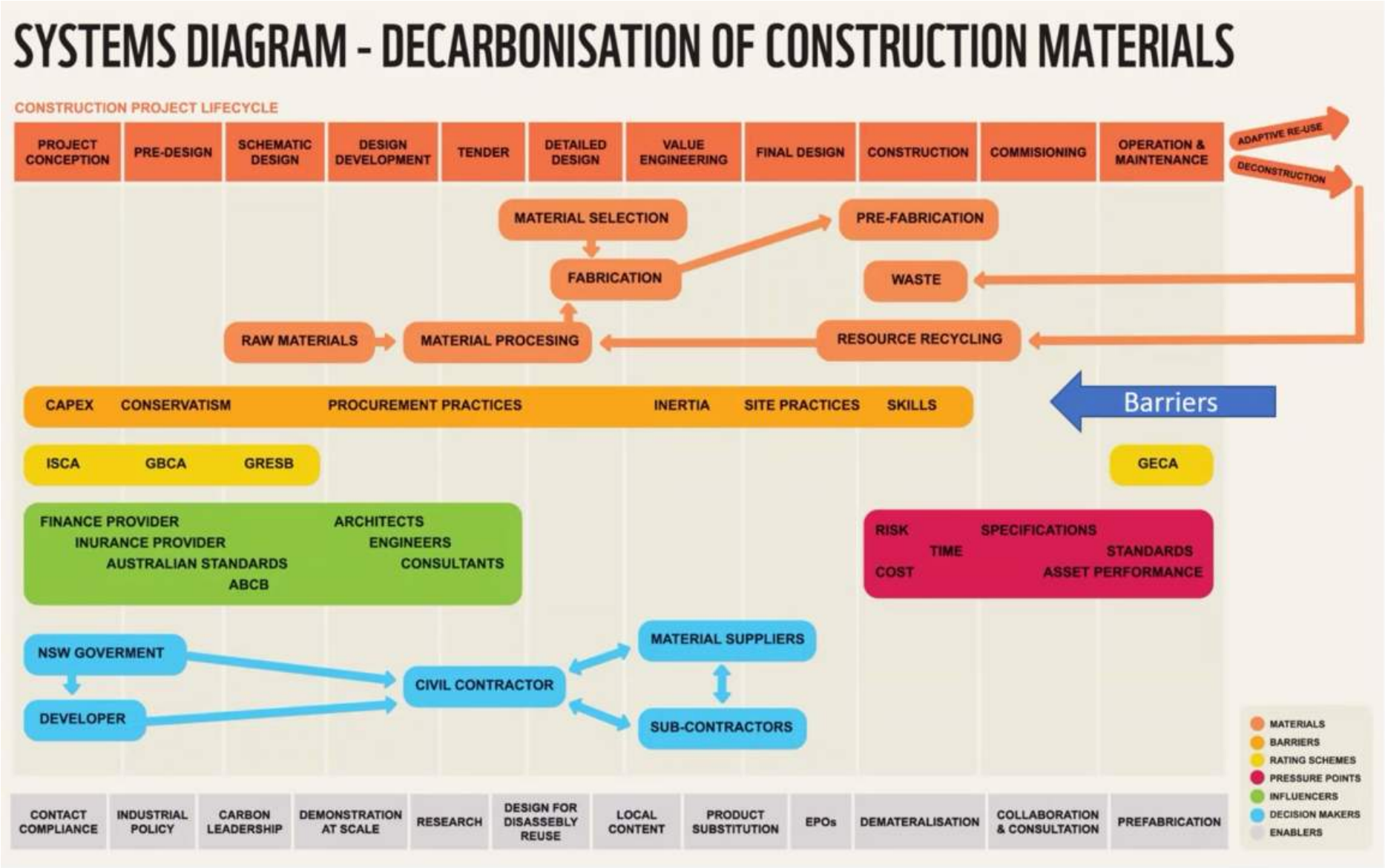


Figure 14: Systems diagram on how to consider decarbonization in the project life cycle (MECLA, 2022))

4.3 Dimensions of sustainability

Sustainability is often divided into three key aspects or dimensions – environmental, social and economic (Ben Purvis, 2019).

Current discussions in the industry in response to climate change have a strong focus on decarbonisation and achieving net zero.

Feedback from industry showcases the importance for a "best practice" sustainability framework to take a broader approach, beyond decarbonisation. The majority of the respondents also consider social and financial dimensions very important or essential (see Figure 15).

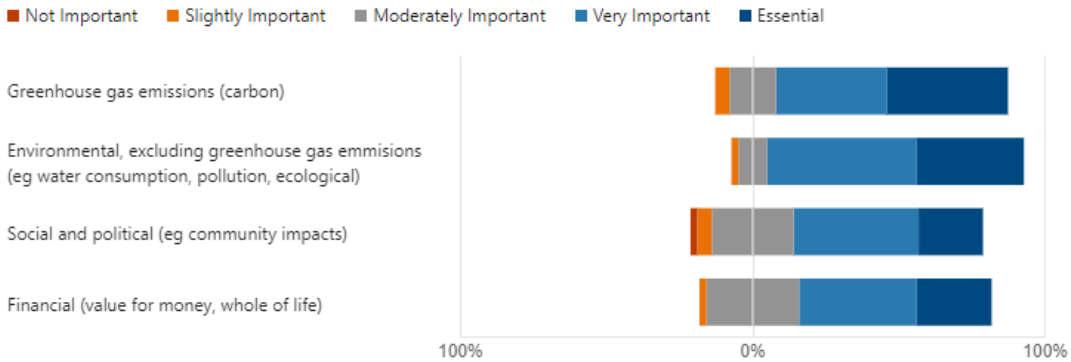


Figure 15: Relative importance of various sustainability factors

While greenhouse gases and carbon are relatively straightforward to measure, broader environmental impacts and the social and financial dimensions can be more subjective.

Frameworks such as ISO 21931-2:2019 provide an example of indicators that can be used for quantitative assessment of the environmental, social and economic impacts of construction projects, as per Table 5.

Table 5: Indicators for sustainability dimensions and their unit of measure (ISO/DIS 21931-2:2019, 2019)

Dimension	Category	Indicators (core set)	Unit of measure
Environmental	Acidification	Acidification potential (AP)	mol H^+ eq
	Biodiversity	Eco-toxicity (freshwater) Potential soil quality index (SQP)	CTUe Dimensionless
	Climate change (total)	Global warming potential total (GWP-total) (fossil + biogenic + land use and land use change)	Kg CO_2 eq
	Depletion of abiotic resources – minerals & metals	Abiotic depletion potential for non-fossil resources (ADPE)	kg Sb eq
	Depletion of abiotic resources – fossil fuels	Abiotic depletion potential for fossil resources (ADPF)	MJ, net calorific value
	Eutrophication	Eutrophication potential (EP – freshwater) Eutrophication potential (EP – marine) Eutrophication potential (EP – terrestrial)	kg P eq kg N eq kg N eq mol N eq
	Ozone depletion	Ozone depletion potential (ODP)	kg CFC 11 eq
	Photochemical ozone creation	Photochemical ozone creation potential (POCP)	kg NMVOC eq
Social	Health and comfort	Ionizing radiation, human health (PIR)	KBq U235 eq
		Human toxicity, cancer effects (HTP c)	CTUh
		Human toxicity, non-cancer effects (HTP nc)	CTUh
		Particulate matter emissions (PM)	Disease incidence
		Water use deprivation potential (WDP)	m^3 world deprived eq
Economic	Life cycle economic balance	Direct life cycle costs (LCC) and incomes	e.g., Euro
	External cost	Environmental externalities	e.g., Euro

4.4 Measuring relevant outcomes

4.4.1 Principles for quantification

To reduce the impact the transport industry has on climate change, all planning and asset management decisions regarding transport networks should include consideration of whole-of-life emissions. Where possible, the lowest emission option should be preferred. Options that should be considered include:

- Planning and designing of infrastructure and services to estimate the total emissions for each option in construction and operation and preference given to the least emitting.
- Modification and reusing existing infrastructure or recycle materials from replaced assets, in preference to demolition of existing assets and/or new materials.
- Substitution of long-life (e.g., stone), recycled (e.g., tyre rubber) or renewable (e.g., plant-based) materials for disposable or fossil fuel-based materials (e.g., plastics).
- Designing infrastructure with unavoidably high embodied energy to have a longer service life, minimising waste.
- Adopting a policy of no net increase in emissions in new construction. This may be achieved by means such as revegetation, renewable power and purchase of carbon offsets.

ISO 21930:2017 Sustainability in buildings and civil engineering works is an international standard that adopts lifecycle stages aligned with EN15804 Environmental Protection Declaration (EPD). The quantitative assessment of embodied carbon can consider some or all of these stages in the assessment. Determination of the right balance of effort for outcome is difficult; however, more emphasis and detail should be placed on lifecycle stages with the biggest impact to the overall outcome.

Table 6: Lifecycle stages from ISO21930:2017

Lifecycle Stage	ISO 21930:2017 lifecycle stage
Extraction and production *Product Stage*	▪ A1 – Extraction and upstream production (virgin materials and sourcing of recycled materials) ▪ A2 – Transport (to asphalt or manufacturing plant) ▪ A3 – Manufacturing (production processes)
Construction *Construction Stage*	▪ A5 – Construction-installation process (mixing and placement) ▪ C1 – De-construction/demolition (optional removal of existing pavement in preconstruction)
Maintenance *Use Stage*	▪ B2 – Maintenance (routine) ▪ B3 – Repair (periodic) ▪ B4 – Replacement (rehabilitation) ▪ B5 – Refurbishment (resurfacing) ▪ C1 – De-construction demolition (optional layer removal)
End of life	▪ C1 – De-construction demolition (optional) ▪ C3 – Waste processing (applicable only for in-situ reuse) ▪ C4 – Disposal
Transportation/ haulage *Construction + End of Life*	▪ A4 – Transport (materials to site) ▪ C2 – Transport to waste processing (including recycling facilities) or disposal
Use (traffic)	▪ B1 – Use (traffic) ▪ B6 – Operational energy use (not applicable) ▪ B7 – Operational water use (not applicable)

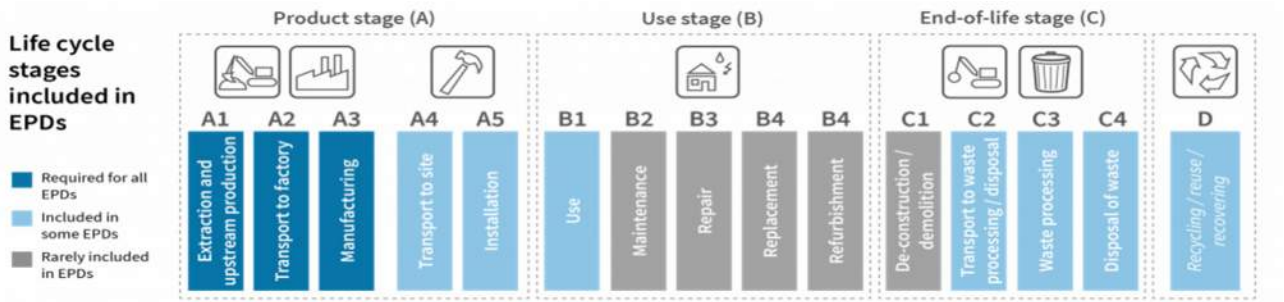


Figure 16: Lifecycle stages from ISO21930 represented graphically (Carbon Leadership Forum, 2020)

4.4.2 Measuring embodied carbon

One of the commonly used methods to quantify greenhouse gas emissions or embodied carbon is the use of emissions factors. A first-principles buildup of the total embodied carbon can be conducted by quantifying the activities, e.g., distance of haulage from quarry to site, and materials, e.g., kg of sand. This approach extrapolated across the lifecycle stages of the project and the 'sum of all parts', will provide an estimate of total embodied carbon.

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).
(United States Environmental Protection Authority, 2022)

-/unit		kg CO_2 equivalents	kg CFC-11 equivalents	kg SO_2 equivalents	kg PO_4^{3-} equivalents	kg C_2H_4 equivalents	kg SB equivalents	MJ surplus
	Name							
0.00E+00	Asphalt (RAP), applied as base, aggregate or fill material	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.78E-01	Ballast	9.52E+00	2.34E-07	1.44E-02	3.33E-03	8.56E-04	1.29E-06	1.11E+02
3.72E-01	Crushed Blast Furnace Slag	1.80E+01	2.45E-07	6.26E-02	5.56E-03	1.35E-02	8.66E-07	2.33E+02
4.56E-02	Crushed Limestone	2.20E+00	2.25E-07	2.43E-02	5.62E-03	2.58E-03	4.85E-08	2.85E+01
1.78E-01	Crushed Rock	9.52E+00	2.34E-07	1.44E-02	3.33E-03	8.56E-04	1.29E-06	1.11E+02
0.00E+00	General Fill	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.69E-02	Gravel (DGB/DGS)	5.04E+00	2.06E-07	7.98E-03	1.69E-03	6.20E-04	5.87E-07	6.06E+01
7.84E-02	Recycled Crushed Concrete/Masonry	3.70E+00	3.60E-07	6.80E-03	1.04E-03	7.98E-04	8.98E-07	4.90E+01
9.90E-02	Recycled Crushed Glass	5.13E+00	2.44E-07	1.39E-02	3.18E-03	2.17E-03	2.83E-09	6.18E+01
7.53E-02	Sand	3.84E+00	1.98E-07	6.27E-03	1.25E-03	5.57E-04	3.99E-07	4.71E+01
7.44E+01	Bitumen	3.84E+02	4.33E-04	4.85E+00	4.89E-01	7.25E-01	3.28E-06	4.65E+04
4.65E+00	Downer Reconophalt AC10 C320 R10	6.52E+01	2.31E-05	3.39E-01	5.02E-02	2.09E-02	8.46E-05	2.91E+03
3.83E+00	Downer Reconophalt AC10 C320 R30	5.52E+01	1.86E-05	2.71E-01	3.98E-02	1.69E-02	6.45E-05	2.40E+03
2.93E+00	Downer Reconophalt AC14 C170 R50	4.58E+01	1.35E-05	1.99E-01	2.97E-02	1.27E-02	4.96E-05	1.83E+03
7.22E+01	Foam bitumen (3% water)	3.73E+02	4.20E-04	4.70E+00	4.74E-01	7.03E-01	3.18E-06	4.51E+04

Figure 17: Example of emissions factors sourced from ALCAS for various construction materials (Arcadis, 2022)

Through reviewing available literature on this topic, we identified the following sources of emission factors exist, noting there may be others.

- The Transport Authorities Greenhouse Group (TAGG) published "Greenhouse Gas Assessment Workbook for Road Projects" which lists emission factors used to estimate greenhouse gas emissions from road projects (Transport Authorities Greenhouse Group, 2013).
- Australian Life Cycle Assessment Society (ALCAS) has released emission factors specifically for the construction sector (ALCAS, n.d.).
- Environmental Product Declarations (Australasia EPD, 2022).
- National Greenhouse Accounts (NGA) Factors (Australian Government Department of Climate Change, Energy, the Environment and Water, 2021).

To report on emissions reduction progress, infrastructure asset emissions are quantified by using an inventory of emissions sources. The methods used to estimate emissions are constantly improving over time as new information and estimation techniques emerge. Further, a multitude of approaches to calculating infrastructure asset emissions exist, leading to varied approaches across industry.

5 Existing Sustainability Frameworks

5.1 Nationwide Agency Approaches

Further research was conducted into the nationwide industry approaches to Sustainability in Design. As tabulated below, we found that various state agencies have developed their own approaches.

Table 7: Agency approaches to Sustainability in Design

Agency	Approach
Transport for New South Wales (TfNSW)	A TfNSW project must either demonstrate achieving a TfNSW Sustainable Design Guideline rating or an Infrastructure Sustainability Council rating
Queensland Department of Transport and Main Roads (TMR) & Main Roads Western Australia (MRWA)	Sustainability Assessment Tool (NACOE, 2022) can be used for the assessment of innovative pavements
VicRoads	Greenhouse Emissions Assessment Methodology for Road Construction, CarbonGauge Tool (VicRoads, 2022)
Department of Infrastructure and Transport South Australia	Infrastructure Sustainability Council rating (Department of Infrastructure and Transport South Australia, 2020)

"There are no national frameworks or methodologies currently being used across all states that comprehensively cover all stages of an asset's lifecycle which also include mechanisms to assess social, environmental, cultural and carbon impacts to improve decision making."

(KPMG, Roads Australia, Australasian Railway Association, Infrastructure Sustainability Council, ARUP, 2022)

5.2 Lifecycle Stage Approaches

The approach to setting the system boundaries (scope of the assessment) on quantification of embodied carbon and greenhouse gas emissions for transport infrastructure assets was found to vary across industry. The system boundaries for the operations, maintenance and decommissioning phases of an asset lifecycle are not consistently considered. This could lead to loss of comparability of results as the project evolves, affecting confidence in understanding whether improvements were achieved in the project when assessed against the baseline. For example, if 'Framework A' does not account for material recycling achieved through demolition and decommissioning of an asset at the end of its life, it could appear to have worse outcomes than if assessed using 'Framework B', one that does account for the decommissioning phase.

Some of the existing methodologies implemented at various lifecycle stages of transport infrastructure projects are summarised in Table 8.

Table 8: Tools for sustainability throughout project lifecycle phases

Project Lifecycle	Sustainability Frameworks
Planning	▪ Infrastructure Sustainability Council's Planning Tool ▪ TfNSW Carbon Estimate Reporting Tool ▪ Infrastructure Australia's Assessment Framework (Infrastructure Australia, 2022)
Design and Construction	▪ Infrastructure Sustainability Council's Design and As-Built rating ▪ The Material Circularity Indicator (MCI) tool (Ellen Macarthur Foundation, 2022) ▪ Green Star – Design & Asbuilt (Green Building Council Australia, 2022) ▪ TfNSW Sustainable Design Guidelines Version 4.0 (TfNSW, 2022) ▪ TfNSW Carbon Estimate Reporting Tool ▪ Transport Authorities Greenhouse Group – Greenhouse Gas Assessment for Road Projects
Operation	▪ NABERS ▪ Infrastructure Sustainability Council's Operations rating
All Stages ▪ Planning ▪ Design and Construction ▪ Operation ▪ Decommissioning	▪ Life Cycle Assessment as outlined in ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines ▪ Pavements – Sustainability Assessment Tool (NACOE, 2022)

The Sustainability Assessment Tool used by Queensland Department of Transport and Main Roads includes all lifecycle phases in the sustainability assessment. The tool developed also included a toggleable option to add/omit the **use phase emissions** since this aspect dominates the outcomes, and in order to make judgement decisions on pavement options, it needed the ability to separate these emissions out from the overall total.

5.3 Review of Existing Sustainability Frameworks

Following the results of the survey in Section 2, and the principles discussed in Section 4, our group has undertaken an analysis of the most prominent frameworks encountered within the transport industry. Our objective was to identify the advantages and disadvantages of each framework to make recommendations for a hybrid approach that could be termed the 'Ideal Framework'.

In addition to the prominent frameworks in the public domain we have leaned on group representatives from Arcadis and WSP to showcase the sustainability workflow applied within each company. These have been included in the review to uncover any specific innovations that may be transferrable.

This analysis is documented within Table 9 overleaf.

Table 9: Analysis of sustainability frameworks used in transport industry

Item	Assessment Points	Arcadis Framework	WSP Framework	IS Design/As-built	Green Star (NABERS rates the effectiveness of the operation of the building)	NACOE Sustainability Assessment Tool (SAT)	TfNSW Sustainable Design Guidelines
1	*What are the particular barriers to the adoption of this framework by Industry?*	▪ At this point, end of life is not considered in the calculations as there are too many unknowns and the benefits could be over-represented if they're also calculated in the construction of the next project ▪ Some components are still in development	▪ Further development and implementation of in-house tools for measurement, i.e., WSP decarbonisation app, DAISY tool (only structures) ▪ Aligning decarbonisation tools with external tool use (training and skills plans) ▪ Aligning carbon and cost tools to enable robust quantitative assessments, i.e., integrated with digital engineering delivery methods	▪ Third party review period of 3 months duration before knowing final rating score. ▪ Registration fees ▪ Requires a full-time staff member on the project to be dedicated to developing the base case and collating data for the as-built, this person must be an IS Accredited Professional (ISAP) ▪ The Design rating is undertaken at the completion of project design.	▪ Only applies to buildings ▪ Green Star submissions are reviewed by an independent panel of sustainable development experts and an overall score is assigned ▪ The assessment and certification fees are linked to the value of the project	▪ The SAT is in pilot project testing phase, so is currently only available for TMR, MRWA and ARRB staff to use.	▪ Online tool is currently under development which will provide a platform for projects to report on the guideline's performance. This is currently being managed through an excel based checklist ▪ Construction GHG emissions and Sustainable procurement are only considered at Detail Design and Construction phases
2	*Is the framework targeting State, National or International audiences?*	▪ International	▪ International	▪ Australia ▪ New Zealand	▪ National	▪ Western Australia ▪ Queensland	▪ New South Wales
3	*What standards do the embodied carbon calculations rely upon?*	▪ EN15978 modules ▪ ALCAS (Australian Life Cycle Assessment Society) ▪ ECI (Environmental Cost Indicator) developed in the Netherlands, taking into account 15 different impact categories ▪ LCC (Life Cycle Cost) – Austroads Guide to Pavement Technology Part 5, 2019	▪ PAS 2080: Carbon Management in Infrastructure (UK British Standards) ▪ TfNSW Carbon Estimate and Reporting Tool Guidelines	▪ Environmental Product Declarations registered with EPD Australasia complying with the EN 15804:2012+A1:2013 standard ▪ Australian National Life Cycle Inventory Database (AusLCI) ▪ The AusLCI "shadow database"	▪ LCA (Life Cycle Assessment) calculator in excel format. Available to subscribed members. ▪ ALCAS (Australian Life Cycle Assessment Society) ▪ EN15804 modules (EPDs) ▪ EN15978 modules	▪ Infrastructure Sustainability Enviropoints	▪ AusLCI ▪ NGA 2016 ▪ TAGG 2013 ▪ EPDs
4	*What infrastructure assets does the framework cover?*	▪ Transport (roads), specifically pavements	▪ Advisory and Digital ▪ Earth & Environment ▪ Property & Buildings ▪ Mining & Energy ▪ Transport (roads, rail, structures/ bridges, maritime, aviation) ▪ Water	▪ Airports, Energy, Ports, Rail, Road, Social, Waste, Water, Telecommunications	▪ Buildings and community projects	▪ Innovative pavement materials, designs and processes e.g., recycled pavements, crumb rubber asphalt, warm mixes and in-situ stabilization.	▪ All NSW Projects, dependent on the Capex and non-Capex related thresholds, which determines which of the compulsory requirements needs to be applied.
5	*Does the framework consider other sustainability elements, not just embodied carbon? If yes, what are the sustainability elements that are covered by the framework?*	Yes. The framework includes assessment across four aspects: ▪ Environmental ▪ Social ▪ Political ▪ Financial	Yes. The framework focuses on four Future Ready pillars and includes: ▪ Climate: hotter & dryer, coastal risks; net zero & beyond; more extreme events; climate risk disclosure & litigation ▪ Society: diverse & divided; indigenous influence; focus on health; local places; access for all ▪ Technology: automation & digital augmentation; networked world; data, transparency & cyber security; digital expectations; new mobility ▪ Resources: supply chains under stress; human capital & skills; valuing natural capital; the energy transition; circular economy and water scarcity	Yes. The framework includes assessment across four aspects: ▪ Governance ▪ Economic ▪ Environment ▪ Social	Yes. There are 6 calculators in the rating tool. These are: ▪ Responsible Products credits ▪ Upfront carbon emissions ▪ Energy ▪ Water use ▪ Life cycle impacts ▪ Movement and place	Enables a comparative assessment of traditional and innovative pavement designs in terms of lifecycle greenhouse gas emissions and economics. ▪ Sustainability outputs ▪ Lifecycle greenhouse gas emissions ▪ Other air-pollutants ▪ Energy use ▪ Water use ▪ Material quantities (tonnes) ▪ Infrastructure Sustainability EnviroPoints ▪ Economic outputs o Costs ($Net Present Value) o Benefit-Cost Ratio (BCR)	Yes. The guidelines cover the following sustainability themes: ▪ Energy and greenhouse ▪ Climate resilience ▪ Materials and waste ▪ Water ▪ Pollution control ▪ Biodiversity ▪ Community benefit The guidelines apply to the whole asset lifecycle and include compulsory requirements which address the following project lifecycle stages: feasibility, design, construction, operations, maintenance and disposal.

Item	Assessment Points	Arcadis Framework	WSP Framework	IS Design/As-built	Green Star (NABERS rates the effectiveness of the operation of the building)	NACOE Sustainability Assessment Tool (SAT)	TfNSW Sustainable Design Guidelines
6	*What tools does the framework implement?*	▪ Pavement Maintenance Diary spreadsheet which is used to determine and confirm the Maintenance requirements ▪ Calculator Inventory that includes the coefficient database from ALCAS (Australian Life Cycle Assessment Society) ▪ Iconography used on drawings to show the measured sustainability associated with the product	▪ Future Ready Toolkits to be used in Pursuit Planning, Bids and Project Delivery ▪ DAISY – Structures measurement tool ▪ Transport Carbon Zero – Embodied Carbon Dashboard ▪ Assign Carbon to Bill of Quantities (BoQ) (in progress) ▪ ECAM Tool – water/ wastewater	▪ IS Materials Calculator Spreadsheet	▪ Green Star documents are completed and submitted to demonstrate that the building, fit out or community meets the Green Star sustainability benchmarks ▪ Green Star reviews (Independent panel) and a Green Star rating is awarded (Typically involves a 2-round assessment) ▪ PEAK platform data analytic outputs	▪ User friendly and visually appealing web-based tool ▪ 'Checklist of Input Information Requirements'	▪ The Carbon Estimate and Reporting Tool (CERT) ▪ Excel based checklist
7	*Ease of use*	▪ Easy. Templates and worksheets are set up to extract information for inclusion on the drawings as outputs. Involves pavement and sustainability engineers. Pavement engineers developing pavement profiles and maintenance diaries are business as usual. The sustainability design team uses the pavement design outputs to calculate the carbon footprints and IS EnviroPoints.	▪ Easy to use framework, with training videos/ webinars/ podcasts, case studies, toolkits, checklists, innovation labs, newsletters and marketing collateral material focused on four key pillars – Climate, Society, Resources and Technology. The framework also includes a Steer Co and Working Groups that actively partner, collaborate and knowledge-share to move the industry forward.	▪ Support and training sessions are available ▪ Client requirements specify when the rating must be achieved	▪ Comprehensive process which takes time to complete (collect all the information for submission, and completing the documentation for assessment) ▪ It becomes easier if you have project experience working with the Green Star rating tools and documents	▪ Intention is for release as a free public website ▪ Flexible inputs depending on information available and knowledge of the user ▪ Default values can be adopted if user doesn't have specific information to enable a cursory assessment for BAU	▪ There are 6 key steps to using the guidelines. ▪ There are key tasks identified for delivery at each project stage ▪ Reporting is required at each project stage, 6 monthly during construction, and at completion. Reporting requires supporting documents and evidence.
8	*How are carbon emissions and sustainability elements presented as deliverables of sustainability in design*	▪ On drawings and within the design report	▪ Sustainability management plans ▪ Sustainability reporting ▪ Design reports ▪ Future ready checklists ▪ Decarbonisation dashboard/app	▪ Under the IS Rating Scheme, a project is rated out of 100 points, with 10 bonus points available for innovation.	▪ A star rating out of 6	▪ Stacked bar chart graphically representing option performance– tonnes of CO_2 emissions per lane.km of pavement ▪ Stacked bar chart graphically showing the emissions cost ($/lane.km) for various lifecycle stages of each option. ▪ Deliverables would be written reports/memorandum summarising the option performance outcomes in terms of emissions and Present Value. ▪ The 'Checklist of Input Information Requirements' could be attached as validation to the assessment.	There are 14 compulsory requirements, and indicatively shown that the following 5 compulsory requirements are needed at Business Case/Feasibility phase (Strategic Design): ▪ Operational Energy ▪ Climate Change Risk ▪ Vegetation Offsets ▪ Urban Design ▪ Innovation and Project Legacy 2 more compulsory requirements are needed at Reference Design (Concept Design) ▪ Urban Sensitive Urban Design ▪ Operational Water Carbon emissions are only required from Detail Design phase onwards.

5.4 Summary of Sustainability Frameworks

5.4.1 Limitations and Implementations

Our framework analysis covered several areas of the transport industry, namely transport, buildings, airports, rail, mining, energy and water.

The Arcadis and SAT (NACOE Sustainability Assessment Tool) focus on pavement design. For both these framework tools, the whole of life is not considered in the calculations as there are too many unknowns and the benefits could be over-represented if they are calculated in the construction of the next project. For the Arcadis Framework, End of Life (C1 – C4) calculations are excluded and beyond Building LC (D) (Reuse, recovery, recycling and exported energy) calculations are excluded. The SAT is in pilot project testing phase, so is currently only available for TMR, MRWA and ARRB staff to use.

The WSP Framework covers many aspects of the industry. The development team has identified a reluctance by the industry to implement change in the design development. They have, together with Arcadis and NACOE, identified the need to set up intermediate decarbonisation reduction targets from early stages of the developing design (At Strategic and Concept design).

Green Star and NABERS have been available for use by our industry since 2003. Both tools rate the sustainability features of a building or development. Both ratings are voluntary, but more and more developers and property owners are opting into these schemes. The main difference between the two tools is that Green Star rates the design of the building (both at the conceptual and at the 'as built' stages) and NABERS rates the effectiveness of the operation of the building (after it is built and is operational) (Green Star V NABERS, 2010).

The Green Star rating system assesses the sustainability of building projects at all stages of the built environment lifecycle. The process to obtain a rating is to complete templates and provide supporting documentation. This information is then reviewed by an independent panel of sustainability development experts. If your submission passes, you will receive a Green Star certification trademark. This process is lengthy and costly but can lead to positive financial gains for the project and brand reputation for the developer resulting from the environmental performance achieved.

5.4.2 Standards and Codes

Generally, all of the frameworks are using the same standards and reference documentation to extract environmental and carbon coefficients.

5.4.3 Framework outputs and coverages

Our framework analysis indicates that they all measure more than just carbon. What our assessment does outline is that it appears there are no clear guideline of what should be assessed as part of the sustainability outputs. The sustainability elements that are assessed and measured as part of the Arcadis Framework, WSP Framework, IS Design, NACOE (SAT) and Transport for NSW Sustainability Design Guidelines can be seen in Table 10.

Table 10: Sustainability aspects included for measurement within various frameworks

Sustainability Framework	Carbon	Environment	Social	Political	Financial	Climate	Technology	Resources	Governance	Economic	Materials & Waste	Water	Pollution Control	Biodiversity
Arcadis Framework	✓	✓	✓	✓	✓									
WSP Framework	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓
IS Design / As-built	✓	✓	✓						✓	✓				
NACOE (SAT)	✓				✓							✓		
TfNSW Sustainability Design Guidelines	✓		✓		✓	✓					✓	✓	✓	✓

Green star omitted as less relevant to transport infrastructure projects

5.4.4 Ease of use

Most of the frameworks are being assessed by external parties. The process involves completing templates and documents, which need to be assessed by supporting documentation, which is then assessed for confirming the sustainability rating associated with the design.

However, some of the frameworks are set up to be assessed by the in-house design teams. The process involves using the developed design outputs and calculating the carbon and environmental impacts using ALCAS and formulas from standards. This provides the opportunity to develop sustainability outputs as part of the design, rather than bolting the outputs onto the design at the back end.

5.4.5 Positive observations

The multitude of frameworks that have been established and implemented within the transport industry shows proactivity in working towards Net Zero. Various methods have been innovated to quantify and report on the sustainability impacts of transport infrastructure projects, enabling decision makers to be informed with the facts that will lead to outcomes in the best interest of sustainable delivery.

Frameworks that engage independent reviewers are harnessing the knowledge and expertise of accredited professionals and removing project team bias.

Some of the sampled frameworks offered training and accreditations which substantiate adequate skill in application of the processes. This generally results in upskilling our industry and raising the quality standard.

5.4.6 Potential improvements

Availability of framework user guidance, support resources and/or training material were lacking in some cases. This may preclude an industry professional with the right intention to improve sustainability outcomes from attempting to do so due to lack of knowledge and skills.

Another large barrier to the uptake of some frameworks is the financial outlay for registering a project to use the system. In some cases, it can cost upwards of $100,000 to implement a framework for the design and construction stages of the project.

The measurement criteria for various frameworks are inconsistent across environmental, social and financial.

There is a lack of structure noted across all existing frameworks around how to estimate the sustainability impacts at the end of life/decommissioning of assets.

Frameworks are quite cumbersome or overly involved, limiting their effective use for optioneering when the primary concern is – does Option A or Option B perform better with respect to sustainability?

5.5 Key Learnings from Sustainability Frameworks

Some of the suggested improvements from our analysis of existing approaches that could see enhanced outcomes are:

- Government agencies to develop and finance a framework for their projects to avoid framework costs being a barrier to driving sustainability.
- Converge the industry approaches to fewer frameworks, ideally one. Provide sufficient guidance, support and training for the retained framework(s), leaving to familiarity with process and requirements and improved efficiency over time saving time and cost.
- Create a user-friendly interface for the implementation of quantities that generates carbon assessments and can be used quickly during optioneering to inform decision making.
- Mandate independent review and verification of the claimed outcomes by a prequalified / accredited professional.
- Further research and development required for measuring and assessing the social and financial impacts.

6 Building the Ideal Framework

This section discusses the key learnings from our research, and how they can be applied in the creation of a new framework.

6.1 Industry Feedback

From the industry feedback we received through our survey, there are a few clear messages:

- ***There is strong support for a greater emphasis on sustainability***. 90% of respondents stated that if there was a process or framework to measure the sustainability of a design, they would use it or review the results of it, reinforcing our team's view on the value of sustainability frameworks.
- ***Sustainability frameworks need to be easy to use***. Quantification of sustainability impacts needs to be simple and flexible. This could be achieved through development of an app that takes inputs such as quantities of material and/or metrics such as haul distance and applies the relevant emissions coefficient to provide comparable results.
- ***Adoption needs to be client driven***. There is a sense of responsibility for clients to drive the inclusion of sustainable delivery in their projects. Businesses need certainty to invest resources in the adoption of a sustainability framework.
- ***A balanced approach to sustainability is important***. Integration of environmental, social and financial dimensions of sustainability is essential.

6.2 Improvements to Procurement Model

In Section 3, we highlighted the varied incentivisation of sustainable project delivery across a number of sample projects of varying size, contract model and scope of works.

Echoing the feedback for 'client driven' initiative, the transport industry needs to adopt mandatory processes within the procurement phase of project delivery that encourage and reward tenderers for proactivity towards driving sustainable project outcomes.

The key learnings from the analysis of past projects are:

- ***An assessment of project sustainability outcomes achieved by the Tenderers solution should be mandatory***. The procuring agency should also be responsible for preparing a baseline assessment of their 'reference design' prior to the RFT period to create a benchmark using the specified framework.
- ***Non-price evaluation should include at least one sustainable delivery focused tender returnable schedule*** – for example:
- *Initial Sustainability Management Plan* (short form of SMP to be prepared during delivery to outline governance of sustainability) demonstrating how the sustainability targets will be met during delivery, key roles and responsibilities, how ongoing performance will be assessed and continually improved
- *Sustainability innovations register* – sustainable changes proposed to reference design or implemented in tender design such as changing materials used or construction methodology improvements that reduce power/water consumption.
- ***Price adjustment should be considered during evaluation.*** Submitted prices should be rewarded (payment bonus or price reduction) based on sustainability gain and penalised (payment set-off or price addition) for sustainability loss, against the baseline set by the agency. An 'adjusted Price' enables sustainability consideration in tender evaluation where inflexibility exists in scoring.

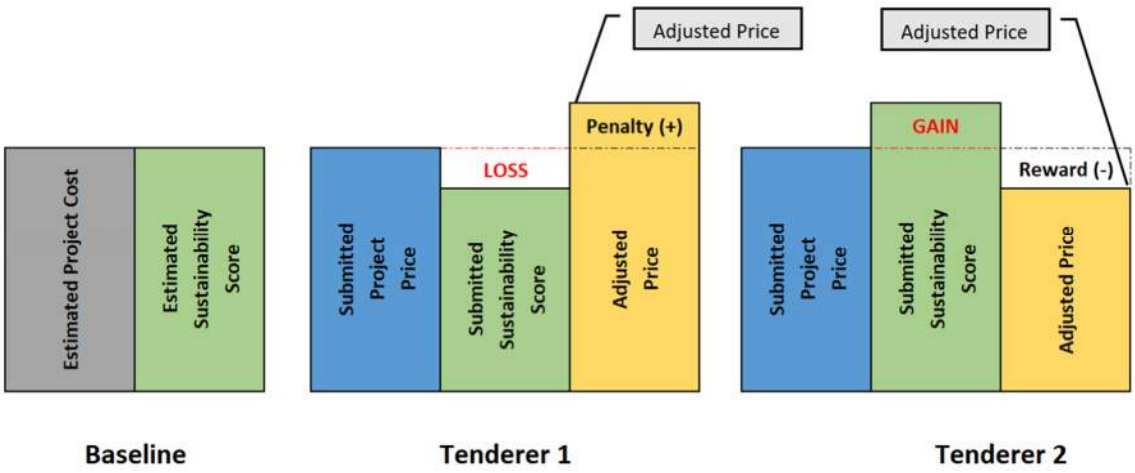


Figure 18: Example of price comparison where equal submitted prices are adjusted to incentivise sustainability performance

- ***An established sustainability framework should form part of the mandatory delivery requirements of the project*** brief/specifications/contract and be allowed for in project planning and tender submissions.
- The ISC tool appears to be quite effective for large scale Design and Construct contract models; however, a scalable process is needed for smaller or less complex projects since the $100,000+ investment for IS Rating can be cost prohibitive.
- As an alternative to a specific framework, delivery objectives should include clear minimum acceptance criteria, set by the agency and its advisors, across various sustainability functions – climate change, energy and carbon, materials and waste, water efficiency, biodiversity conservation.
- ***Independent verification of applied frameworks should be mandatory*** and completed by suitably qualified personnel.
- ***Monitoring of 'planned' sustainability initiatives versus 'actual' achieved outcomes is necessary governance*** and should be ongoing throughout project delivery. Development of a Sustainability Management Plan (or similar) would establish processes and workflows that can be traced and audited. Regular review and reporting to the project leadership level to be mandatory to demonstrate progress made and trajectory for completion – i.e., objectives will be achieved by project close.

6.3 Assessment Timing

As discussed in Section 4.2, the earlier sustainability delivery is emphasized during the design and planning phases of the project, the less potential there is for redundant work caused by making changes. Therefore, any time or cost impact to the project development can potentially be minimised by early and proactive intervention.

Conversely, the earlier in the design and planning phases of the project that quantitative or qualitative assessment for sustainable delivery is undertaken, the less information is available to make this assessment.

We therefore believe ***it is imperative that early assessment of project outcomes related to sustainable delivery becomes mandatory in strategic design and the preparation of business cases***. This should be an ongoing assessment frequently iterated during project evolution in a similar manner to how safety in design practices are applied and transferred through the sequential lifecycle stages of the project.

As shown in Figure 19 the greatest opportunities to reduce embodied carbon occur in the planning and design stages of the project life cycle.

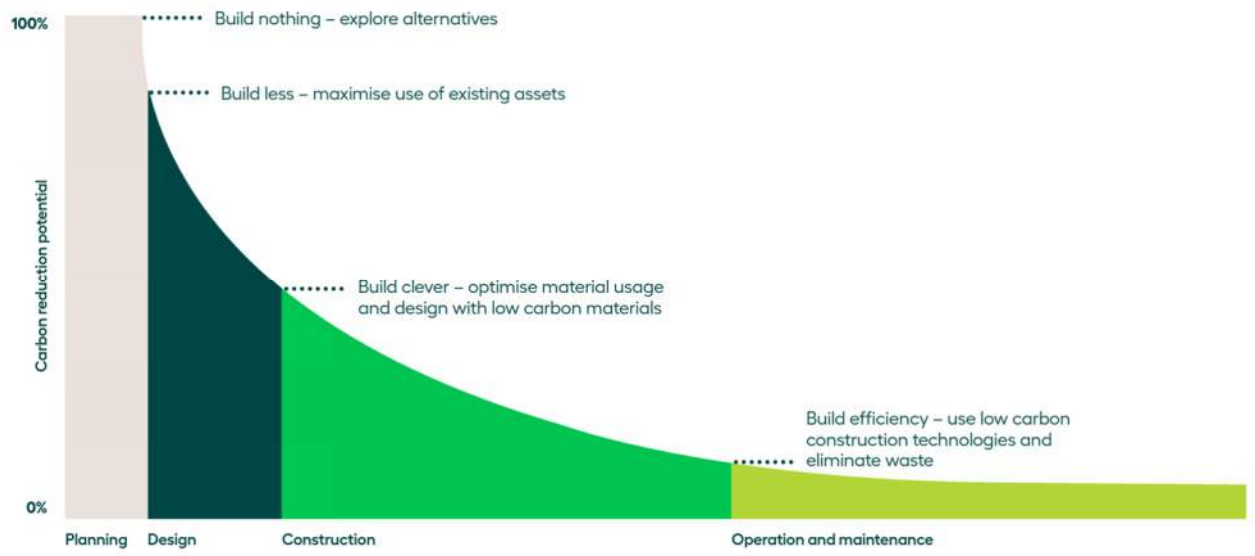


Figure 19: Opportunities to reduce embodied carbon in different project life cycle stages (HM Treasury, 2013)

6.4 Scope of Framework

6.4.1 System Boundaries applied to Project Lifecycle Stages

Stakeholder consultations highlighted that the Use Phase accounts for the majority of the whole-of-life emissions footprint. The design options comparison framework should therefore aim to ***capture as much of the Use Phase emissions as practically possible*** in the initial and ongoing assessments.

Additionally, it is important to ***avoid disproportionate effort for low percentage outcomes***. For example, undertaking an assessment of construction phase emissions during the strategic design lifecycle stage may be a rubbish-in / rubbish-out assessment as there is a high degree of uncertainty over the construction stage and the emissions from this stage could be insignificant throughout the whole of life cycle assessment. Omit or defer elements with less impact until further development of supporting details has been completed.

6.4.2 Sustainability Factors

Ideally, sustainability frameworks should include all three dimensions of sustainability – environmental, social and financial – in order to provide a wholistic assessment of impact.

Given the current barriers to adoption, it is recommended that the ***focus should initially be on the environmental impacts, particularly embodied carbon and/or greenhouse gas emissions*** as:

- This aligns with current political commitments to achieving Net Zero
- There are consistent methods for measurement of embodied carbon and GHG emissions
- There is a greater knowledge base in this area

As use of sustainability frameworks becomes mainstream "business as usual", it is suggested that additional environmental, social and financial aspects are added to the assessment once better known. An immediate action would be for ***Government agencies to invest in further research and development towards the measurement of social and financial impacts***.

To ensure the process remains simple and efficient as the framework matures, agencies should be responsible for assessing what is relevant and including only those indicators in the mandated process requirements.

6.5 Quantitative Assessments

Over time, several methods have been developed for quantification of embodied carbon and GHG emissions. Additionally, several sources exist for the derived emission factors/coefficients of material manufacture,

construction, decommissioning, and recycling. The learnings from our research as it relates to quantification methods and the sampled sustainability frameworks are:

- ***Select a single source of emissions factors*** to be reference and used in the quantification of embodied carbon and GHG emissions to promote consistency and familiarity with process.
- ***Standardise the approach adopted across the nation*** – currently we have state-based approaches, diluting our skillset and ability to efficiently work interstate to address resource shortages.

6.5.1 Measurement principles and baselining

Quantification principles for Delivering Net Zero should consider (WSP Australia Pty Ltd, 2022):

- Avoiding the risk of disproportionate effort being needed to baseline emissions. Disclose and justify any assumptions/exclusions.
- Understanding the most carbon intensive activities or areas of influence within projects by recording inventories, registers, drawings, etc. Achieve sufficient accuracy to enable users to make decisions within reasonable assurance as to the integrity of the reported information.
- Creating a "reference point" against which changes can be tracked by using consistent methodologies to allow for meaningful comparisons of emissions over time.
- Accepting that there are areas undergoing design development and advise where there is no established approach at present. These areas will work to evolve on the approaches over time and influence. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
- Where data is gathered, ensure raw data is captured to enable subsequent analysis. Account and report on emission sources and activities within the chosen boundaries.
- Capitalising on information already gathered from the industry in delivering projects, including lessons learnt from overseas.

6.6 Useability

A unified sustainability framework and methodology adopted across the industry and across the nation will provide improved consistency, knowledge and reduce the cost for adoption. Other factors promoting usability:

- ***Government agencies must invest to make the unified framework free*** for industry uptake.
- Underpin the proposed framework with ***guidance documentation, training and support resources***.
- ***Establish an easy to use, intuitive, user interface*** where simple data entry of bulk quantities and project parameters can be computed to objective outcomes for option assessment. Inputting haulage distance, material volumes, asset life cycle could lead to a total estimated embodied carbon at the click of a button. While crude, this tool can provide quick and easy relative comparisons.
- ***Provide an industry accreditation scheme*** that allows suitably trained personnel to be pre-qualified as independent assessors of Sustainability in Design practices. This allows for the decentralisation of resourcing from public sectors to private sectors, as will be necessary for the growth of the scheme.
- ***Include visual representation of sustainability performance on deliverables –*** Outcomes from assessments should be included on design Drawings so the implications are considered in decision making. For example, provide sustainability metrics beside each pavement profile (kg CO_2-e / m^2 / year) such that relative comparison is simple and part of the consideration for preferred option(s).

7 ARCADIS Framework Review

The transport industry has already devoted significant effort towards the analysis and quantification of sustainability impacts of infrastructure assets. In this chapter we explore Arcadis' contribution by reviewing their sustainability framework for pavement design option comparisons.

7.1 Key principles from Arcadis' design options comparison framework

Based on discussions with Arcadis, an approach that has proven effective for embedding sustainability assessment earlier in the design process is using a clear and consistent design options comparison framework that includes a range of sustainability criteria. When presented in a clear and visual way, this enables project teams to make informed decisions and can lead to better sustainability outcomes (see Figure 22 for the past project example).

This Arcadis example (see Figure 20) showcases how the results across the three key areas, environment, social, political and financial, are presented graphically to assist the design team with the selection of a preferred option. The Environment category is completed by using quantitative analysis for elements such as the annualised carbon emissions and IS EnviroPoints. The same unit of measurement is used i.e., Lifecycle CO_2 / m^2 / year and lifecycle EnviroPoints / m^2 / year. On the drawings, each pavement option profile will be weighted against the worst performing profile, with the actual values added to the weighted scale bar.

ECI (Environmental Cost Indicator) was developed in the Netherlands and assigns a cost value to life cycle environmental impacts (taking into account fifteen different impact categories). The ECI is used as an environmental threshold in procurement contracts where project offers higher than the maximum value is automatically rejected. This part of the environmental assessment is a new addition to the framework, and the Australian design teams are currently in training on how to use the ECI tool.

Event susceptibility relates to the resilience of the asset. In general, concrete pavements have a low susceptibility, composite pavements are medium and asphalt and granular pavements are highly susceptible to disaster events such as flooding.

Maintenance closure relates to the equivalent number of days where the asset is not available to users.

The life cycle costs (in net present value) of each asset is calculated using the equation as outlined within Austroads Guide to Pavement Technology Part 5, 2019. The formula to combine LCC with ECI is a new addition to the framework, and the Australian design teams are currently in training on how to use the ECI tool.

Figure 20: Arcadis design options framework (Arcadis, 2022)

Note: Figures are provided for illustrative purposes only, ECI = Environmental Cost Indicator, LCC = Life Cycle Cost, NPV = Net Present Value

Further, clarity on the elements of the project lifecycle that are being assessed is an important consideration. For example, Arcadis' framework includes Production, along with some elements of Construction and Use Phases in sustainability assessment (see Figure 21). The unshaded bubbles represent assessment stages that are not currently considered within the framework.

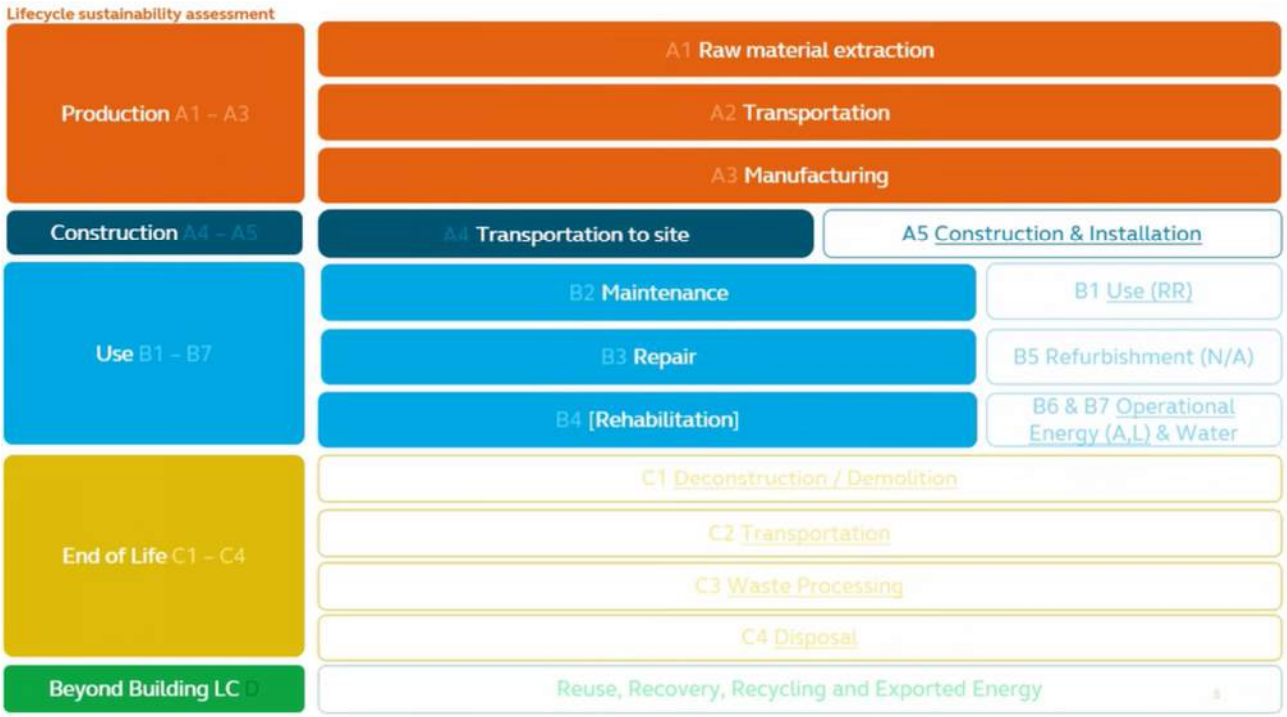


Figure 21: Construction lifecycle stages captured in Arcadis sustainability assessment (Arcadis, 2022)

Note: Arcadis sustainability assessment framework only includes stages A1-A4 and B2-B4 in sustainability assessment, other stages are included for illustrative purposes only

7.2 Implementation for a scenario – pavement design option assessment

Arcadis has successfully applied the design options comparison framework for pavements to projects in the past, leading to the project delivery team selecting a more sustainable option compared to the initial conforming pavement option (see Figure 22).

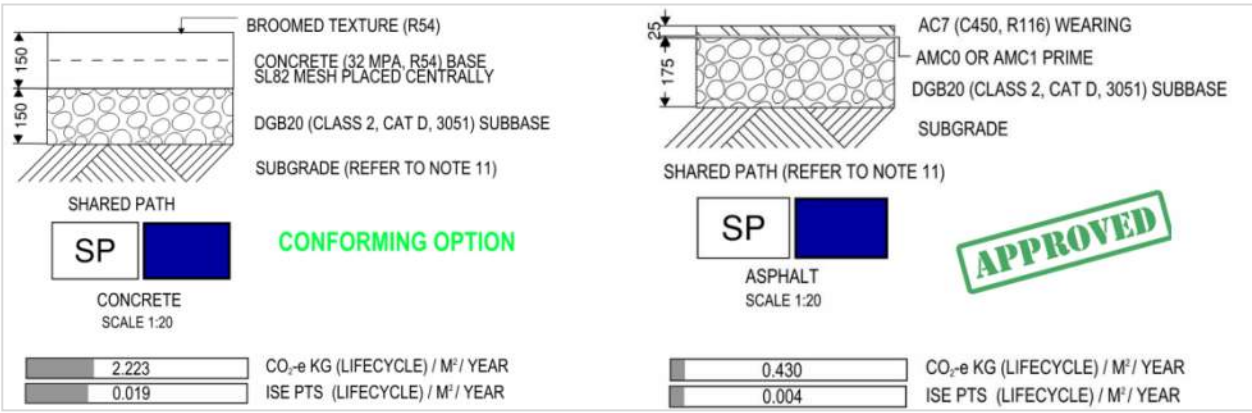


Figure 22: Arcadis pavement design project example (Arcadis, 2022)

The methodology used to identify the most suitable range of pavement design options is as follows:

1. Develop pavement profiles
2. Develop maintenance requirement diaries
3. Calculate the **volume of material** for each pavement type (incl. construction and maintenance)
4. Match the materials to the **eTool**[1] inventory

[1] Arcadis tool, based on the Australian Life Cycle Assessment Society's Australian National Life Cycle Inventory Database

5. Calculate **carbon footprints** and **IS EnviroPoints** (broader measure, not just carbon)
6. Review and obtain certification from eTool
7. Express results in terms of **area and design life**
8. Report results normalised by the highest impact.

The calculation of financial and social/political factors are conducted in parallel to Steps 3 to 6.

Based on the Arcadis sustainability team feedback, carbon emissions factors used to calculate the carbon footprint are reasonably consistent within the industry due to the consistency of inventories used. The scope of emissions included in the analysis (particularly, scope 3 emissions) is the key area that requires harmonisation.

The environment measurements are in two parts, to measure CO_2 separately from the EnviroPoints, as outlined in Figure 23. The outputs are weighted to provide a comparable sustainability output.

Indicator	Weighting for **Carbon**	Weighting for **EnviroPoints**
[CO_2-e] / Global warming	100%	47.5%
Ozone depletion		10.0%
Abiotic resource depletion [E]		10.0%
Abiotic resource depletion [F]		10.0%
Acidification		7.5%
Eutrophication		7.5%
Photochemical smog		7.5%

Figure 23: Environmental measurements split

The methodology is fairly well developed for the pavement design, however there is scope to broaden it to other infrastructure elements. Based on industry feedback, Arcadis should consider how to apply this process to structures and earthworks, as shown in Figure 24.

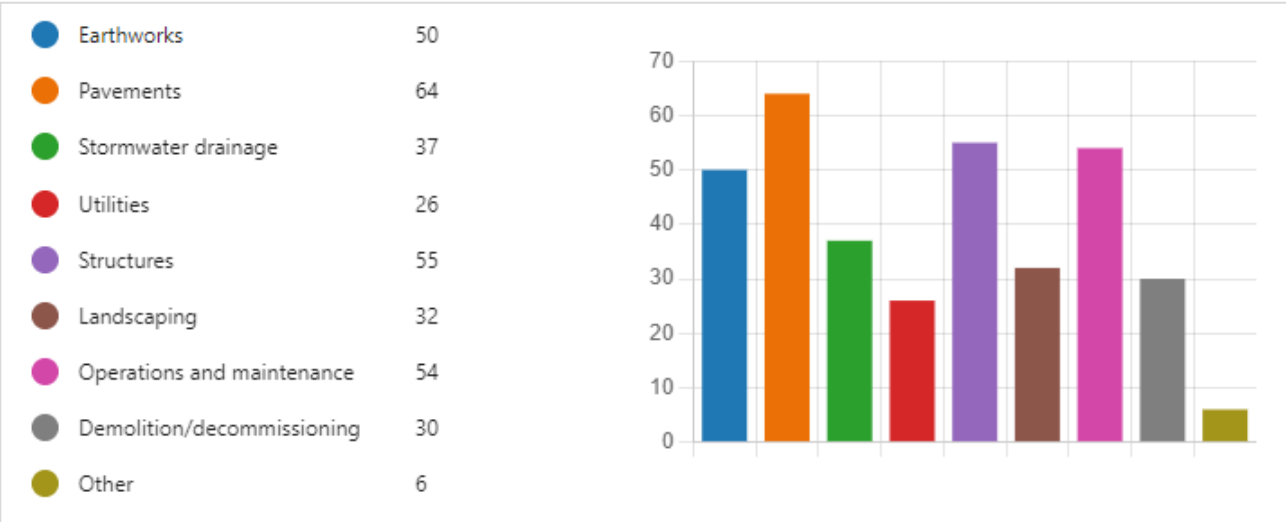


Figure 24: Industry feedback on which aspects of the design should be included in the development of a sustainability in design framework

In Section 8, the team worked with Arcadis to run the tool for firsthand experience on the process.

8 Case Study

8.1 Purpose

The team set out to demonstrate the potential for implementing the Arcadis framework through a case study. The objective is to test and report on how to use the design team resources to embed sustainability as part of the design deliverable during a Concept Design.

8.2 Project Case

Project: Upgrade of an intersection in the Penrith City Council area, Sydney

Design Phase: Concept Design

Scope: Widen the existing road carriageway which requires the construction of a full depth pavement. The site is located within a busy intersection and consideration needs to be given to impacts to community and traffic flow.

Pavement Area: *2 lanes and shoulder over a 100m length, 1000m^2*

Design team:

- ***Design Managers***: Lynette Curry, Nuno Muralha, Robbie Kerr
- ***Construction Management***: Brianna Dorrough and Danielle Turrin
- ***Pavement design engineer***: Nicole Liang/Noora Pradhan
- ***Environment engineer***: Laszlo Horvath, Rachel Sasing, Ken Lunty
- ***CAD***: Lynette Curry

Table 11: Design Criteria

Criteria	Value	Reference
New flexible pavement design life (Heavy Duty Road and TfNSW Roads)	40 years	Latest TfNSW Pavement Design Supplement 2018
New flexible pavement design life (Council Roads)	Refer to local council requirements	
Existing flexible pavement design life	N/A (resurfacing)	
New rigid pavement design life	40 years	Latest TfNSW Pavement Design Supplement 2018
Project reliability	90% (Note 95 % apply to heavy duty road)	Latest TfNSW Pavement Design Supplement 2018
Weighted mean annual pavement temperature for AC modulus calculations and Design traffic loading limit (DESA) for asphalt fatigue check.	28 degrees Celsius	Latest AGPT02
Heavy vehicle operating speed	40km/h	Applied the 20km/h below posted speed design requirement in the latest TfNSW Pavement Design Supplement 2018
Annual Heavy Vehicle (HV) design traffic growth rate	1% (minimum as per supplement) or as per traffic information whichever is greater.	Latest TfNSW Pavement Design Supplement 2018.
Traffic Load Distribution (TLD)	Urban presumptive	Latest TfNSW Pavement Design Supplement 2018
Presumptive CBR	2% minimum and/or geotechnical investigation input	Latest TfNSW Pavement Design Supplement 2018
Average Annual Daily Traffic (AADT)	AADT conversion from traffic data provided by TfNSW	
First Year of Operation: 2024	1.0	Latest AGPT02
Lane Distribution Factor	Derived from traffic data provided by TfNSW	

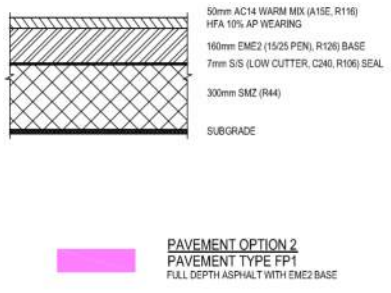
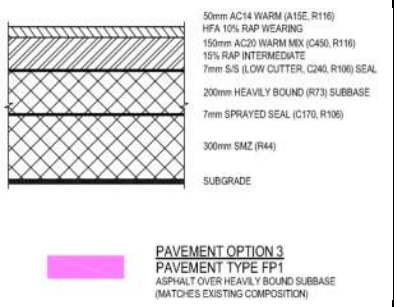
Criteria	Value	Reference
Percentage Heavy Vehicle (HV%)	1.0 or 0.5 (if two-way traffic adopted)	Latest AGPT02
Direction Factor	2.0	TfNSW Pavement Design Supplement
Average number of passenger cars equivalent to a heavy vehicle (EHV)	N_{HVAG} derived from axle group proportions of the TLD used for pavement design calculations	Latest AGPT02
Average HVAG per heavy vehicle (NHVAG)	Factor derived from the TLD used for pavement design calculations	Latest AGPT02
ESA/HVAG from TLD	28 degrees Celsius	Latest AGPT02

8.3 Implementation of Arcadis Framework

8.3.1 Pavement Profiles with Maintenance Diaries

Three pavement profile options were developed for consideration and are presented in Table 12. The maintenance diaries for each pavement can be found in Appendix C.

Table 12: Pavement profile options

Option 1	Option 2	Option 3
		
Thick asphalt on lean-mix concrete subbase (matches existing layer thickness)	***Full depth asphalt pavement with EME2 base material***	***Asphalt on heavily bound subbase (matches existing composition)***

8.3.2 Contractor's review and feedback on proposed Pavement Profiles

Given the site is within a busy intersection, it is assumed that pavement construction will be completed at night.

In terms of constructability, Pavement Option 2 is the preferred option. The benefits of this profile are:

- Absence of heavily bound base – TfNSW Specification R73 has limitations on working time from time of mixing to completion of placement, compaction and trimming of the pavement layer. In Sydney, most plants will only mix heavily bound base during the day, so the window for placement during night shift is limited, reducing productivity.
- Absence of lean mix – Curing time for lean mix adds significant time to the construction program and the pavement layer cannot be trafficked until sufficient strength is achieved, hindering access for other construction activities. Extra over costs for batch plant opening and delivery of concrete at night also add a significant cost.

The drawback with Option 2 is that it doesn't match the existing layer thicknesses so most likely requires interface drains, which add additional time and cost.

If a tack coat can be used in lieu of the 7mm single coat seal, it would be possible to construct Option 2 as expedient pavement under a temporary lane closure and reopen to the traffic at the end of each night shift. Depending on available working space this can be an advantage.

Pavement Option 3 would be the next preference in terms of constructability. The time required to construct the heavily bound base subbase layer is probably similar to the additional time it would take to install additional interface drains for Option 2. However, this option is likely more expensive than Option 2 (depending on new pavement area versus length of interface drain i.e., width of widening).

Pavement Option 1 is least favorable from a constructability point of view due to lean mix – comments above.

8.4 Assessment of the Framework Process implemented as part of the Case Study

The Case Study has been developed to implement the Arcadis framework and test against a set criteria:

Table 13: Case Study Process Assessment Criteria

Project Case Study		Framework Process Assessment and Feedback			
		Ease of use	**Understanding**	**Limitations**	**Time to Complete**
Assessment Criteria		*How does the work associated with each step align with work completed as BAU?* *Is effort disproportional to outcome?*	*How does the understanding of what is required as a deliverable with each step, compare to the work required as a deliverable under a project?*	*What are the limitations associated with the sustainability outputs of the framework?*	*What is the approximate time to complete the assessment?*
1	Develop the design element (Pavement profiles)	5	5		N/A, undertaken during BAU
2	Develop maintenance diaries	5	5		N/A, undertaken during BAU
3	Calculate the volume of material for each element (Incl construction and maintenance)	5	5		Approximately 3hrs / pavement profile + review
4	Match the materials to the calculator inventory	4	4	The inventory needs to be updated to match the current sustainability coefficients, when they change	
5	Calculate the carbon footprints and IS EnviroPoints	5	5		
6	Review and Obtain calculation certification	5	5		
7	Express results in terms of area and design life	5	5		Approximately 1hr / pavement profile
8	Report results normalized by the highest impact	5	5		Approximately 0.5hr / pavement profile
9	Transfer results onto the pavement profile CAD drawing page	5	5		

Note: Scoring on a scale of 1 to 5 (1 = difficult; 5 = easy))

8.4.1 Implementation within the design phase

The use of the Arcadis framework is most beneficial in optioneering phases such as Strategic and Concept Design stages due to its ability to realistically compare asset types used for the same purpose. It does, however, not limit the use of this framework as part of the Detail Design, which still required sustainability assessment as a delivery.

In Detailed Design and Construction phases, the framework can be used to establish a base case and aid in the approval and procurement of specific products for use on project.

8.4.2 Assumptions associated with further development of the Framework

As it is difficult to predict how the asset will be handled after its design life has passed, the Arcadis framework excludes the end of life (module C) and beyond building life cycle (module D) modules of EN15978. Consideration of future use is, instead, assumed to be encapsulated within the sustainability calculations of the next project on the same site. For example, the asset owner of a 10 km urban project constructed in 2022 with a design life of 40 years may use the framework to determine whether it is more beneficial to continue maintaining the asset as is for another 40 years, rehabilitate the asset, demolish and rebuild the asset or a mix of strategies.

8.5 Case Study: Sustainability in Design Output

8.5.1 Pavement Profile options with Sustainability Iconography

The Case Study design team has assessed and calculated the sustainability information associated with the proposed pavement design options. Table 14 shows the updated pavement profiles which include the sustainability information associated with each pavement.

Table 14: Pavement profile options with Sustainability Information

Option 1 – Sustainability output	Option 2 – Sustainability output	Option 3 – Sustainability output
PAVEMENT OPTION 1 PAVEMENT TYPE FP1 THICK ASPHALT OVER LEAN-MIX CONCRETE SUBBASE (MATCHES EXISTING LAYER THICKNESS) 3.93 CO_2-e (KG / M^2 / YR) 0.09 ENVIROPOINTS (/ M^2 / YR) MEDIUM EVENT SUSCEPTIBILITY 4.6E-05 MAINTENANCE CLOSURES (%) 5.4 LCC $NPV (/ M^2 / YR)	PAVEMENT OPTION 2 PAVEMENT TYPE FP1 FULL DEPTH ASPHALT WITH EME2 BASE 1.64 CO_2-e (KG / M^2 / YR) 0.05 ENVIROPOINTS (/ M^2 / YR) HIGH EVENT SUSCEPTIBILITY 5.3E-05 MAINTENANCE CLOSURES (%) 4.2 LCC $NPV (/ M^2 / YR)	PAVEMENT OPTION 3 PAVEMENT TYPE FP1 ASPHALT OVER HEAVILY BOUND SUBBASE (MATCHES EXISTING COMPOSITION) 4.6 CO_2-e (KG / M^2 / YR) 0.1 ENVIROPOINTS (/ M^2 / YR) MEDIUM EVENT SUSCEPTIBILITY 5.8E-05 MAINTENANCE CLOSURES (%) 4.6 LCC $NPV (/ M^2 / YR)
Thick asphalt on lean-mix concrete subbase (match existing layer thickness)	***Full depth asphalt pavement with EME2 base material***	***Asphalt on heavily bound subbase (match existing composition)***

From the weighted scale bar information, pavement Option 2 shows the most favorable environmental impacts but is highly susceptible to disaster events. Option 2 will require 3.1 days of maintenance closures over the 40-year life cycle period, compared to Option 1 and Option 3 which require 2.7 days / 40 years and 3.4 days / 40 years respectively. Option 2 shows to have the lowest life cycle cost.

Our Contractor's team has done an assessment of the pavement options prior to the calculated sustainability outputs (Refer Section 7.2) and have identified pavement Option 2 as the preferred option. In this instance, the Contractor's recommendation was driven by the absence of not having a heavily bound base, which places limitations on night works, and the absence of lean mix which adds time to the construction period.

Option 3 has the highest environmental impacts. Option 3 was also the least favorable option from a constructability point of view.

8.5.2 Effectiveness of the Arcadis Framework

The Arcadis framework is taking a more holistic approach and have aligned civil and sustainability design outcomes so that we can clearly articulate the sustainability impacts of specific design choices to our clients

before committing to a pathway forward. It is a simple innovation; however, it is a detailed one. The inspiration came from the nutritional labels you find on products in the food sector, which lists what you are putting into your body or where ingredients come from. The sustainability outputs shown in Table 14 is easy to read and to draw conclusions as to the benefits of each pavement option.

The methodology used to identify the most suitable range of pavement options is mostly business as usual for pavement engineers, who develop pavement options with maintenance diaries, for review and assessment by clients. It further requires industry recognised and standardised assessment methodologies to quantify the sustainability outcomes of the different pavement design options. These outcomes are then added to the design drawings, where sustainability in design is clearly visible to clients for consideration.

In Section 6, we identified a number of key learnings on what the ideal framework needs to include. Table 15 compares the ideal framework, with our assessment of how the Arcadis framework is implemented.

Table 15: Comparing the ideal framework with the Arcadis framework

Ideal Framework Takeaways	Comparison with Arcadis Framework
Requirement for a greater emphasis on sustainability	▪ The Arcadis framework integrates carbon measurements with cost estimation, optioneering and design decisions. ▪ Typically, when design options are improved to save money, the carbon footprint is also reduced. ▪ The incentive is to clearly outline what the sustainability impacts are associated with the pavement options, to fully understand where value engineering can be considered, which will also reduce carbon. ▪ The Arcadis framework places the focus on sustainability in design.
Sustainability frameworks need to be easy to use	▪ The Arcadis framework is utilising the design team to extract the sustainability information associated with the range of pavement options. ▪ The methodology is largely business as usual, which includes the pavement design engineers, environment design team and the CAD team. In essence, no additional time and effort is required to calculate the sustainability impacts from the pavement design options and placing the information on the CAD drawings, because generally, the sustainability impacts should be calculated as part of the deliverables. ▪ Instead of placing the information in a separate sustainability report, it is visible on the delivery drawings.
Adoption needs to be client driven	▪ The Arcadis framework development started 1,5 years ago. The approach has since been used on seven major projects in Australia and the clients involved on these projects have embraced the ability to assess design options side by side with the sustainability information. ▪ The seven major projects were at various design development stages, and in all of these projects, the sustainability information was beneficial to the project decision making. ▪ However, the framework is being implemented by the industry partners, rather than the client. ▪ More work is underway by the Arcadis Sustainability team to develop benchmarking, working with industry to develop performance-based specifications to unlock new opportunities for material re-use, and extending life cycle assessments to include use and demobilisation phase impacts.
Balance approach to sustainability is important	▪ The Arcadis framework includes the calculation of Environment, Social and Financial impacts, and are captured in the iconograph, which makes the sustainability visible, and accessible to all project decision makers.

9 Conclusion

To achieve Net Zero, the transport industry needs to work together to develop a consistent approach to address embodied carbon associated with transport infrastructure projects.

Our research and findings conclude that the industry needs to consider the following in its response to fighting climate change:

- Consolidation of existing frameworks and methodologies to simplify the way we operate across agencies and state borders.
- Client subsidised and mandated frameworks instilled on the entire project delivery supply chain - consultants, contractors, and the broader sub-contractors.
- Evaluation of sustainability performance during the procurement process, including:
    - Industry contractors and government procurement agencies to specify low carbon materials in their contracts;
    - Tenderers to respond to non-price criteria centred around sustainable practices and substantiated with quantitative assessment compared against an agency prepared 'baseline'; and
    - Environmental cost of tenderers solution to weigh into price evaluation.
- Incorporation of sustainability early in the project lifecycle – ideally from the early strategic phase and development of the business case – most potential to influence outcomes with least cost impact of implementing changes.
- Visual iconography added to design drawings so clients are well informed on the product they are purchasing and the impact they are having.
- Development of a consistent approach for quantifying environmental, social and financial impacts based on global best practices and additional agency driven research.
- Investment to industry wide training, skill development, support resources and accreditation schemes to decentralise the pressure on public sector.

These initiatives will narrow our industry approaches, align states and operators within states to a common business practice, and lead to greater efficiency of driving sustainable project outcomes with a tapering cost investment as familiarity grows and experience is gained.

10 Next Steps

10.1 Further Research

There are several opportunities for further research and investigations to expand on the findings of this report:

- Most survey respondents were based in Sydney, which may create a less representative sample, skewing the survey responses. It is recommended that the survey be repeated with a larger group, targeting a greater geographical spread across Australia. This could be achieved by leveraging the Roads Australia member network.
- Our review of sustainability incentivisation during procurement focused on government projects within NSW. It is recommended that this be extended to look at approaches across Australia, non-government clients and overseas procurement practices.
- The feedback from industry is clear that all three dimensions of sustainability (environmental, social and financial) are very important. Due to the necessary limitations of this project, our report focussed primarily on greenhouse gas emissions and embodied carbon. Further research should be undertaken to appreciate how social and financial dimensions of sustainability can be quantified, in a simple and impartial manner, for integration into sustainability frameworks.

10.2 Follow on Actions

Building on the conclusions provided in Section 9, the following actions are recommended as priority:

- Engagement with clients to ensure sustainability is embedded early in the procurement process and is client led.
- Presentation of recommendations for improvement to framework providers such as ISC.
- Increased education and training opportunities to improve awareness of how sustainability practices can be integrated to projects through all tiers of delivery – agency, consultants, design, delivery, O&M.

Industry bodies such as Roads Australia will play a key role in driving these actions as a national reach is needed to align our national strategy. With a membership group that includes representation across most of Australia's transport agencies, road owners, major contractors and consultants, and other relevant industry groups, Roads Australia are well positioned to champion the voice for a consistent industry approach.

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Appendix A Survey Questions

RA Fellowship Research Project - Sustainability in Design Survey

Brianna Dorrough
To Brianna Dorrough

Reply | Reply All | Forward

Thu 4/08/2022 12:39 PM

You forwarded this message on 4/08/2022 12:43 PM.

Dear industry colleague,

It is becoming imperative that the transport industry operates in a sustainable manner in order to meet the challenges that climate change presents.

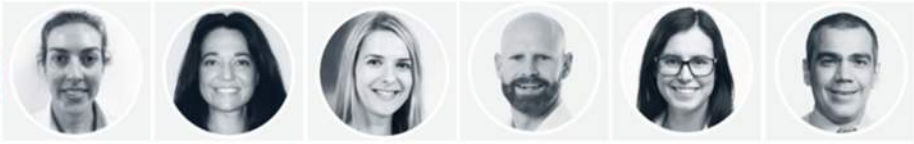
As part of the Roads Australia Fellowship program, we are working on a group project to research how the transport infrastructure sectors are evolving to meet climate change challenges. The purpose of this survey is to obtain industry feedback on existing sustainability measures and approaches as well as collecting views to shape the direction of our research project.

How you can help!
We have prepared a short 10-minute survey targeted at those working within the ***transport industry*** including designers, consultants, contractors and government agencies.
Also, if you have other contacts working within the industry that are part of our target audience then we encourage you to forward this email and help us spread our research far and wide.

The survey can be accessed via the following link:
https://forms.office.com/r/RVqPiQbGiW

We value your input and would appreciate completion of this survey by COB ***Friday the 19th of August***.

Regards,
RA Fellows Group 1



Danielle Turrin	Acciona
Lynette Curry	Arcadis
Maryia Haworth	Infrastructure NSW
Robbie Kerr	Turnbull Engineering
Brianna Dorrough	Ward Civil
Nuno Muralha	WSP

RE: RA Fellowship Research Project - Sustainability in Design Survey

Brianna Dorrough
To Brianna Dorrough

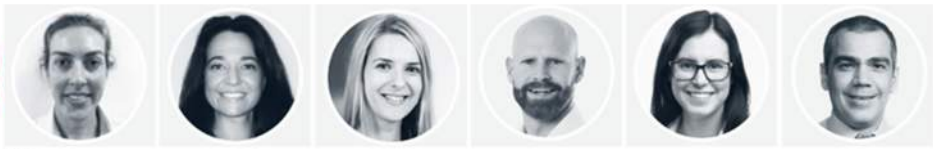
Reply | Reply All | Forward

Tue 16/08/2022 4:59 PM

Thank you to everyone who has responded to the survey so far.

If this has slipped to the bottom of your inbox or to-do list, you still have until ***COB on Friday*** to submit a response.

Regards,
RA Fellows Group 1



Danielle Turrin	Acciona
Lynette Curry	Arcadis
Maryia Haworth	Infrastructure NSW
Robbie Kerr	Turnbull Engineering
Brianna Dorrough	Ward Civil
Nuno Muralha	WSP

Sustainability in Design

It is becoming imperative that the transport industry operates in a sustainable manner in order to meet the challenges that climate change presents.

As part of the Roads Australia Fellowship program, we are working on a group project to research how the transport infrastructure sectors are evolving to meet climate change challenges.

The purpose of this survey is to obtain industry feedback on existing sustainability measures and approaches as well as collecting views to shape the direction of our project.

...

Demographic Data

All responses collected are anonymous

1. Company Type

- ◯ Designer
- ◯ Consultant
- ◯ Contractor
- ◯ Government Agency
- ◯ Other

2. Number of Employees

- ◯ 1-50
- ◯ 50-200
- ◯ 200-500
- ◯ 500+

3. Role

Enter your answer

4. Years in Industry

- ◯ 1-5
- ◯ 5-10
- ◯ 10-20
- ◯ 20-30
- ◯ 30+

5. Age

- ◯ 18-24
- ◯ 25-34
- ◯ 35-44
- ◯ 45-54
- ◯ 55-64
- ◯ 65+

6. Which gender do you mostly identify with?

- ◯ Male
- ◯ Female
- ◯ Non-binary
- ◯ Prefer not to say

7. Location

- ◯ Sydney
- ◯ NSW excluding Sydney
- ◯ ACT
- ◯ VIC
- ◯ QLD
- ◯ NT
- ◯ WA
- ◯ SA
- ◯ TAS

Next

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Sustainability in Design

...

Current State

8. How important is sustainability to you?

1=not at all, 10=very

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

9. Would you like to see a greater emphasis on sustainability in the construction industry?

- ◯ Yes
- ◯ No

10. For you: how important are the following factors of sustainability?

	Not Important	Slightly Important	Moderately Important	Very Important	Essential
Greenhouse gas emissions (carbon)	○	○	○	○	○
Environmental, excluding greenhouse gas emmisions (eg water consumption, pollution, ecological)	○	○	○	○	○
Social and political (eg community impacts)	○	○	○	○	○
Financial (value for money, whole of life)	○	○	○	○	○

11. Which of these tools have you heard of?

- ☐ Infrastructure Sustainability Design and As-Built rating tool (ISC)
- ☐ Green Star (Green Building Council of Australia)
- ☐ NABERs Ratings
- ☐ NACOE Sustainability Assessment

12. Is there a Sustainability Representative / Team within your organisation?

- ○ Yes
- ○ No

13. Do your organisation's project contracts include a focus, assessment or incentive relating to sustainability?

- ○ Rarely
- ○ Occasionally
- ○ Frequently
- ○ Always

14. Do you consider sustainability during the following stages of the design process?

- [ ] Strategic design
- [ ] Concept/reference/tender design
- [ ] Detailed design
- [ ] All of the above
- [ ] None of the above
- [ ] Not applicable to me

15. Have you ever read the appendix associated with sustainability in a concept/reference/tender design (eg. SWTC for Sustainability)?

- ◯ Yes
- ◯ No
- ◯ N/A

16. What do you see as the key current barriers to applying sustainability considerations more broadly in the design process?

- [ ] Lack of knowledge
- [ ] Over prescriptive contract/tender requirements
- [ ] Lack of client incentive
- [ ] Cost
- [ ] Market capacity/resource constraints
- [ ] Lack of leadership support
- [ ] Lack of interest
- [ ] Other

17. Please rank the following elements of transport infrastructure projects based on your perception of their contribution to greenhouse gas emissions?

Greatest impact to least

- Cement and concrete
- Material transport
- Onsite plant
- Steel
- Asphalt
- Aggregates
- Other materials
- Operational energy

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Sustainability in Design

Future State

We are aiming to develop a holistic design option comparison framework for transport infrastructure projects to inform design decisions by embedding sustainability assessment into the design. The objective is to provide a visual style output, clearly shown on plans, that provides the sustainability metrics and enables like-for-like, whole-of-life assessment of various design options.

18. If there was a process or framework to measure the sustainability of a design, would you use it or review the results of it?

- ◯ Yes
- ◯ No
- ◯ N/A

19. What factors would incentivise you to use such a framework?

1=least likely/important, 5=most likely/important

	1	2	3	4	5
Ease of use (simplicity, flexibility)	○	○	○	○	○
Client requirements	○	○	○	○	○
Company values	○	○	○	○	○
Adoption by competing organisations	○	○	○	○	○

20. Other factors that would incentives you to use such a framework

Excluding those already noted above

Enter your answer

21. In the development of a sustainability in design framework, what aspects of the design should be included?

Select top 3 priorities

- ☐ Earthworks
- ☐ Pavements
- ☐ Stormwater drainage
- ☐ Utilities
- ☐ Structures
- ☐ Landscaping
- ☐ Operations and maintenance
- ☐ Demolition/decommissioning
- ☐ Other

22. Other feedback or comments

Enter your answer

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Appendix B Survey Responses

Refer over.

ID	Start time	Completion time	Email	Name	Company Type	Number of Employees	Role	Years in Industry	Age	Which gender do you mostly identify with?	Location	How important is sustainability to you?	Would you like to see a greater emphasis on sustainability in the construction industry?	Greenhouse gas emissions (carbon)	Environmental, excluding greenhouse gas emmisions (eg water consumption, pollution, ecological)	Social and political (eg community impacts)	Financial (value for money, whole of life)	Which of these tools have you heard of?	Is there a Sustainability Representative / Team within your organisation?	Do your organisation's project contracts include a focus, assessment or incentive relating to sustainability?
1	7/22/22 13:28:47	7/22/22 13:47:45	anonymous		Consultant	500+	Design Manager	20-30	35-44	Female	ACT	8	Yes	Essential	Essential	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);	Yes	Frequently
2	7/25/22 15:13:08	7/25/22 15:18:14	anonymous		Consultant	500+	Major Projects Executive/ Client Executive	10-20	35-44	Male	Sydney	10	Yes	Essential	Very Important	Essential	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Occasionally
3	7/26/22 8:08:16	7/26/22 8:32:32	anonymous		Designer	50-200	Project Manager	10-20	25-34	Male	Sydney	7	Yes	Very Important	Very Important	Moderately Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);	No	Rarely
4	8/4/22 12:58:55	8/4/22 13:06:12	anonymous		Contractor	50-200	Estimator	10-20	35-44	Male	Sydney	8	Yes	Moderately Important	Essential	Moderately Important	Very Important	Green Star (Green Building Council of Australia);Infrastructure Sustainability Design and As-Built rating tool (ISC);NABERs Ratings;	Yes	Frequently
5	8/4/22 15:43:41	8/4/22 15:50:48	anonymous		Consultant	500+	Sustainability Consultant	10-20	35-44	Male	NSW excluding Sydney	10	Yes	Essential	Very Important	Moderately Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
6	8/5/22 11:15:03	8/5/22 11:18:30	anonymous		Consultant	500+	Project Director	10-20	35-44	Female	NSW excluding Sydney	8	Yes	Essential	Very Important	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;		Rarely
7	8/5/22 11:17:15	8/5/22 11:19:17	anonymous		Consultant	500+	bim modeller	5-10	35-44	Male	VIC	5	Yes	Essential	Essential	Moderately Important	Slightly Important		No	Occasionally
8	8/5/22 11:13:52	8/5/22 11:24:21	anonymous		Consultant	500+	Principal Drainage Engineer	20-30	45-54	Male	Sydney	6	Yes	Slightly Important	Very Important	Moderately Important	Moderately Important		Yes	Frequently
9	8/5/22 11:20:18	8/5/22 11:25:27	anonymous		Designer	50-200	Flooding	10-20	25-34	Male	Sydney	6	Yes	Slightly Important	Essential	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
10	8/5/22 11:20:51	8/5/22 11:30:10	anonymous		Consultant	500+	Principal Engineer	10-20	35-44	Male	Sydney	8	Yes	Moderately Important	Moderately Important	Very Important	Essential	Green Star (Green Building Council of Australia);	Yes	Frequently
11	8/5/22 11:46:35	8/5/22 11:50:37	anonymous		Designer	500+	Structural Engineer	10-20	35-44	Male	Sydney	7	Yes	Very Important	Very Important	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Frequently
12	8/5/22 11:52:38	8/5/22 11:56:53	anonymous		Consultant	500+	Regional Digital Engineering Lead	20-30	45-54	Male	Sydney	8	Yes	Very Important	Very Important	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
13	8/5/22 11:54:21	8/5/22 11:59:30	anonymous		Designer	500+	engineer	5-10	25-34	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Very Important	Green Star (Green Building Council of Australia);	Yes	Frequently
14	8/5/22 11:59:52	8/5/22 12:06:49	anonymous		Designer	500+	Signalling Engineer	5-10	25-34	Male	Sydney	7	Yes	Moderately Important	Slightly Important	Moderately Important	Very Important	Green Star (Green Building Council of Australia);	Yes	Occasionally

15	8/5/22 11:58:34	8/5/22 12:22:11	anonymous	Designer	500+	Technical Director	20-30	45-54	Male	Sydney	8	Yes	Essential	Very Important	Essential	Moderately Important		Yes	Always
16	8/5/22 12:14:14	8/5/22 12:25:44	anonymous	Consultant	500+	Senior Project Manager	30+	55-64	Prefer not to say	Sydney	9	Yes	Very Important	Very Important	Moderately Important	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
17	8/5/22 13:01:36	8/5/22 13:14:27	anonymous	Consultant	500+	Principal Engineer ASP3, verifier and Manager	10-20	55-64	Female	Sydney	9	Yes	Moderately Important	Very Important	Essential	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
18	8/5/22 13:23:37	8/5/22 13:34:39	anonymous	Contractor	1-50	Project manager	1-5	18-24	Male	Sydney	8	Yes	Very Important	Very Important	Very Important	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	No	Rarely
19	8/5/22 14:04:02	8/5/22 14:06:40	anonymous	Consultant	500+	Engineer	1-5	25-34	Male	Sydney	10	Yes	Very Important	Very Important	Very Important	Very Important	NABERs Ratings;Green Star (Green Building Council of Australia);	Yes	Occasionally
20	8/5/22 14:55:19	8/5/22 14:58:05	anonymous	Designer	500+	Sustainability Consultant	1-5	25-34	Female	Sydney	10	Yes	Very Important	Essential	Moderately Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
21	8/5/22 16:50:12	8/5/22 16:54:37	anonymous	Consultant	500+	Engineer	5-10	25-34	Female	Sydney	10	Yes	Essential	Essential	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;NACOE Sustainability Assessment;	Yes	Always
22	8/6/22 14:03:50	8/6/22 14:08:09	anonymous	Consultant	500+	Designer/Planner	20-30	55-64	Male	Sydney	9	Yes	Essential	Essential	Very Important	Moderately Important	Green Star (Green Building Council of Australia);Infrastructure Sustainability Design and As-Built rating tool (ISC);	Yes	Always
23	8/8/22 8:04:30	8/8/22 8:11:58	anonymous	Contractor	50-200	Bid Manager	10-20	45-54	Female	NSW excluding Sydney	10	Yes	Essential	Essential	Essential	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
24	8/8/22 10:39:29	8/8/22 10:46:17	anonymous	Designer	500+	Commercial Manager	10-20	45-54	Female	Sydney	10	Yes	Essential	Essential	Very Important	Moderately Important	NABERs Ratings;	Yes	Rarely
25	8/8/22 12:19:48	8/8/22 12:28:20	anonymous	Designer	500+	Technical Director	20-30	45-54	Male	Sydney	10	Yes	Essential	Essential	Essential	Moderately Important	Green Star (Green Building Council of Australia);	Yes	Rarely
26	8/8/22 13:18:26	8/8/22 13:21:37	anonymous	Consultant	500+	Design Engineer	5-10	25-34	Male	Sydney	10	Yes	Essential	Essential	Essential	Essential	Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
27	8/8/22 13:20:48	8/8/22 13:26:16	anonymous	Consultant	500+	Project Manager	20-30	35-44	Male	Sydney	9	Yes	Moderately Important	Very Important	Moderately Important	Moderately Important		Yes	Occasionally
28	8/8/22 15:59:03	8/8/22 16:04:08	anonymous	Consultant	50-200	Transport Planning Lead	10-20	35-44	Male	Sydney	9	Yes	Essential	Essential	Moderately Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	No	Frequently

29	8/8/22 15:54:16	8/8/22 16:04:55 anonymous	Designer	1-50	Design Manager	10-20	25-34	Male	Sydney	8	Yes	Very Important	Very Important	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	No	Frequently
30	8/8/22 16:11:45	8/8/22 16:20:43 anonymous	Designer	50-200	Technical Director	20-30	35-44	Male	Sydney	10	Yes	Very Important	Very Important	Very Important	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	No	Frequently
31	8/8/22 16:35:18	8/8/22 16:42:35 anonymous	Designer	50-200	Drainage designer	5-10	25-34	Male	Sydney	10	Yes	Essential	Very Important	Moderately Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	No	Rarely
32	8/8/22 16:44:24	8/8/22 16:49:54 anonymous	Designer	50-200	Project Manager	5-10	25-34	Male	Sydney	9	Yes	Very Important	Essential	Very Important	Very Important	Green Star (Green Building Council of Australia);	No	Occasionally
33	8/8/22 17:26:39	8/8/22 17:30:39 anonymous	Designer	50-200	Director	30+	55-64	Male	Sydney	8	Yes	Slightly Important	Very Important	Moderately Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	No	Rarely
34	8/8/22 17:28:31	8/8/22 17:32:36 anonymous	Consultant	50-200	Bridge Engineer	10-20	25-34	Male	Sydney	8	Yes	Very Important	Very Important	Essential	Essential	Green Star (Green Building Council of Australia);	Yes	Occasionally
35	8/8/22 16:50:42	8/8/22 17:47:45 anonymous	Designer	50-200	Director	10-20	35-44	Male	Sydney	8	Yes	Essential	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	No	Rarely
36	8/8/22 20:37:58	8/8/22 20:47:51 anonymous	Consultant	500+	Sustainability Director	10-20	35-44	Female	Sydney	10	Yes	Essential	Essential	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	
37	8/9/22 8:09:27	8/9/22 8:13:29 anonymous	Designer	50-200	Project Manager	10-20	25-34	Male	Sydney	9	Yes	Very Important	Essential	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	No	Occasionally
38	8/9/22 8:42:39	8/9/22 8:46:42 anonymous	Consultant	500+	Draftsperson	30+	55-64	Male	Sydney	8	Yes	Very Important	Essential	Essential	Very Important	Green Star (Green Building Council of Australia);	Yes	Frequently
39	8/9/22 9:14:31	8/9/22 9:22:02 anonymous	Consultant	50-200	Utilities Lead	10-20	35-44	Male	Sydney	10	Yes	Essential	Essential	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
40	8/9/22 9:34:13	8/9/22 9:39:29 anonymous	Contractor	500+	Senior Project Engineer	5-10	25-34	Female	Sydney	8	Yes	Very Important	Moderately Important	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Occasionally
41	8/9/22 10:09:15	8/9/22 10:12:05 anonymous	Consultant	50-200	Structural engineer	10-20	25-34	Male	Sydney	7	Yes	Moderately Important	Very Important	Slightly Important	Essential	Green Star (Green Building Council of Australia);	No	Rarely

42	8/9/22 10:14:37	8/9/22 10:19:47	anonymous	Contractor	500+	Engineer / Estimator	10-20	35-44	Male	Sydney	3	No	Slightly Important	Slightly Important	Not Important	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);	Yes	Occasionally
43	8/9/22 10:22:04	8/9/22 10:25:38	anonymous	Contractor	500+	Project Manager	20-30	45-54	Male	Sydney	8	Yes	Very Important	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Always
44	8/9/22 10:18:27	8/9/22 10:26:52	anonymous	Contractor	500+	Design Lead (Contractor)	5-10	25-34	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Always
45	8/9/22 10:37:58	8/9/22 10:43:19	anonymous	Contractor	500+	Graduate Engineer	1-5	25-34	Male	Sydney	6	Yes	Essential	Essential	Essential	Essential	Green Star (Green Building Council of Australia);	Yes	Occasionally
46	8/9/22 12:27:13	8/9/22 12:34:29	anonymous	Contractor	500+	Estimating Manager	30+	55-64	Male	Sydney	8	Yes	Very Important	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
47	8/9/22 15:26:43	8/9/22 15:33:54	anonymous	Contractor	500+	Engineering Manager	20-30	35-44	Male	Sydney	10	Yes	Essential	Essential	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;NACOE Sustainability Assessment;	Yes	Frequently
48	8/9/22 15:37:10	8/9/22 15:41:42	anonymous	Contractor	200-500	Project Manager	10-20	35-44	Male	Sydney	7	Yes	Moderately Important	Moderately Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Always
49	8/9/22 15:50:26	8/9/22 15:53:27	anonymous	Contractor	500+	Senior Project Engineer	5-10	35-44	Female	Sydney	9	Yes	Essential	Very Important	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Always
50	8/9/22 16:39:25	8/9/22 16:54:27	anonymous	Contractor	500+	Graduate Engineer	1-5	18-24	Male	Sydney	8	Yes	Very Important	Essential	Not Important	Moderately Important	Green Star (Green Building Council of Australia);	Yes	Always
51	8/10/22 7:08:28	8/10/22 7:30:28	anonymous	Contractor	500+	Environment & Sustainability Manager	10-20	35-44	Male	Sydney	10	Yes	Essential	Essential	Moderately Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
52	8/10/22 8:27:01	8/10/22 8:35:42	anonymous	Designer	500+	Sustainability Consultant	5-10	25-34	Female	Sydney	9	Yes	Essential	Essential	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
53	8/10/22 9:00:19	8/10/22 9:05:30	anonymous	Consultant	500+	Civil Engineer - Highways	1-5	25-34	Male	Sydney	7	Yes	Very Important	Essential	Moderately Important	Moderately Important	Green Star (Green Building Council of Australia);Infrastructure Sustainability Design and As-Built rating tool (ISC);	Yes	Frequently
54	8/10/22 9:39:00	8/10/22 9:41:44	anonymous	Consultant	500+	Civil Engineer	20-30	45-54	Male	Sydney	8	Yes	Essential	Essential	Essential	Essential	NABERs Ratings;Green Star (Green Building Council of Australia);	Yes	Frequently

55	8/10/22 9:42:27	8/10/22 9:55:59	anonymous	Designer	500+	Technical Director	20-30	45-54	Male	Sydney	10	Yes	Essential	Essential	Moderately Important	Slightly Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Frequently
56	8/10/22 10:43:00	8/10/22 10:50:21	anonymous	Designer	500+	Technical Discipline Leader - Civil	30+	55-64	Male	Sydney	7	No	Very Important	Very Important	Very Important	Essential	Green Star (Green Building Council of Australia);	Yes	Always
57	8/10/22 13:37:36	8/10/22 13:49:58	anonymous	Designer	500+	Commerical	10-20	45-54	Male	Sydney	8	Yes	Moderately Important	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Always
58	8/10/22 13:41:26	8/10/22 13:54:58	anonymous	Consultant	200-500	Technical director	30+	65+	Male	Sydney	10	Yes	Very Important	Essential	Very Important	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);NABERs Ratings;	Yes	Always
59	8/11/22 11:56:35	8/11/22 12:21:18	anonymous	Contractor	500+	Quality Manager	30+	45-54	Male	Sydney	8	Yes	Moderately Important	Very Important	Slightly Important	Essential	Green Star (Green Building Council of Australia);	Yes	Always
60	8/11/22 14:29:01	8/11/22 14:42:23	anonymous	Consultant	50-200	Principle Engineer	30+	55-64	Female	Sydney	9	Yes	Moderately Important	Very Important	Very Important	Essential	NACOE Sustainability Assessment;Green Star (Green Building Council of Australia);Infrastructure Sustainability Design and As-Built rating tool (ISC);NABERs Ratings;	Yes	Always
61	8/12/22 9:41:25	8/12/22 9:45:14	anonymous	Designer	50-200	Project Director	20-30	45-54	Male	Sydney	10	Yes	Very Important	Very Important	Essential	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
62	8/12/22 17:13:42	8/12/22 17:17:21	anonymous	Consultant	50-200	Civil Engineer	1-5	25-34	Male	Sydney	5	Yes	Moderately Important	Moderately Important	Very Important	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;Infrastructure Sustainability Design and As-Built rating tool (ISC);	No	Rarely
63	8/15/22 11:05:50	8/15/22 11:15:03	anonymous	Consultant	500+	Senior Project Manager	10-20	35-44	Male	Sydney	8	Yes	Essential	Moderately Important	Slightly Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Occasionally
64	8/15/22 12:06:34	8/15/22 12:10:29	anonymous	Consultant	500+	Civil Engineer	5-10	25-34	Prefer not to say	Sydney	9	Yes	Very Important	Very Important	Very Important	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Occasionally
65	8/15/22 12:49:55	8/15/22 12:57:16	anonymous	Consultant	50-200	Project / design manager	5-10	25-34	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Moderately Important	Green Star (Green Building Council of Australia);	No	Occasionally

66	8/15/22 14:41:41	8/15/22 14:52:16	anonymous	Designer	500+	Technical Executive	20-30	35-44	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Moderately Important	Green Star (Green Building Council of Australia);Infrastructure Sustainability Design and As-Built rating tool (ISC);	Yes	Frequently
67	8/15/22 14:43:12	8/15/22 14:53:30	anonymous	Consultant	500+	Technical Executive - Transport Structures	30+	65+	Male	VIC	10	Yes	Very Important	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NACOE Sustainability Assessment;NABERs Ratings;	Yes	Frequently
68	8/15/22 14:52:00	8/15/22 15:03:08	anonymous	Contractor	500+	Engineer	10-20	25-34	Male	Sydney	6	Yes	Moderately Important	Moderately Important	Moderately Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Frequently
69	8/15/22 15:41:33	8/15/22 15:48:35	anonymous	Consultant	500+	Major Project Executive	20-30	35-44	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	Yes	Frequently
70	8/15/22 15:44:12	8/15/22 15:48:56	anonymous	Contractor	50-200	Manager	10-20	35-44	Male	Sydney	8	Yes	Very Important	Very Important	Moderately Important	Essential	Green Star (Green Building Council of Australia);	Yes	Occasionally
71	8/15/22 15:46:38	8/15/22 16:29:50	anonymous	Consultant	500+	Executive Director	20-30	45-54	Male	QLD	8	Yes	Essential	Very Important	Very Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
72	8/16/22 9:01:51	8/16/22 9:12:52	anonymous	Designer	500+	Project Director	30+	65+	Male	Sydney	10	Yes	Essential	Essential	Essential	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
73	8/16/22 14:14:37	8/16/22 14:19:56	anonymous	Consultant	50-200	Technical Director	30+	55-64	Male	Sydney	9	Yes	Essential	Essential	Very Important	Very Important	Green Star (Green Building Council of Australia);NABERs Ratings;	No	Rarely
74	8/16/22 14:13:25	8/16/22 14:26:34	anonymous	Designer	50-200	Technical Director Drainage & Flooding	20-30	45-54	Male	Sydney	10	Yes	Essential	Essential	Essential	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	No	Frequently
75	8/16/22 17:00:12	8/16/22 17:02:57	anonymous	Contractor	500+	Delivery Director	10-20	35-44	Female	QLD	8	Yes	Very Important	Moderately Important	Slightly Important	Very Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently

76	8/16/22 17:03:55	8/16/22 17:13:32	anonymous	Designer	500+	Net Zero Advisory	5-10	35-44	Male	Sydney	10	Yes	Essential	Moderately Important	Moderately Important	Essential	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
77	8/16/22 19:11:59	8/16/22 19:15:28	anonymous	Designer	500+	Sustainability lead	10-20	35-44	Female	VIC	10	Yes	Essential	Very Important	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	Yes	Frequently
78	8/17/22 8:46:01	8/17/22 8:52:41	anonymous	Designer	50-200	Senior Principal	10-20	35-44	Male	Sydney	10	Yes	Essential	Essential	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);NABERs Ratings;	No	Rarely
79	8/17/22 15:22:31	8/17/22 15:28:07	anonymous	Consultant	500+	pavement design	30+	65+	Male	Sydney	9	Yes	Very Important	Very Important	Very Important	Moderately Important	NACOE Sustainability Assessment;	Yes	Frequently
80	8/19/22 8:20:37	8/19/22 8:30:12	anonymous	Designer	50-200	Director of Operations	10-20	35-44	Male	Sydney	8	Yes	Essential	Very Important	Very Important	Essential	Green Star (Green Building Council of Australia);NABERs Ratings;Infrastructure Sustainability Design and As-Built rating tool (ISC);	No	Occasionally
81	8/19/22 12:14:46	8/19/22 12:19:48	anonymous	Designer	50-200	Design Manager	10-20	35-44	Female	Sydney	10	Yes	Moderately Important	Very Important	Very Important	Moderately Important		No	Frequently
82	8/23/22 7:06:17	8/23/22 7:09:51	anonymous	Contractor	50-200	Pre-Contracts Lead	5-10	25-34	Female	NSW excluding Sydney	10	Yes	Essential	Very Important	Very Important	Moderately Important	Infrastructure Sustainability Design and As-Built rating tool (ISC);Green Star (Green Building Council of Australia);	No	Rarely

Do you consider sustainability during the following stages of the design process?	Have you ever read the appendix associated with sustainability in a concept/reference/tender design (eg. SWTC for Sustainability)?	What do you see as the key current barriers to applying sustainability considerations more broadly in the design process?	Please rank the following elements of transport infrastructure projects based on your perception of their contribution to greenhouse gas emissions?	If there was a process or framework to measure the sustainability of a design, would you use it or review the results of it?	If no, why not?	Ease of use (simplicity, flexibility)	Client requirements	Company values	Adoption by competing organisations	Other factors that would incentives you to use such a framework	In the development of a sustainability in design framework, what aspects of the design should be included?	Other feedback or comments
	Yes	Over prescriptive contract/tender requirements		Yes		5	5	5	5			
Detailed design;	Yes	Over prescriptive contract/tender requirements		Yes		5	4	5	3			
None of the above;	No	Lack of interest;lack of incentive, lack of knowledge;		Yes		5	5	3	4			
All of the above;	No	Cost;Lack of client incentive;	Material transport;Cement and concrete;Asphalt;Steel;Aggregates;Onsite plant;Operational energy;Other materials;	N/A		5	4	1	5		Pavements;Landscaping;Structures;	
All of the above;	Yes	Lack of knowledge;Lack of client incentive;Cost;Market capacity/resource constraints;Lack of leadership support;Lack of interest;	Operational energy;Cement and concrete;Steel;Material transport;Aggregates;Asphalt;Onsite plant;Other materials;	Yes		5	5	3	3	consistency of use, benchmarking and performance metrics across all road projects nationally	Earthworks;Landscaping;Pavements;	The road sector urgently needs to adjust decision making to incorporate road user emissions. In almost every sustainability benchmark this is excluded and the responsibility of the road user, however, decision making of any project can influence this. Without considering these emissions the true emission reductions will not be captured in reporting and the true reductions achieved go unknown.
All of the above;	Yes	Lack of knowledge;Lack of client incentive;Cost;Lack of leadership support;		Yes		5	5		1		Pavements;Stormwater drainage;Utilities;Structures;Operations and maintenance;	
All of the above;	No	Cost;		N/A		3	3	3	3			
Not applicable to me;	N/A	Market capacity/resource constraints;	Cement and concrete;Material transport;Steel;Onsite plant;Asphalt;Aggregates;Other materials;Operational energy;	Yes		4	5	3	4		Demolition/decommissioning;Structures;Earthworks;Pavements;Landscaping;	
Concept/reference/tender design;Detailed design;	No	Over prescriptive contract/tender requirements;Lack of client incentive;Cost;	Cement and concrete;Steel;Material transport;Onsite plant;Asphalt;Aggregates;Operational energy;Other materials;	Yes		5	4	3	2		Operations and maintenance;Earthworks;Structures;	
Concept/reference/tender design;Detailed design;	Yes	Cost;Market capacity/resource constraints;Lack of leadership support;Lack of client incentive;	Cement and concrete;Steel;Asphalt;Operational energy;Onsite plant;Aggregates;Material transport;Other materials;	Yes		5	4	4	4	Locally available green materials, design concept that achieves sustainability targets	Earthworks;Pavements;Utilities;Landscaping;Operations and maintenance;	There is a lack of technical appreciation when sustainability is concerned. Client's targets were often unrealistic if the market can respond in a cost effective way. This is a two way response, and the market needs time to create substainable materials, methods and products. The government has been chasing the cheapest solution, and have not been considering the cost of substainability. This is repeatedly reflected in the overcosting of major infrastructure projects.
All of the above;	No	Lack of knowledge;Over prescriptive contract/tender requirements;Cost;Lack of leadership support;	Cement and concrete;Material transport;Steel;Asphalt;Aggregates;Operational energy;Onsite plant;Other materials;	Yes		5	3	3	3		Structures;Operations and maintenance;Demolition/decommissioning;	
Concept/reference/tender design;Detailed design;	No	Lack of knowledge;Lack of client incentive;Market capacity/resource constraints;	Cement and concrete;Steel;Material transport;Operational energy;Onsite plant;Asphalt;Aggregates;Other materials;	Yes		4	4	4	3	Agility, need to see how "What if" scenarios could be quickly produced to make deicions.	Pavements;Operations and maintenance;Structures;	
All of the above;	Yes	Lack of client incentive;Lack of knowledge;	Operational energy;Material transport;Asphalt;Cement and concrete;Steel;Onsite plant;Aggregates;Other materials;	Yes		5	5	4	4		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
Concept/reference/tender design;Strategic design;	Yes	Market capacity/resource constraints;Lack of client incentive;	Operational energy;Material transport;Onsite plant;Cement and concrete;Asphalt;Aggregates;Steel;Other materials;	Yes		4	4	4	4		Earthworks;Stormwater drainage;Utilities;Structures;Operations and maintenance;Demolition/decommissioning;	

All of the above;	No	Cost;Lack of client incentive;Lack of leadership support;	Material transport;Operational energy;Onsite plant;Steel;Asphalt;Cement and concrete;Aggregates;Other materials;	Yes	4	5	5	4		Operations and maintenance;Earthworks;Stormwater drainage;	
Concept/reference/tender design;Detailed design;	Yes	Lack of client incentive;Market capacity/resource constraints;Cost;	Cement and concrete;Steel;Material transport;Operational energy;Onsite plant;Asphalt;Aggregates;Other materials;	Yes	4	4	5	3		Structures;Pavements;Operations and maintenance;	
All of the above;	Yes	Lack of knowledge;Lack of experience in checking for the entire project life and the associated networks and connecting systems;	Operational energy;Cement and concrete;Steel;Other materials;Material transport;Onsite plant;Asphalt;Aggregates;	Yes	5	3	4	5	Adoption/acceptance by NSW electrical utilities	Utilities;Stormwater drainage;Operations and maintenance;	Sustainability means working with the existing networks and systems, not just relocating in the immediate area can sometimes bring greater savings but designers need training/experience to look for these opportunities.
Not applicable to me;	No	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Market capacity/resource constraints;Lack of leadership support;Lack of interest;	Cement and concrete;Steel;Operational energy;Onsite plant;Material transport;Asphalt;Aggregates;Other materials;	Yes	5	5	4	5		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
Not applicable to me;	N/A	Lack of knowledge;	Material transport;Cement and concrete;Onsite plant;Steel;Operational energy;Asphalt;Aggregates;Other materials;	Yes	4	5	4	2		Operations and maintenance;Pavements;Earthworks;	
All of the above;	Yes	Cost;Market capacity/resource constraints;Lack of knowledge;	Cement and concrete;Steel;Asphalt;Material transport;Onsite plant;Aggregates;Other materials;Operational energy;	Yes	5	4	4	2		Structures;Pavements;Demolition/decommissioning;	
All of the above;	Yes	Lack of knowledge;Lack of client incentive;Reluctance from clients to accept innovative solutions;	Steel;Cement and concrete;Asphalt;Aggregates;Onsite plant;Material transport;Operational energy;Other materials;	Yes	5	5	3	5		Pavements;Earthworks;Structures;	
Strategic design;Concept/reference/tender design;All of the above;Detailed design;	Yes	Lack of client incentive;Lack of leadership support;Market capacity/resource constraints;	Operational energy;Cement and concrete;Steel;Material transport;Aggregates;Asphalt;Onsite plant;Other materials;	Yes	5	3	5	4	Cost effectiveness	Operations and maintenance;Utilities;Structures;	
Not applicable to me;	No	Lack of knowledge;Lack of client incentive;	Steel;Material transport;Onsite plant;Operational energy;Cement and concrete;Aggregates;Asphalt;Other materials;	Yes	5	5	5	4	The framework could be used to form the baseline for reporting progress and outcomes	Utilities;Earthworks;Operations and maintenance;	
Not applicable to me;	N/A	Lack of client incentive;Lack of interest;Cost;	Operational energy;Material transport;Cement and concrete;Asphalt;Aggregates;Steel;Onsite plant;Other materials;	N/A	5	5	5	3	In my experience, it is the client buy-in that is lacking. If a client is disinterested in Sustainability, they will not prioritise it.	Demolition/decommissioning;Pavements;Landscaping;	
Concept/reference/tender design;	Yes	Lack of client incentive;Cost;Lack of political commitment;		Yes	4	5	3	5	N/A	Operations and maintenance;Pavements;Environmental benefits;	
All of the above;	No	Lack of knowledge;Cost;	Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;Operational energy;	Yes	5	5	5	5		Structures;Pavements;Landscaping;Utilities;	
All of the above;	Yes	Lack of client incentive;Cost;	Cement and concrete;Steel;Asphalt;Aggregates;Material transport;Onsite plant;Other materials;Operational energy;	Yes	4	5	4	1	Regulatory	Earthworks;Pavements;Operations and maintenance;Demolition/decommissioning;Structures;	
Not applicable to me;	Yes	Lack of knowledge;Lack of client incentive;Cost;Politics - push to get job done quickly;	Operational energy;Cement and concrete;Steel;Aggregates;Onsite plant;Asphalt;Other materials;Material transport;	Yes	3	5	3	4	Awareness of such a framework - e.g. promotion at events.	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	

All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Difficulty in getting non-conformant elements approved, particularly without a long performance record ;	Cement and concrete;Operational energy;Steel;Material transport;Asphalt;Onsite plant;Aggregates;Other materials;	No	Would need it to be legislated to ensure adequate use.	4	5	5	4		Operations and maintenance;Earthworks;Pavements;	This could be a great tool for understanding the whole of life cost of designs. I expect this would need adoption by clients or through legislation though.
All of the above;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Market capacity/resource constraints;	Cement and concrete;Steel;Asphalt;Aggregates;Material transport;Onsite plant;Other materials;Operational energy;	Yes		5	4	5	5	In house sustainability lead to assist	Pavements;Structures;Landscaping;	
All of the above;	Yes	Lack of knowledge;Lack of client incentive;	Cement and concrete;Steel;Asphalt;Aggregates;Material transport;Onsite plant;Other materials;Operational energy;	Yes		5	5	5	3		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Lack of client incentive;Cost;Lack of leadership support;	Cement and concrete;Steel;Asphalt;Material transport;Aggregates;Other materials;Operational energy;Onsite plant;	Yes		4	5	4	4	Availability of the framework (free/online)	Earthworks;Pavements;Stormwater drainage;	
Concept/reference/tender design;Strategic design;	Yes	Lack of client incentive;	Cement and concrete;Steel;Asphalt;Material transport;Aggregates;Onsite plant;Operational energy;Other materials;	Yes		4	5	2	4	Specified as a scope of work requirement	Earthworks;Pavements;Stormwater drainage;Structures;Embedded carbon ;	
All of the above;	No	Lack of client incentive;Lack of leadership support;	Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;Operational energy;	Yes		5	2	4	5	Cashback incentive from TfNSW being split 50/50 with the contractor/client.	Earthworks;Pavements;Stormwater drainage;Landscaping;Operations and maintenance;	
All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Market capacity/resource constraints;Lack of leadership support;Lack of interest;	Steel;Cement and concrete;Asphalt;Material transport;Onsite plant;Aggregates;Operational energy;Other materials;	Yes		4	5	3	1		Operations and maintenance;Earthworks;Structures;	
All of the above;	Yes	Lack of client incentive;Cost;Lack of leadership support;	Cement and concrete;Steel;Asphalt;Material transport;Onsite plant;Operational energy;Aggregates;Other materials;	Yes		4	4	4	1	Ability to demonstrate the sustainability achievements through application of the framework	Demolition/decommissioning;Operations and maintenance;Landscaping;Structures;Utilities;Stormwater drainage;Pavements;Earthworks;	
Detailed design;	No	Lack of client incentive;Lack of knowledge;Lack of interest;	Cement and concrete;Steel;Aggregates;Asphalt;Material transport;Onsite plant;Operational energy;Other materials;	Yes		5	4	2	3	Personal values, quantitative outcomes	Earthworks;Pavements;Operations and maintenance;	
Detailed design;	No	Lack of knowledge;Lack of client incentive;Cost;Market capacity/resource constraints;Lack of interest;	Cement and concrete;Steel;Asphalt;Material transport;Onsite plant;Aggregates;Other materials;Operational energy;	Yes		5	5	5	4		Structures;Utilities;Landscaping;Operations and maintenance;Demolition/decommissioning;	
All of the above;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;Lack of leadership support;Lack of knowledge;	Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;Operational energy;	Yes		4	4	4	5	Enforced Standards	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
Not applicable to me;	Yes	Lack of knowledge;Lack of client incentive;Market capacity/resource constraints;	Cement and concrete;Asphalt;Onsite plant;Material transport;Operational energy;Aggregates;Steel;Other materials;	Yes		5	5	4	3	Accessibility, if it comes at a cost the business would have to approve the use of the framework	Pavements;Structures;Operations and maintenance;Demolition/decommissioning;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;	Cement and concrete;Steel;Onsite plant;Material transport;Asphalt;Aggregates;Operational energy;Other materials;	Yes		4	4	3	4		Structures;Landscaping;Earthworks;Pavements;Demolition/decommissioning;	

Not applicable to me;	Yes	Cost;Lack of interest;Over prescriptive contract/tender requirements;Lack of knowledge;	Material transport;Steel;Cement and concrete;Aggregates;Asphalt;Other materials;Operational energy;Onsite plant;	No	Lack of time.	5	2	3	1	None	Structures;Operations and maintenance;Earthworks;Pavements;Stormwater drainage;Utilities;Landscaping;Demolition/decommissioning;	
All of the above;	Yes	Over prescriptive contract/tender requirements;	Cement and concrete;Steel;Asphalt;Material transport;Onsite plant;Aggregates;Other materials;Operational energy;	Yes		4	5	4	4		Structures;Pavements;Earthworks;	
Detailed design;Concept/reference/tender design;	Yes	Lack of knowledge;Cost;	Cement and concrete;Asphalt;Aggregates;Steel;Operational energy;Onsite plant;Material transport;Other materials;	Yes		5	4	2	5	Adoption by industry	Pavements;Stormwater drainage;Utilities;Landscaping;Operations and maintenance;	
Not applicable to me;	No	Cost;Market capacity/resource constraints;	Cement and concrete;Material transport;Steel;Asphalt;Aggregates;Onsite plant;Operational energy;Other materials;	Yes		5	5	5	3		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
All of the above;	No	Lack of client incentive;Market capacity/resource constraints;Lack of knowledge;	Cement and concrete;Steel;Asphalt;Operational energy;Aggregates;Material transport;Onsite plant;Other materials;	Yes		5	5	5	5	Produces real outcomes measured against real base lines. Currently ISC credits are gained by comparison to a base line that isn't reflective of the local market or design. ie inclusion of flyash in concrete. Flyash has been specified and used in NSW for 30+ years. Projects shouldn't get ISC credits for this. It should be the ISC base line for NSW.	Pavements;Stormwater drainage;Structures;Earthworks;Operations and maintenance;	
All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Market capacity/resource constraints;Lack of leadership support;Lack of interest;	Cement and concrete;Steel;Asphalt;Operational energy;Material transport;Onsite plant;Aggregates;Other materials;	Yes		5	5	5	5	Champion the fact that at times, a high environmental cost in construction may be a low environmental cost over the life of an asset.	Operations and maintenance;Structures;Pavements;	
All of the above;	No	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;	Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;Operational energy;	Yes		4	4	4	4		Pavements;Operations and maintenance;Earthworks;	
All of the above;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Lack of leadership support;	Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;Operational energy;	Yes		5	3	3	3		Earthworks;Pavements;Structures;	
All of the above;	No	Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;	Asphalt;Steel;Operational energy;Onsite plant;Material transport;Aggregates;Cement and concrete;Other materials;	No		5	1	4	5		Stormwater drainage;Demolition/decommissioning;Earthworks;	
None of the above;	Yes	Lack of client incentive;Cost;Over prescriptive contract/tender requirements;	Onsite plant;Cement and concrete;Material transport;Asphalt;Aggregates;Steel;Operational energy;Other materials;	Yes		3	5	3	3		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Lack of client incentive;Market capacity/resource constraints;Lack of leadership support;Limitations in design specifications ;	Operational energy;Cement and concrete;Steel;Asphalt;Aggregates;Other materials;Material transport;Onsite plant;	Yes		5	5	3	3		Operations and maintenance;Structures;Pavements;	
All of the above;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;	Material transport;Onsite plant;Cement and concrete;Operational energy;Asphalt;Steel;Aggregates;Other materials;	Yes		5	3	3	4		Earthworks;Pavements;Landscaping;Operations and maintenance;	
Detailed design;	Yes	Lack of knowledge;Lack of leadership support;Lack of client incentive;	Material transport;Operational energy;Onsite plant;Cement and concrete;Steel;Asphalt;Aggregates;Other materials;	Yes		5	4	4	4		Earthworks;Structures;Landscaping;Operations and maintenance;	

All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;	Cement and concrete;Steel;Operational energy;Material transport;Onsite plant;Asphalt;Aggregates;Other materials;	Yes		4	5	5	4	Personal values	Earthworks;Pavements;Road/rail geometry (vertical in particular);	A framework that looks at whole of life sustainability would, in my opinion, be a good framework. For example able to asses the carbon produced in construction, operation and demolition as separate values would mean that designers could balance out the contributors. eg a large amount of carbon produced in constructing a road to be flatter means the operation carbon is much less.
All of the above;	No	Cost;Market capacity/resource constraints;Over prescriptive contract/tender requirements;	Material transport;Onsite plant;Operational energy;Cement and concrete;Steel;Aggregates;Asphalt;Other materials;	Yes		5	5	5	4		Structures;Operations and maintenance;Demolition/decommissioning;	
All of the above;	N/A	Over prescriptive contract/tender requirements;	Cement and concrete;Steel;Asphalt;Operational energy;Aggregates;Material transport;Onsite plant;Other materials;	Yes		5	4	4	3	Ability to rank areas / activities that significantly influence the sustainability	Pavements;Earthworks;Structures;	
All of the above;	Yes	Cost;	Steel;Cement and concrete;Material transport;Asphalt;Onsite plant;Aggregates;Operational energy;Other materials;	Yes		5	4	5	4	whole of life costs including insurance payout costs and cost of biodiversity	Pavements;Stormwater drainage;Demolition/decommissioning;use of forever chemicals and their products ;	maintenance of environmental biodiversity, clean water, clean air, healthy soil
Concept/reference/tender design;Detailed design;	Yes	Over prescriptive contract/tender requirements;Lack of knowledge;Lack of client incentive;Cost;Market capacity/resource constraints;		No	Because we need to get the basic correct first.	5	5	2	5		Earthworks;Pavements;Stormwater drainage;Structures;Landscaping;	At present clients are requesting sustainability requirements that create more damage than benefit (Blast Furnas slag in concrete) . The client needs to get on-board and take responsibility for innovation and not push it all back to the contractor with unrealistic deliverables. I could provide multiple example where we have tried to implement innovation (rubber, glass, recycled product, list goes on) into the works and despite having clear data that shows it is suitable they make us do it at 100% our risk despite the fact we are prepared to pay the extra to try it. Clients need to fund testing and trails so they can develop realistic specs so it becomes the normal, it is a difficult and time consuming task but until we have clear guidelines and specs then contractors will not want to try. We cant have clients enforcing us to use products that cant meet spec (working time of blast furnace slag) and we end up sending more concrete to waste than in the works and deem this a "sustainable outcome".... madness. My true belief is we first need to have refined design (reduced pavement thickness, concrete thickness requirements etc) and stop rework, doing stuff multiple time is not a sustainable outcome.
Strategic design;Concept/reference/tender design;Detailed design;All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;	Asphalt;Onsite plant;Cement and concrete;Material transport;Steel;Aggregates;Other materials;Operational energy;	Yes		3	4	3	5		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
Strategic design;Concept/reference/tender design;Detailed design;	No	Lack of client incentive;Cost;	Steel;Operational energy;Asphalt;Cement and concrete;Material transport;Onsite plant;Aggregates;Other materials;	Yes		5	2	4	2	the carbon benefits of the adopted design	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
None of the above;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Lack of interest;Lack of knowledge;	Cement and concrete;Steel;Aggregates;Other materials;Asphalt;Material transport;Operational energy;Onsite plant;	Yes		4	4	3	4	none	Landscaping;Demolition/decommissioning;Earthworks;	
All of the above;	No	Lack of knowledge;Lack of leadership support;	Operational energy;Cement and concrete;Material transport;Onsite plant;Steel;Asphalt;Aggregates;Other materials;	Yes		5	4	4	4		Pavements;Stormwater drainage;Structures;Operations and maintenance;	
Detailed design;	Yes	Lack of client incentive;Lack of leadership support;Cost;Market capacity/resource constraints;	Operational energy;Onsite plant;Material transport;Steel;Cement and concrete;Asphalt;Aggregates;Other materials;	Yes		5	4	4	3		Earthworks;Stormwater drainage;Demolition/decommissioning;Operations and maintenance;Landscaping;Structures;Utilities;Pavements;	
Detailed design;	No	Cost;	Steel;Cement and concrete;Asphalt;Aggregates;Other materials;Material transport;Onsite plant;Operational energy;	Yes		3	1	4	2	Evidence of the process resulting in change	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	

Detailed design;	No	Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;	Cement and concrete;Aggregates;Operational energy;Material transport;Steel;Onsite plant;Asphalt;Other materials;	Yes	4	5	4	3	Contractor adoption	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Operations and maintenance;Demolition/decommissioning;	
All of the above;	Yes	Cost;Lack of client incentive;Lack of knowledge;	Cement and concrete;Steel;Operational energy;Material transport;Onsite plant;Asphalt;Aggregates;Other materials;	Yes	5	5	4	5	TENDERS EVALUATION DONE WITH WEIGHTED FACTORS FOR SUSTAINABILITY: COST, PEOPLE, ENVIRONMENT, CULTURE	Structures;Operations and maintenance;Demolition/decommissioning;Pavements;	
Concept/reference/tender design;Detailed design;	No	Lack of knowledge;Over prescriptive contract/tender requirements;Cost;Market capacity/resource constraints;	Cement and concrete;Asphalt;Aggregates;Material transport;Onsite plant;Steel;Operational energy;Other materials;	Yes	5	2	2	4		Stormwater drainage;Operations and maintenance;Pavements;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Cost;Lack of client incentive;	Cement and concrete;Steel;Material transport;Operational energy;Onsite plant;Asphalt;Aggregates;Other materials;	Yes	5	5				Structures;Earthworks;Operations and maintenance;	
Not applicable to me;	No	Lack of client incentive;Market capacity/resource constraints;	Onsite plant;Material transport;Cement and concrete;Steel;Asphalt;Aggregates;Operational energy;Other materials;	N/A	4	3	3	3		Pavements;Stormwater drainage;	
Strategic design;Concept/reference/tender design;Detailed design;	Yes	Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;Cost;Lack of leadership support;	Cement and concrete;Steel;Asphalt;Operational energy;Onsite plant;Material transport;Aggregates;Other materials;	Yes	4	5	5	2	Alignment with government / client objectives	Pavements;Earthworks;Structures;Operations and maintenance;	
Strategic design;Concept/reference/tender design;Detailed design;	Yes	Lack of client incentive;Market capacity/resource constraints;Lack of leadership support;Lack of interest;Over prescriptive contract/tender requirements;Lack of knowledge;	Cement and concrete;Steel;Asphalt;Aggregates;Other materials;Material transport;Onsite plant;Operational energy;	Yes	5	3	5	2	My own values	Pavements;Operations and maintenance;Demolition/decommissioning;	Hopefully whatever you produce avoids the use of such meaningless phrases like "holistic design option comparison framework". (refer above under "future state"). Q 21 is a bit odd. If you are really addressing sustainability Ops & Maintenance and Demolition Decommissioning have to be included (circular economy?). Why have these with all the design aspects? Whatever you come up with, keep it simple, digital approach, automate. If it takes up time it will be shoved to one side.
None of the above;	No	Over prescriptive contract/tender requirements;Lack of client incentive;Lack of leadership support;Market capacity/resource constraints;Cost;	Cement and concrete;Material transport;Operational energy;Steel;Onsite plant;Asphalt;Aggregates;Other materials;	Yes	5	4	5	3	Own values	Operations and maintenance;Pavements;Structures;Stormwater drainage;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;Lack of time during delivery stage to fully investigate opportunities. If a strategy is not well developed at tender the chance to incorporate during detailed design is minimal because procurement occurs very quickly after contract award. There is also a need to 'prove' some initiative works during design period. Type approval from Clients (pre-approved mix designs for example) would be a good step forward for sustainability to be business as usual rather than an addition to the process.;	Cement and concrete;Operational energy;Steel;Material transport;Onsite plant;Asphalt;Aggregates;Other materials;	Yes	5	4	4	5	Target Cost approach to reductions. Say at Strategic/concept has an allowance, Tenderers attempt to match, or submit a reasonable goal, detailed design aims to reduce from Tender, construction aims to reduce further, and some Tax offset/credit is provided. Gamify via monitary incentives during projects.	Earthworks;Structures;Operations and maintenance;Pavements;For roads: Fuel efficiency savings based on geometry relative to existing road.;Stormwater drainage;Utilities;Landscaping;	
All of the above;	Yes	Lack of knowledge;Over prescriptive contract/tender requirements;Lack of client incentive;Market capacity/resource constraints;Cost;	Cement and concrete;Material transport;Steel;Onsite plant;Asphalt;Aggregates;Other materials;Operational energy;	Yes	5	4	2	4		Earthworks;Pavements;Stormwater drainage;Utilities;Structures;	

All of the above;	Yes	IS Rating process very resource intensive, and generally only applied to major projects. Need a more streamlined approach for small and medium projects;	Operational energy;Cement and concrete;Steel;Onsite plant;Material transport;Asphalt;Aggregates;Other materials;	Yes	5	5	2	2	Seeing impactful sustainability outcomes driven by requirements	Earthworks;Pavements;Stormwater drainage;Structures;Operations and maintenance;User emissions. This is the elephant in the room for any road project. Risk of greenwashing if this is ignored;	Question 17 mentions operational energy and not user emissions. Road user emissions are number one source of transport related emissions
All of the above;	Yes	Lack of client incentive;	Operational energy;Cement and concrete;Steel;Asphalt;Aggregates;Onsite plant;Material transport;Other materials;	Yes	3	5	3	4	Genuine outcomes on design and construction	Pavements;Earthworks;Stormwater drainage;	
All of the above;	Yes	Lack of knowledge;Lack of client incentive;Cost;Lack of leadership support;	Operational energy;Cement and concrete;Material transport;Asphalt;Onsite plant;Steel;Aggregates;Other materials;	Yes	4	5	4	3		Earthworks;Pavements;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
All of the above;	No	Market capacity/resource constraints;Over prescriptive contract/tender requirements;Lack of client incentive;Cost;		Yes	5	4	4	4		Pavements;Stormwater drainage;Structures;Operations and maintenance;	
None of the above;	Yes	Lack of client incentive;Market capacity/resource constraints;Potential additional costs vs client likelihood of awarding to lowest cost bidder ;	Cement and concrete;Steel;Onsite plant;Material transport;Asphalt;Operational energy;Aggregates;Other materials;	Yes	5	5	3	5	While the industry is developing necessary skills to adopt framework, client to consider a ITC or similar reimbursable cost model to implement this. This avoid the concern that a competitor who lacks understanding of sustainability and underprices the costs/risks, is able to win a tender due to lower price.	Earthworks;Pavements;Stormwater drainage;Utilities;Structures;Landscaping;Operations and maintenance;Demolition/decommissioning;	
Concept/reference/tender design;Detailed design;	Yes	Lack of knowledge;Cost;	Material transport;Steel;Onsite plant;Asphalt;Cement and concrete;Aggregates;Other materials;Operational energy;	Yes	4	4	4	2		Pavements;Landscaping;Structures;Demolition/decommissioning;	
Not applicable to me;	N/A	Lack of client incentive;Lack of knowledge;Market capacity/resource constraints;Lack of interest;	Cement and concrete;Steel;Asphalt;Aggregates;Operational energy;Material transport;Onsite plant;Other materials;	Yes	4	5	3	5		Pavements;Structures;Stormwater drainage;	

Appendix C Maintenance Diaries

PAVEMENT TAG	FP1A
PAVEMENT DESCRIPTION	AC over LMC
PAVEMENT DESIGN LIFE	40 years
DESIGN TRAFFIC LOADING	-
DESIGN SUBRADE CBR	<2%

Year	Proposed maintenance, rehabilitation or reconstruction treatment	Roughness (IRI)	Cracking (%)	Road Surface Skid Resistance SCRIM (SFC)	Rut Depth (mm)	Texture Depth (mm)
2027	Initial Construction & Open to traffic	1.50	0.00	0.60	0.00	0.80
2028	Routine Maintenance	1.58	0.04	0.59	0.45	0.78
2029	Routine Maintenance	1.67	0.08	0.58	0.91	0.75
2030	Routine Maintenance	1.75	0.13	0.58	1.36	0.73
2031	Routine Maintenance	1.83	0.17	0.57	1.82	0.70
2032	Routine Maintenance	1.92	0.21	0.56	2.27	0.68
2033	Routine Maintenance	2.00	0.25	0.55	2.73	0.65
2034	Routine Maintenance	2.08	0.29	0.54	3.18	0.63
2035	Routine Maintenance	2.17	0.33	0.53	3.64	0.60
2036	Routine Maintenance	2.25	0.38	0.53	4.09	0.58
2037	Routine Maintenance	2.33	0.42	0.52	4.55	0.55
2038	Heavy Patch 1 % of total Area	2.42	0.46	0.51	0.00	0.53
2039	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.45	0.80
2040	Routine Maintenance	1.58	0.04	0.59	0.91	0.78
2041	Routine Maintenance	1.67	0.08	0.58	1.36	0.75
2042	Routine Maintenance	1.75	0.13	0.58	1.82	0.73
2043	Routine Maintenance	1.83	0.17	0.57	2.27	0.70
2044	Routine Maintenance	1.92	0.21	0.56	2.73	0.68
2045	Routine Maintenance	2.00	0.25	0.55	3.18	0.65
2046	Routine Maintenance	2.08	0.29	0.54	3.64	0.63
2047	Routine Maintenance	2.17	0.33	0.53	4.09	0.60
2048	Routine Maintenance	2.25	0.38	0.53	4.55	0.58
2049	Heavy Patch 1.5 % of total Area	2.33	0.42	0.52	0.00	0.55
2050	Routine Maintenance	2.42	0.46	0.51	0.45	0.53
2051	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.91	0.80
2052	Routine Maintenance	1.58	0.04	0.59	1.36	0.78
2053	Routine Maintenance	1.67	0.08	0.58	1.82	0.75
2054	Routine Maintenance	1.75	0.13	0.58	2.27	0.73
2055	Routine Maintenance	1.83	0.17	0.57	2.73	0.70
2056	Routine Maintenance	1.92	0.21	0.56	3.18	0.68
2057	Routine Maintenance	2.00	0.25	0.55	3.64	0.65
2058	Routine Maintenance	2.08	0.29	0.54	4.09	0.63
2059	Routine Maintenance	2.17	0.33	0.53	4.55	0.60
2060	Heavy Patch 1.5 % of total Area	2.25	0.38	0.53	0.00	0.58
2061	Routine Maintenance	2.33	0.42	0.52	0.45	0.55
2062	Routine Maintenance	2.42	0.46	0.51	0.91	0.53
2063	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	1.36	0.80
2064	Routine Maintenance	1.58	0.04	0.59	1.82	0.78
2065	Routine Maintenance	1.67	0.08	0.58	2.27	0.75
2066	Routine Maintenance	1.75	0.13	0.58	2.73	0.73
2067	Routine Maintenance	1.83	0.17	0.57	3.18	0.70

Figure 25: Option 1 – Maintenance Diary FP1A AC over LMC

PAVEMENT TAG	FP1B
PAVEMENT DESCRIPTION	FDA
PAVEMENT DESIGN LIFE	40 Years
DESIGN TRAFFIC LOADING	-
DESIGN SUBRADE CBR	>2%

Year	Proposed maintenance, rehabilitation or reconstruction treatment	Roughness (IRI)	Cracking (%)	Road Surface Skid Resistance SCRIM (SFC)	Rut Depth (mm)	Texture Depth (mm)
2027	Initial Construction & Open to traffic	1.50	0.00	0.60	0.00	0.80
2028	Routine Maintenance	1.58	0.04	0.59	0.45	0.78
2029	Routine Maintenance	1.67	0.08	0.58	0.91	0.75
2030	Routine Maintenance	1.75	0.13	0.58	1.36	0.73
2031	Routine Maintenance	1.83	0.17	0.57	1.82	0.70
2032	Routine Maintenance	1.92	0.21	0.56	2.27	0.68
2033	Routine Maintenance	2.00	0.25	0.55	2.73	0.65
2034	Routine Maintenance	2.08	0.29	0.54	3.18	0.63
2035	Routine Maintenance	2.17	0.33	0.53	3.64	0.60
2036	Routine Maintenance	2.25	0.38	0.53	4.09	0.58
2037	Routine Maintenance	2.33	0.42	0.52	4.55	0.55
2038	Heavy Patch 1 % of total Area	2.42	0.46	0.51	0.00	0.53
2039	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.45	0.80
2040	Routine Maintenance	1.58	0.04	0.59	0.91	0.78
2041	Routine Maintenance	1.67	0.08	0.58	1.36	0.75
2042	Routine Maintenance	1.75	0.13	0.58	1.82	0.73
2043	Routine Maintenance	1.83	0.17	0.57	2.27	0.70
2044	Routine Maintenance	1.92	0.21	0.56	2.73	0.68
2045	Routine Maintenance	2.00	0.25	0.55	3.18	0.65
2046	Routine Maintenance	2.08	0.29	0.54	3.64	0.63
2047	Routine Maintenance	2.17	0.33	0.53	4.09	0.60
2048	Routine Maintenance	2.25	0.38	0.53	4.55	0.58
2049	Heavy Patch 2 % of total Area	2.33	0.42	0.52	0.00	0.55
2050	Routine Maintenance	2.42	0.46	0.51	0.45	0.53
2051	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.91	0.80
2052	Routine Maintenance	1.58	0.04	0.59	1.36	0.78
2053	Routine Maintenance	1.67	0.08	0.58	1.82	0.75
2054	Routine Maintenance	1.75	0.13	0.58	2.27	0.73
2055	Routine Maintenance	1.83	0.17	0.57	2.73	0.70
2056	Routine Maintenance	1.92	0.21	0.56	3.18	0.68
2057	Routine Maintenance	2.00	0.25	0.55	3.64	0.65
2058	Routine Maintenance	2.08	0.29	0.54	4.09	0.63
2059	Routine Maintenance	2.17	0.33	0.53	4.55	0.60
2060	Heavy Patch 2 % of total Area	2.25	0.38	0.53	0.00	0.58
2061	Routine Maintenance	2.33	0.42	0.52	0.45	0.55
2062	Routine Maintenance	2.42	0.46	0.51	0.91	0.53
2063	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	1.36	0.80
2064	Routine Maintenance	1.58	0.04	0.59	1.82	0.78
2065	Routine Maintenance	1.67	0.08	0.58	2.27	0.75
2066	Routine Maintenance	1.75	0.13	0.58	2.73	0.73
2067	Routine Maintenance	1.83	0.17	0.57	3.18	0.70

Figure 26: Option 2 – Maintenance Diary FP1B FDA

PAVEMENT TAG	FP1C
PAVEMENT DESCRIPTION	AC over HBSB
PAVEMENT DESIGN LIFE	40 Years
DESIGN TRAFFIC LOADING	-
DESIGN SUBRADE CBR	>2%

Year	Proposed maintenance, rehabilitation or reconstruction treatment	Roughness (IRI)	Cracking (%)	Road Surface Skid Resistance SCRIM (SFC)	Rut Depth (mm)	Texture Depth (mm)
2027	Initial Construction & Open to traffic	1.50	0.00	0.60	0.00	0.80
2028	Routine Maintenance	1.58	0.04	0.59	0.45	0.78
2029	Routine Maintenance	1.67	0.08	0.58	0.91	0.75
2030	Routine Maintenance	1.75	0.13	0.58	1.36	0.73
2031	Routine Maintenance	1.83	0.17	0.57	1.82	0.70
2032	Routine Maintenance	1.92	0.21	0.56	2.27	0.68
2033	Routine Maintenance	2.00	0.25	0.55	2.73	0.65
2034	Routine Maintenance	2.08	0.29	0.54	3.18	0.63
2035	Routine Maintenance	2.17	0.33	0.53	3.64	0.60
2036	Routine Maintenance	2.25	0.38	0.53	4.09	0.58
2037	Routine Maintenance	2.33	0.42	0.52	4.55	0.55
2038	Heavy Patch 1 % of total Area	2.42	0.46	0.51	0.00	0.53
2039	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.45	0.80
2040	Routine Maintenance	1.58	0.04	0.59	0.91	0.78
2041	Routine Maintenance	1.67	0.08	0.58	1.36	0.75
2042	Routine Maintenance	1.75	0.13	0.58	1.82	0.73
2043	Routine Maintenance	1.83	0.17	0.57	2.27	0.70
2044	Routine Maintenance	1.92	0.21	0.56	2.73	0.68
2045	Routine Maintenance	2.00	0.25	0.55	3.18	0.65
2046	Routine Maintenance	2.08	0.29	0.54	3.64	0.63
2047	Routine Maintenance	2.17	0.33	0.53	4.09	0.60
2048	Routine Maintenance	2.25	0.38	0.53	4.55	0.58
2049	Heavy Patch 2 % of total Area	2.33	0.42	0.52	0.00	0.55
2050	Routine Maintenance	2.42	0.46	0.51	0.45	0.53
2051	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	0.91	0.80
2052	Routine Maintenance	1.58	0.04	0.59	1.36	0.78
2053	Routine Maintenance	1.67	0.08	0.58	1.82	0.75
2054	Routine Maintenance	1.75	0.13	0.58	2.27	0.73
2055	Routine Maintenance	1.83	0.17	0.57	2.73	0.70
2056	Routine Maintenance	1.92	0.21	0.56	3.18	0.68
2057	Routine Maintenance	2.00	0.25	0.55	3.64	0.65
2058	Routine Maintenance	2.08	0.29	0.54	4.09	0.63
2059	Routine Maintenance	2.17	0.33	0.53	4.55	0.60
2060	Heavy Patch of 3% of total Area	2.25	0.38	0.53	0.00	0.58
2061	Routine Maintenance	2.33	0.42	0.52	0.45	0.55
2062	Routine Maintenance	2.42	0.46	0.51	0.91	0.53
2063	Mill & Resheet wearing course AC14 A15E 100 % of total Area	1.50	0.00	0.60	1.36	0.80
2064	Routine Maintenance	1.58	0.04	0.59	1.82	0.78
2065	Routine Maintenance	1.67	0.08	0.58	2.27	0.75
2066	Routine Maintenance	1.75	0.13	0.58	2.73	0.73
2067	Routine Maintenance	1.83	0.17	0.57	3.18	0.70

Figure 27: Option 3 – Maintenance Diary FP1C AC over HBSB