Australian Government | Infrastructure Australia

December 2022

Supporting appendices

Infrastructure Market Capacity Report

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Appendix A: Demand-side analysis methodology

Infrastructure Australia's Major Public Infrastructure Pipeline

The analysis in the 2022 *Infrastructure Market Capacity* report is based on the aggregation of project-level data to inform a portfolio view of Australia-wide infrastructure, with data current as at August 2022.

Infrastructure Australia established the 'Major Public Infrastructure Pipeline' in the 2021 *Infrastructure Market* Capacity report – this included a database of identifiable publicly funded infrastructure projects which met certain criteria for inclusion.

Projects were included in the database if the investment value was above a threshold capital cost (over $50 million for South Australia, Tasmania, the Northern Territory and the Australian Capital Territory, and over $100 million for all other Australian states). The periods covered within the portfolio were between 2014−15 and 2024−25 – that is projects were included on the basis that there was (or would be) a non-zero amount of construction activity across those ten years.

Project data gathering and collation

This report has involved an update to the public project-level information contained in the 2021 *Infrastructure Market Capacity* report, using the most recent obtainable information. The process used to collate project-level data for public infrastructure has changed since the previous report – the majority of data on public infrastructure is sourced from states and territories infrastructure agencies (as opposed to private industry sources). This also extends to a partnership with the Australian Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) – the Department have provided budgeted transport infrastructure project expenditure from 2017−18 onwards.

The exception to this is the energy and fuels sector, wherein activity has been estimated by projected upgrades to generation capacity as specified by the Australian Energy Market Operator (AEMO) in their Integrated System's Plan (ISP). With regard to transmission activity, the 2021 dataset on transmission line projects collated by the University of Technology Sydney has been retained in this report

The inclusion of project-level data in the major public infrastructure pipeline follows the same criteria as in 2021 (i.e. threshold value cut-offs and publicly funded works). However, a key addition to the pipeline is the inclusion of activity in the energy and fuels sector as noted above. Furthermore, the collation of project-level data has expanded during the development of the 2022 Infrastructure Market Capacity report – identifiable projects that are privately funded across all value ranges have also been gathered and added to the project database. While these projects are not covered in the major public infrastructure pipeline, the outlook of the entire project database will be examined in later sections of the report.

For each project, the database includes information, where available, on the following fields:

- Location (including jurisdiction)
- Investment cost (or megawatts for energy projects)
- Project stage (preconstruction stages, under construction or completed)
- Project schedule
- Funding source (public, private, mixed)
- Project type (project classification)

Data classification

The project database classifies infrastructure projects at varying resolutions – each project is assigned a 'typecast' of which there are 40 distinct areas of activity.

Each typecast lies within a corresponding 'master type' of which there are 17 different subsectors. Finally, the master types can be aggregated into the three following infrastructure 'sectors':

- **Transport**, which includes roads, railways, level crossings and other transport projects such as airport runways (noting that airport buildings are represented in the 'Building' sector)
- **Utilities**, which includes water and sewerage, energy and fuels, gas and water pipelines and telecommunications
- **Building**, which includes non-residential building across health, education, sport, justice, transport building (parking facility and warehouse) and other building (art facilities, civic/convention centres, and offices). New additions in this report include the residential sector (broken into detached, semi-detached and housing), data centres, and retail stores.

The number of unique typecasts has expanded from 31 covered in the 2021 *Infrastructure Market Capacity* report to the 40 covered in this report due to the inclusion of new project types not adequately covered until now.

The naming conventions have been adjusted from the 2021 *Infrastructure Market Capacity* report to better reflect the types of projects now included in the demand analysis. A full list of (sub)sectors and a comparison between the typecasts in the 2021 and 2022 reports is available in *Appendix D: Infrastructure typecasts.*

Projects are classified according to project stage and funding source, as follows:

Project stage classifications:

- Planning
- Procurement
- Implementation, and
- Completed (in Operations and Maintenance)

Funding source classifications:

- Public
- Private
- Public/Private.

Creating a portfolio of major project activity

The transformation of project-level data into a portfolio (i.e., a monthly timeline) follows the principles established in the 2021 *Infrastructure Market Capacity* report. For each individual project, the total investment cost is split across time using start and finish dates (estimated for projects not yet commenced and/or finalised). This distribution of costs assumed that each project undergoes three distinct phases of investment, in order of size: the construction phase (80%), planning phase (15%) and the commissioning stage (5%).

Project investment costs are allocated to the planning and commissioning phases in a linear fashion, whereas a sigmoidal function (or 'S-curve') has been applied to the proportion of investment within the construction phase.[1] This method of cost distribution best reflects the general pattern of project expenditure over the construction phase: activity starts from small beginnings then accelerates over time to reach a climax before slowing to project completion.

Translating portfolio activity to resource demands

Similarly, translating the portfolio of project activity into resource demands follows the same process established in the 2021 *Infrastructure Market Capacity* report. For each individual typecast/sector, Turner & Townsend completed a detailed review of the project costing information across multiple project types and disciplines. This has allowed Turner & Townsend to develop a 'typical' project cost breakdown for each of the specific typecasts. Turner & Townsend's industry experience and knowledge was utilised to split these construction resources into more detailed cost breakdowns (per typecast – up to level four within the 'International Construction Measurement Standards'). These cost breakdowns have remained largely unchanged from the 2021 *Infrastructure Market Capacity* report although the expansion of the project database to include new typecasts has required the development of new cost breakdowns.

These cost breakdowns per typecast have been reconciled by Turner & Townsend over each resource category (plant, labour, equipment and materials) against industry accepted percentages. Finally, for each resource per typecast, a low, median and high estimate of demand was provided. This is to reflect the fact that although a 'typical' cost breakdown has been used for each typecast in this analysis, every individual infrastructure project is inherently different, even within the same sector. Consequently, the resulting individual resource demands are typically presented as occurring within a 'P90 range' (+-20% of the demand estimate generated) – that is, there is a 90% confidence that the actual demand lies in that range. For similar reasons, estimated growth in resource demands provided in this report are rounded to the nearest 5%.

The costs are as of 2021−22, with an appropriate level of escalation applied where applicable. In occurrences where there were variances within costs for certain items, an average of all costs collated was applied.

Turner & Townsend utilised the benchmarked rates for each resource per typecast to estimate the level of demand for each individual labour, plant, material and equipment construction resource based on the project expenditure per month for each individual project. The final output assigns a monthly expenditure for every cost item per project per typecast.

Resource classifications used in this analysis

The key resource categories used in the analysis remain unchanged from the 2021 *Infrastructure Market Capacity* report. However, there have been numerous additions to the resources within these categories to account for the sectoral expansion of the project database (for instance, plasterboard due to the inclusion of residential building).

The key resource categories developed for the infrastructure portfolio can be summarised by the acronym 'PLEM':

- Plant
- Labour
- Equipment
- Materials.

Plant covers individually distinct (and mostly mobile) capital items typically used in the implementation of major projects. It is further classified as either:

- Site plant: including cranes, scaffolding and scissor lifts
- Preliminaries: including site offices, lunchrooms and toilets
- Civil plant: including mobile plant such as excavators, graders, bulldozers and compactors

- Speciality plant: including items that are purpose built, modified or manufactured for a specific application/use such as tunnel boring machines, modified excavators and pile driving plant, augers, heavy transportation and low loaders amongst other items.

Labour covers workforce occupation categories and subcategories across the following major occupational groups (see *Appendix E: Resource classifications* for a complete list):

- Project Management Professionals: including occupational roles in Risk Management, Project Management, Commercial Management, Construction Management and Environmental and Occupational Health Professionals
- Engineering, Scientists and Architects: including a range of professional non-management roles including different types of Engineers, Surveyors, Architects, IT Professionals, Geologists, Maintenance Planners, Safety Officers and Procurement roles.
- Structures and Civil Trades and Labour: including Plant Operators, Concreters, Bricklayers, Carpenters and Joiners, Drillers, Rail Track Workers and Structural Steel Erectors amongst other roles.
- Finishing Trades and Labour: including Telecommunications Field Staff and Cablers, Plumbers, Electricians, Electrical Line Workers, Tilers, Glazers, Plasterers and Painters.

Equipment reflects generally non-distinct capital investment items and have been categorised as either control, electrical or mechanical equipment. Being non-distinct (and often bespoke) items, demand for equipment is expressed in dollar terms, not as units. This also applies to electrical bulk which is included in the materials category.

Materials cover the resources which are 'put in place' and include the following distinct items:

- Concrete, including aggregates, sand and cement
- Wall and frame materials, including timber, bricks, and plasterboard
- Rock and bluestone
- Steel: including structural and reinforcing steel as well as rail track
- Bitumen binders
- Asphalt
- Electrical bulk, representing mainly electrical cables, accessories and fittings, conductors, insulators, transformers, switches and other related items.

Interpreting the results

Last year's project-based view of the infrastructure market focussed almost exclusively on major public infrastructure pipeline; that is including public projects over $50 million for South Australia, Tasmania, the Northern Territory and the Australian Capital Territory, and $100 million for all other Australian states.

The market view has now been greatly expanded to include smaller value-works, achieving a truer view of public infrastructure demand. In addition, this analysis now also includes private construction demand data to increase our view of demand further. Both these factors are included in this report's findings.

For an even greater view of macro-level demand, this analysis is working towards the eventual inclusion of longtail project demands - i.e., the requirements of a project once it moves into the 'maintenance' phase of its lifecycle. Some progress has been made into this in the 'Roads' section in this report.

Appendix B: Supply-side analysis methodology

Introduction and methodology

Methodology

Unlike labour, where relatively consistent and detailed data is collected regularly by the Australian Bureau of Statistics, there is no equivalent single source of quantitative 'truth' for the supply capacity of some critical non-labour infrastructure inputs. This includes concrete and quarry products, other construction materials or construction plant and equipment.

- In the case of quarry materials, different state jurisdictions are responsible for publishing their own state production data (although not all state production is readily available) as well as a diverse range of information about individual quarries. Critically, there is little or no data on latent capacity (or legal capacity, given restrictions on production and truck movements) of the quarrying industry to increase production to meet rising demand.
- Similarly, while data for the steel industry, through the Australian Steel Institute and Australian Bureau of Statistics trade data, can provide trends in local steel production, exports and imports, there is little quantitative data on the extent by which local production can be increased to meet rising demand, how long it would take to increase local supply or whether high quality imports can be procured to bridge the gap.
- Unpublished plant and equipment sales data may be obtainable from private databases, though the Australian Bureau of Statistics maintains detailed data on the volume of construction plant and equipment exported and imported through trade statistics.
- For other key construction inputs materials – including fuel, oil, cement, concrete, clay bricks, roofing tiles and sawn timber – the Australian Bureau of Statistics historically published local production data through its Manufacturing Production (Cat. No. 8301.0.55.001) and Production of Selected Construction Materials (Cat. No. 8301.0) surveys, but these were discontinued in 2004 and 2014 respectively.[2]

Because quantifying supply is challenging, we have combined published production and trade data with industry surveys and interviews.

Insights are gathered and assessed from various commercial participants on what they see as the looming limitations on delivering Australia's ambitious infrastructure program. In these soundings, industry had both positive and negative feedback regarding the state of the Australian infrastructure market, the outlook and opportunities for activity, the way the infrastructure program is being procured and delivered, and the greatest risks to capacity. Through this approach, key 'pinch-points' in Australia's infrastructure supply chain have been identified which are under pressure now or could come under pressure in coming years.

Industry engagement

In fleshing out capacity challenges facing the local infrastructure supply chain, a two-stage industry engagement process was adopted:

- **Detailed surveys of builders and civil contractors.** Builders and civil contractors represent the main interface with public and private sector infrastructure clients, but also have broad oversight of the industry's draw on PLEM resources and so have insights as to where supply chains are being challenged. For this report it was important to gather perspectives across a diverse industry spectrum, from very large builders and contractors to smaller and medium sized businesses. The views of the former are generally reflected in a survey conducted by BIS Oxford Economics over March and April 2022, referred to in this report as the "BIS Oxford Economics Industry Survey", while perspectives from predominantly smaller and medium sized enterprises have been captured by a similar survey of its member base by the Civil Contractors Federation during May 2022.[3]
- **Deeper industry interviews with the wider supply chain.** These industry soundings, conducted over April and May 2022, allowed more time and discussions for deeper probing of challenges with major infrastructure industry suppliers. These soundings helped pinpoint where capacity challenges were already apparent or at risk, their potential causes as well as possible solutions that would help mitigate capacity risk. For this report, these interviews were held with
    a. Suppliers of quarry materials, concrete and related products
    b. Steel producers and fabricators, and
    c. Distributors of plant and construction equipment.

Industry survey insights

To better understand the nature of supply side constraints affecting the broad spectrum of the infrastructure market, three industry surveys were undertaken focusing on builders and civil contractors. These were the 2022 Infrastructure Australia survey, the 2022 Civil Contractors Federation (Tier 3) member survey (noted below), both of which surveyed a broad spectrum of the market focusing on both large Tier 1s and smaller businesses (Tier 3s).

- **2022 BIS Oxford Economics industry survey.** This survey, conducted by telephone over March and April 2022, generally focused on larger builders and civil contractors which operate in the Australian market. These include many 'tier 1' businesses that have greater capacity to bid for larger infrastructure projects, including 'megaprojects' that exceed $1 billion in value. Being larger companies, they are also more likely to operate across multiple state jurisdictions. By combining the key characteristics of respondents with answers provided, the BIS Oxford Economics Industry Survey identifies differences in responses based on the industry segment (builder or civil contractor), business size (capital value of projects and number of employees) and location (state, or metropolitan versus smaller regions).
- **2022 CCF member infrastructure market capacity survey.** During May 2022, the National Branch of the Civil Contractors Federation (CCF), at the behest of Infrastructure Australia, coordinated a survey of its own member base. The CCF is the peak body representing Australia's civil construction industry, with approximately 2,000 contractor and associate members nationally. While the CCF does include some Tier 1 businesses, it is predominantly populated by smaller and medium sized contractor businesses that are located throughout metropolitan and regional Australia. Therefore the CCF survey will stress 'Tier 3' in this document. 80% of CCF (TIER 3) Member survey respondents reported that their maximum contract size was under $20 million (and over half reported a maximum contract size of under $5 million). This compares to the 5% in the BIS Oxford Economics survey who reported a largest contract size of under $10 million, and the 73% of respondents which reported a maximum contract size of over $500 million. Unlike the smaller BIS Oxford

Economics Industry Survey (which was conducted via a 30 minute telephone interview) the CCF (Tier 3) Member Survey was conducted online.

By undertaking data collection across the spectrum of infrastructure businesses, it was hoped that an overarching 'industry view' would not be biased towards either very small or very large organisations. There were interesting similarities in the responses to some of the questions asked, suggesting that some concerns are not isolated to just large or small companies. However, there were also critical differences, particularly in relation to industry capacity to deliver and proposed solutions to capacity challenges.

Survey questions asked

The structure of the survey was broadly as follows:

- Respondent characteristics (size, location, segment, ownership etc.)
- Recently experienced growth in activity
- Anticipated growth in activity in coming years
- Factors impacting capacity and capability
- Specific supply chain challenges by input
- Recent experience with cost escalation (labour and non-labour inputs)
- Impacts from the COVID-19 pandemic
- Potential solutions to mitigate capacity/capability risk
- Confidence in delivering infrastructure over next 12 months, two to four years, or beyond five years
- Confidence to proportionally scale up to meet increases in public infrastructure investment

Tier 3 survey methodology summary

From 11 to 22 July, 2022, Infrastructure Australia surveyed 190 decision-makers in Tier 3 construction companies. These were defined as companies offering:

a. Companies where the value of the largest contract they held over the past 3 years is $100 million or less.

b. Sole traders with the value of their largest contract they held over the past 3 years is $500,000 or less or average annual turnover up to $1 million are excluded.

A range of company sizes was engaged, with carpentry, licensed building, engineering, electrical and plumbing being the main services represented.

Surveys were conducted online and were approximately 10 minutes in length.

The maximum margin of error on the total sample of n=190 is +/-7.1% at the 95% confidence level. Differences of +/-1% for net scores are due to rounding.

Appendix C: Infrastructure typecasts

Project information sources and data difficulties

Project information sources

The project-level data that provides the basis for analysis within the *Infrastructure Market Capacity* report is a product of collaboration between private sector suppliers (GlobalData, BIS Oxford Economics), Infrastructure Australia, the Jurisdictions and the Australian Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA).

The Major Public Infrastructure Pipeline (major public infrastructure pipeline) utilised publicly funded project information mainly sourced from data-sharing partnerships between Infrastructure Australia, the Jurisdictions and DITRDCA. The data received from the states and territories included infrastructure projects that were allocated funding in the 2020—21 budget. The data received from DITRDCA included transport infrastructure projects that have been allocated federal funding since 2017−18.

Both these datasets contained information on projects that had commenced prior to 2020−21 (2017-18) if they were still underway. However, these datasets did not provide information on projects that had already finalised by those years. Project-level data provided by GlobalData and supplemented by BIS Oxford Economics was used to fill gaps in the project database – this included projects which had finalised before the dates above, or projects that were otherwise outside of the scope of the jurisdictional/federal lists (for instance, council projects that were valued above the $50/$100 million cut-off).

In some instances, projects were disaggregated so that they could be appropriately categorised across different infrastructure typecasts. For instance, a rail project that involved stations, tunnelling and aboveground line works would be split into three components that would sit in three different typecasts – those being 'Station (Rail)', 'Tunnel (Rail)', and 'Main Line Works (Rail) (Greenfield)'.

The expansion of the project database to include privately funded projects and publicly funded projects beneath the threshold value cut-off was facilitated by data provided by GlobalData and BIS Oxford Economics. Furthermore, the road construction and maintenance market forecasts were provided by BIS Oxford Economics.

Data difficulties

The gathering and collation of project-level data across the variety of sources has allowed for an enhanced view of project activity across Australia. In combination, the data sources provided more than 10,000 project entries. This was then reduced to 5,772 unique entries that would constitute the Total Infrastructure Pipeline (and 775 unique entries within that which constitute the Major Public Infrastructure Pipeline).

The substantial reduction in project entries is reflective of an intensive manual data cleaning process during the development of this report. This process was required for numerous reasons, most importantly, the project-level data provided by the different sources was not tailored to the data requirements of this report. As such, each source (including different jurisdictions) contained unique formatting that had to be collated and standardised.

Due to the above, the main difficulty was the duplication of project entries across different data sources – for instance, transport projects with split state and federal funding would be contained in two lists. Furthermore, the project-level data sourced from GlobalData and BIS Oxford Economics contained both publicly and privately funded infrastructure such that the aforementioned transport project could potentially be found across four datasets. The unique formatting (and naming conventions) of the different data sources made identifying these duplicates an intensive manual process.

The main difficulties are summarised below, with the guidelines used to deal with them:

- Duplication across data sources: in the instance where the same project was identified across numerous data sources, jurisdictional and federal project information was treated as the most accurate source.
- Projects outside of scope: despite the widening of the project database, there are still certain types of projects which were excluded in this report. This includes offshore projects, Defence projects, projects that finalised before 2014-15, projects with insufficient explanatory detail, projects that had not yet been confirmed (speculative, not relevant to jurisdictional/federal data) and projects which belonged to a typecast outside of the scope of the 2022 Infrastructure Market Capacity report (notably, mining and heavy industry).
- Programs of work: programs of work and the individual projects that constitute these programs were identified across the data sources. In the instance where the individual projects provided additional detail (compared to the program of works), then they were included in the database and the program of works was excluded to avoid a double count of expenditure. In the instance where the individual project expenditure did not sum to the total value of the program of works, then the program of works was included and assigned a capital cost equal to the difference between the total program value and the summed individual projects.

Infrastructure typecasts

The portfolio comprises 3 broad infrastructure sectors:

- Transport
- Utilities, and
- Buildings

The portfolio breaks these three sectors down across the following 17 Master Types and 62 separate typecasts as shown in Table 1 below.

Table 1: Infrastructure typecasts

SuperSector	MasterType	Typecast
Transport	Road	State Road (Highway/Freeway)
Transport	Road	Bridge (Road)
Transport	Road	Low Use Road
Transport	Road	Tunnel (Road)
Transport	Road	Routine Road Maintenance
Transport	Road	State Road (Highway/Freeway) Rehabilitation Maintenance
Transport	Road	Low Use Road Rehabilitation Maintenance
Transport	Rail	Station (Rail)

Transport	Rail	Main Line Works (Rail) (Greenfield)
Transport	Rail	Tunnel (Rail)
Transport	Rail	Bridge (Rail)
Transport	Rail	Light Rail (Greenfield)
Transport	Rail	Light Rail, Stabling, and Signalling Works (Brownfield)
Transport	Rail	Main Line Works (Rail) (Brownfield)
Transport	Road/Rail	Level Crossing
Transport	Aviation	Airport Runway
Utilities	Energy and Fuels	Gas Pipeline
Utilities	Energy and Fuels	Wind
Utilities	Energy and Fuels	Utility Solar
Utilities	Energy and Fuels	Hydro
Utilities	Energy and Fuels	Pumped Hydro
Utilities	Energy and Fuels	Transmission Line: Single Circuit
Utilities	Energy and Fuels	Transmission Line: Double Circuit
Utilities	Energy and Fuels	Transmission (other)
Utilities	Energy and Fuels	Coal
Utilities	Energy and Fuels	CCGT
Utilities	Energy and Fuels	Peaking Gas+Liquids
Utilities	Telecomm and Digital	Telecommunications
Utilities	Water and Sewerage	Water Pipeline
Utilities	Water and Sewerage	Dam
Utilities	Water and Sewerage	Water Treatment Plant
Buildings	Aviation	Airport Building
Buildings	Education	School (Greenfield)
Buildings	Education	School (Brownfield)
Buildings	Education	Higher Education (Brownfield)
Buildings	Education	Higher Education (Greenfield)
Buildings	Education	Higher Education (Addon/Brownfield)
Buildings	Health	Hospital (Greenfield)
Buildings	Health	Hospital (Addon/Brownfield)
Buildings	Health	Health Facility (Greenfield)
Buildings	Health	Health Facility (Brownfield)
Buildings	Health	Aged Care Facility (Greenfield)
Buildings	Health	Aged Care Facility (Brownfield)
Buildings	Health	Health Facility (Addon/Brownfield)
Buildings	Health	Aged Care Facility (Addon/Brownfield)
Buildings	Justice	Correctional Centre
Buildings	Justice	Courthouse
Buildings	Justice	Police Facility
Buildings	Justice	Fire and Emergency Facility
Buildings	Other Building	Civic/Convention Centre
Buildings	Other Building	Office
Buildings	Other Building	Arts Facility
Buildings	Other Building	Laboratory
Buildings	Residential	Detached Residential
Buildings	Residential	Multi Residential
Buildings	Residential	Semi-detached Residential

Buildings	Residential	Accommodation
Buildings	Retail	Retail Store
Buildings	Sports Facility	Arena/Sporting Facility
Buildings	Telecomm and Digital	Data Centre
Buildings	Transport Building	Parking Facility
Buildings	Transport Building	Warehouse

Appendix D: Resource classifications

Resource Classifications

Labour was focused on the following occupational breakdowns considered most relevant to the infrastructure market and consistent with the Australian and New Zealand Standard Classification of Occupations (ANZSCO).

Table 2: Labour occupation classification

PLEM Category	Major Subdivision	Minor Subdivision	Detailed Item
Labour	Engineering, Scientists and Architects	Architect	Architect
Labour	Engineering, Scientists and Architects	Civil Engineer Professionals	Civil Engineer
Labour	Engineering, Scientists and Architects	Civil Engineer Professionals	Geotech Engineer
Labour	Engineering, Scientists and Architects	Civil Engineer Professionals	Quantity Surveyor
Labour	Engineering, Scientists and Architects	Civil Engineer Professionals	Structural Engineer
Labour	Engineering, Scientists and Architects	Draftsperson	Draftsperson
Labour	Engineering, Scientists and Architects	Electrical Engineer	Electrical Engineer
Labour	Engineering, Scientists and Architects	Electronic Engineer	Electronic Engineer
Labour	Engineering, Scientists and Architects	Engineering Manager	Engineering Manager
Labour	Engineering, Scientists and Architects	Environmental Professionals	Environmental Professionals
Labour	Engineering, Scientists and Architects	Geologists, Geophysicists and Hydrogeologists	Geologists, Geophysicists, and Hydrogeologists
Labour	Engineering, Scientists and Architects	Industrial, Mechanical and Production Engineers	Mechanical Engineer
Labour	Engineering, Scientists and Architects	IT Professionals	IT Professionals
Labour	Engineering, Scientists and Architects	Landscape Architect	Landscape Architect
Labour	Engineering, Scientists and Architects	Maintenance Planner	Maintenance Planner
Labour	Engineering, Scientists and Architects	Other Professional Engineers	Other Professional Engineers
Labour	Engineering, Scientists and Architects	Procurement	Procurement
Labour	Engineering, Scientists and Architects	Safety Officer	Safety Officer
Labour	Engineering, Scientists and Architects	Surveyor	Building Surveyor
Labour	Engineering, Scientists and Architects	Surveyor	Land Surveyor

Labour	Engineering, Scientists and Architects	Telecoms Engineer	Telecoms Engineer
Labour	Finishing Trades and Labour	Electrical Line Workers	Electrical Line Workers
Labour	Finishing Trades and Labour	Electricians	Electricians
Labour	Finishing Trades and Labour	Glazer	Glazer
Labour	Finishing Trades and Labour	Painting Trades	Painting Trades
Labour	Finishing Trades and Labour	Plasterers	Plasterers
Labour	Finishing Trades and Labour	Plumbers	Plumbers
Labour	Finishing Trades and Labour	Telecoms Cabler	Telecoms Cabler
Labour	Finishing Trades and Labour	Telecoms Field Staff	Telecoms Field Staff
Labour	Finishing Trades and Labour	Tiler	Tiler
Labour	Project Management Professionals	Enviro. & Occupational Health Professionals	Enviro. & Occupational Health Professionals
Labour	Project Management Professionals	Project Management Professionals	Commercial Management
Labour	Project Management Professionals	Project Management Professionals	Construction Management
Labour	Project Management Professionals	Project Management Professionals	Project Management
Labour	Project Management Professionals	Project Management Professionals	Risk Management
Labour	Structures and Civil Trades and Labour	Bricklayer	Bricklayer
Labour	Structures and Civil Trades and Labour	Carpenters and Joiners	Carpenters and Joiners
Labour	Structures and Civil Trades and Labour	Concreter	Concreter
Labour	Structures and Civil Trades and Labour	Crane Op	Crane Op
Labour	Structures and Civil Trades and Labour	Driller (Piling/Foundations)	Driller (Piling/Foundations)
Labour	Structures and Civil Trades and Labour	General Construction Labourer	General Construction Labourer
Labour	Structures and Civil Trades and Labour	Other	Other
Labour	Structures and Civil Trades and Labour	Plant Op	Plant Op
Labour	Structures and Civil Trades and Labour	Rail Track Worker	Rail Track Worker
Labour	Structures and Civil Trades and Labour	Rigger & Dogman	Rigger & Dogman
Labour	Structures and Civil Trades and Labour	Road Based Civil Plant Op	Road Based Civil Plant Op
Labour	Structures and Civil Trades and Labour	Structural Steel Erector	Structural Steel Erector

Plant, materials and equipment was classified according to the system adopted in Table 3.

Table 3: Plant, material and equipment classification

PLEM Category	Major Subdivision	Minor Subdivision	Detailed Item
Material	Asphalt	Asphalt	Asphalt
Material	Bitumen Binders	Bitumen Binders	Bitumen Binders
Material	Concrete	Concrete	Aggregate
Material	Concrete	Concrete	Cement
Material	Concrete	Concrete	Sand
Material	Electrical Bulk	Electrical Bulk	Electrical Bulk
Material	Other	Linemarking & Road Furnitures	Linemarking & Road Furnitures
Material	Rock/Bluestone	Rock/Bluestone	Rock/Bluestone
Material	Steel	Girders	Girders
Material	Steel	Rail Track	Rail Track

Material	Steel	Steel – Structural Elements	Steel – Structural Elements
Material	Steel	Steel Re-inforcement	Steel Re-inforcement
Material	Walls	Bricks	Bricks
Material	Walls	Plasterboard	Plasterboard
Material	Walls	Timber	Timber
Plant	Civil	Bulldozers	Bulldozers
Plant	Civil	Compactor	Compactor
Plant	Civil	Excavator	Excavator
Plant	Civil	Graders	Graders
Plant	Prelims	Site Offices, Lunchrooms	Site Offices, Lunchrooms
Plant	Prelims	WC	WC
Plant	Site	Mobile Cranes	Mobile Cranes
Plant	Site	Scaffold (tubular)	Scaffold (tubular)
Plant	Site	Scissor Lifts	Scissor Lifts
Plant	Site	Street Sweeper	Street Sweeper
Plant	Site	Tower Cranes	Tower Cranes
Plant	Speciality Plant	Speciality Plant	Speciality Plant
Equipment	Control Equipment	Control Equipment	Control Equipment
Equipment	Electrical Equipment	Electrical Equipment	Electrical Equipment
Equipment	Mechanical	Mechanical	Mechanical

Appendix E: Workforce and skills methodology

Definitions

Demand

- **Major public infrastructure pipeline demand** refers to the estimated workforce resources (that is, the sum of full-time equivalents in occupations as defined by Infrastructure Australia) required to undertake major public building and engineering construction. Major projects are those with a value above either $100 million (in New South Wales, Victoria, Queensland or Western Australia) or $50 million (South Australia, Tasmania, the Australian Capital Territory or the Northern Territory), as well as all energy projects regardless of total value.
- **Total public infrastructure pipeline demand** refers to the workforce required to undertake total public infrastructure building and engineering construction. This includes all of the major public infrastructure pipeline, as well as publicly funded projects below the major public infrastructure pipeline threshold, all roads maintenance, and privately funded public infrastructure.
- **Non-major public infrastructure pipeline demand** refers to those public infrastructure projects not otherwise captured by major public infrastructure pipeline.
- **Privately funded public infrastructure** is any building or engineering construction that is privately built, but is for public use, regardless of ultimate ownership or operation. All transport and utilities projects are considered public infrastructure, as are a subset of non-residential buildings. For example, hospitals may be privately funded, owned, and operated, but are considered public infrastructure.
- **Private demand** refers to the workforce required to complete all other private engineering construction and building, which is anything that is privately funded and not otherwise captured by the definitions above. This comprises mostly residential building, but it includes a portion of private non-residential building and private engineering construction for private use.
- **Building and engineering construction** for the definitions above refer to projects relating respectively to fixed structures with a roof, and anything without a roof (e.g., roads, rail, pipelines). ‘Building’ and ‘construction’ may be used interchangeably elsewhere in the report. The ‘construction industry/sector’ (as defined in the ANZSIC standard) captures work on both buildings and engineering construction.

Occupational groups

The public infrastructure workforce consists of four main occupational groups, each consisting of discrete occupations.

- **Project management professionals** plan, organise, direct, control and coordinate the construction process. They are typically responsible for the physical and human resources engaged across the construction lifecycle.
- **Engineers, scientists and architects** design, plan, organise and manage the detailed specifications of the construction and maintenance. They are engaged throughout the construction process and include many subspecialists.
- **Structures and civil trades and labour** do construction and the preparation for construction. They include those who support these tasks, such as truck drivers and crane operators.
- **Finishing trades and labourers** move infrastructure projects from construction to completion. They fit out construction projects and ensure they are operational and can be used for their particular purpose.

Occupations and roles

Occupations were defined using the Australian and New Zealand Standard Classification of Occupations (ANZSCO), through consultation with Infrastructure Australia's industry experts and additional key stakeholders.

Roles were defined using job advertisement data from Burning Glass and consultation with industry stakeholders. Roles provide a greater specificity on the workforce needed to support the current and future infrastructure pipeline that would otherwise be masked by occupational analysis.

Burning Glass aggregates job advertisements to create insight into the supply and demand for talent. The data set includes millions of job advertisements covering every occupation and industry in Australia.

Skills

Skills were defined using the Burning Glass skills taxonomy. Burning Glass developed this taxonomy using proprietary algorithms that defined and referenced over 1,500 general and technical skills identified by employers as important for new hires. This can be used to understand trends in skill demand, including skill needs for specific occupations.

Workforces

The engaged workforce is made up of those workers engaged on public infrastructure construction work. The adjacent workforce is made up of those in the rest of the construction industry, who would take zero to six months to train. The trainable workforce is made up of those working outside the construction industry who have a high level of overlapping skills, who would take approximately six to 12 months to train. The distant workforce is made up of those working outside the construction industry who have only some overlaps in skills, who would take one to three years to train.

The trainable and distant workforces work in industries such as professional, scientific, and technical services; transport, postal and warehousing; public administration and safety; and mining.

Occupational shortage assessment

The table below shows how the overall assessment of occupational shortages was produced. **Overall assessment** reflects whether occupations were likely in shortage (fulfilled three or more criteria), potentially in shortage (fulfilled two criteria) or unlikely to be in shortage (fulfilled less than two criteria).

There are four criteria:

- **NSC Skill Priority List** – is the occupation considered in shortage across Australia in the June 2021 Skills Priority List? Note that this assessment replaces the 'Migration shortage list' assessment used in the 2021 report.
- **Recognised by industry** – is an occupation suggested to be in shortage in relevant literature or by industry stakeholders in consultations?
- **Existing worker shortage in public infrastructure** – is the demand for an occupation in public infrastructure exceeding the supply for an occupation in our modelling? Assessed as at June 2022.
- **Labour market Indicators** – is an occupation in shortage according to the following criteria: change in advertised salary; change in share of job advertisements; and share of advertisements posted for more than 30 days?

Table 4: Assessment of shortage and the relevant indicators for each occupation by occupational group

Project management professionals

Occupations	Overall Assessment	NSC Skills Priority List	Recognised by industry	Existing worker shortage	Labour Market Indicators
Commercial management	**Unlikely**			x	
Construction management	**Potential**	x	x		
Environmental and occupational health professional	**Unlikely**			x	-
Procurement	**Unlikely**			x	-
Project management	**Unlikely**		-	x	-
Risk management	**Likely**	x	x	x	-

Engineers, scientists and architects

Occupations	Overall Assessment	NSC Skills Priority List	Recognised by industry	Existing worker shortage	Labour Market Indicators
Architect	**Unlikely**		-		
Building surveyor	**Potential**		x	x	-
Civil engineer	**Likely**	x	x	x	
Draftsperson	**Unlikely**		-	x	-
Electrical engineer	**Potential**	x	x	x	
Electronic engineer	**Unlikely**				X
Engineering manager	**Potential**	x	x		-

Environmental professional	**Likely**		x	x	x
Geologist, geophysicist, and hydrogeologist	**Likely**	x	x	x	x
Geotech engineer	**Likely**	x		x	x
IT professionals/engineer	**Potential**		x	x	-
Land surveyor	**Likely**	x	x	x	-
Landscape architect	**Unlikely**				
Maintenance planner	**Unlikely**			x	-
Mechanical engineer	**Potential**	x	x		
Other professional engineer, scientist, etc.	**Potential**	N/A	x	x	-
Production engineer	**Potential**		x		x
Quantity surveyor	**Likely**	x	x	x	
Structural engineer	**Potential**	x	-	x	
Materials Engineer	**Potential**		x		x
Telecommunications Engineers	**Unlikely**		x	x	x

Structural and civil trades and labour

Occupations	Overall Assessment	NSC Skills Priority List	Recognised by industry	Existing worker shortage	Labour Market Indicators
Bricklayer	**Likely**	x	x	x	-
Carpenters and Joiners	**Potential**	x	x		
Concreter	**Potential**		x	x	-
Crane op	**Potential**		x	x	
Driller (piling/foundations)	**Potential**		x	x	-
Plant operator	**Potential**	x		x	-
Rigger and dogman	**Unlikely**			x	-
Road based civil plant operator	**Likely**	x		x	x
Truck drivers	**Unlikely**		-		-
Rail Track Worker	**Unlikely**		N/A	x	N/A
Structural Steel Erector	**Unlikely**		N/A	x	N/A

Finishing trades and labourers

Occupations	Overall Assessment	NSC Skills Priority List	Recognised by industry	Existing worker shortage	Labour Market Indicators
Electrical or telecommunications trades assistant	**Potential**	#N/A	x		x
Electricians	**Potential**	x	x		-
General construction labourer	**Potential**		x	x	-

Glazier	**Likely**	x	x	x	-
Mechanical engineering trades workers	**Unlikely**	x			-
Painting trades	**Likely**	x	x	x	
Plasterers	**Potential**	x			x
Plumbers	**Unlikely**	x	-		-
Safety officer	**Potential**			x	x
Telecoms cabler	**Likely**	x	x	x	-
Tiler	**Likely**	x	x		x
Electrical Line Workers	**Potential**	x	N/A	x	N/A
Telecoms Field Staff	**Unlikely**		N/A	x	N/A

Note: Cells with grey backgrounds differ from the same assessment in the 2021 report.

Modelling methodology

Introduction

The fundamental question addressed by this report is to what extent the current and projected supply of labour can support Australia's proposed investment in public infrastructure. To understand this, it was necessary to clearly define the occupations and skills that underpin this workforce and to estimate the numbers of workers available at different points in time, including projections for the future. The broad approach was:

- To estimate numbers of workers in or near the infrastructure workforce as determined by official statistics and our own forecasts or modelling based on those statistics
- To confront these estimates with additional data (such as job advertisements) that provides extra information on variables (such as skills) not covered by the official statistics, and extra granularity (such as estimates down to the level of 'roles', below existing ANZSCO unit groups) on variables which required further detail than official statistics provided.

The analytical work has two elements: developing classifications and making estimates. The two elements overlap, as we used data-based estimates to define our classifications, but it is useful to understand the steps separately.

Two key classifications were developed for this work and are used throughout the report. These classifications build on the standard classifications used for occupation and industry: the Australian and New Zealand Standard Classification of Occupations (ANZSCO) and the Australia and New Zealand Standard Industrial Classification (ANZSIC). Using data to categorise, combine (and in some cases add) our final occupational classifications added additional granularity to the standard measures. The two classifications are:

1. Which occupations and roles are relevant to public infrastructure?
2. Which parts of the workforce in relevant occupations are engaged in, adjacent to, trainable for or distant from public infrastructure?

These classifications were developed to capture the full range of occupations that contribute to public infrastructure in a single streamlined taxonomy. They also support a more nuanced view of the labour force that recognises the portability of skills across and between sectors. Finally, the addition of roles provides a level of granularity which is not present in ANZSCO but which is critical to understanding skill needs.

There were six key pieces of data analysis that built on those classifications, seeking to estimate:

1. Historical and current labour supply

2. Anticipated workforce attrition
3. Future labour supply
4. Workforce shortages
5. Skill profiles
6. Demographics.

The methods used for these two classifications and six pieces of analysis are outlined in more detail below.

The most important data sources across the project were the 2016 Census and the ongoing Labour Force Survey, to quantify where supply matched demand until 2036; and job advertisement data from Burning Glass as an indicator of demand. Each of these data sources has its own strengths and weaknesses, which limits the conclusions that can be drawn:

- The Census is comprehensive but infrequent; it is self-completed and depends on respondents identifying their own occupation and industry.
- The Labour Force Survey is carefully calibrated to definitive population totals and has higher quality consistent use of classifications, but it is based on a sample.
- The job advertisements are also a sample, but of a varying and unknown proportion of the full quantum of demand – varying not just over time but also by occupation and industry.
- The classification of job advertisements to industry and occupation is done by a statistical / machine learning algorithm based on analysis of the original text, introducing its own statistical noise.

Key limitations of the analysis can be understood in several categories:

- Measurement noise – such as Census respondents misclassifying their industry or occupation in a way different to any misclassification that takes place in the Labour Force Survey
- Processing noise – such as the Burning Glass Technologies machine learning algorithm misclassifying the occupation of a job advertisement
- Analytical assumptions – such as assuming that the proportions of detailed job titles within an ANZSCO unit group in the workforce reflect the proportion of those titles appearing in job adverts for that ANZSCO unit group; or that the proportion of people in each industry working in each occupation at the time of the Census (the best source at that level of granularity) has not changed materially since.

Every effort has been made to control for these problems, as outlined in the detail below, but significant uncertainty and limitations are inevitable.

Defining public infrastructure relevant occupations and roles

Methodology

An occupational and role taxonomy was developed in partnership with Infrastructure Australia and their other consulting partners. Before the start of this project Infrastructure Australia identified a three-tier taxonomy, including group, classification, and sub-classification.

An initial mapping of sub-classifications was provided to Nous for review. Nous mapped unit level ANZSCOs to Infrastructure Australia classifications to enable alignment with the Infrastructure Australia and ANZSCO taxonomies.

With classifications defined, job advertisement data provided by Burning Glass Technologies was used to identify key roles by occupational classification. Roles are a level below ANZSCO unit group.

Under guidance of Infrastructure Australia, we were advised that many project management roles on public infrastructure projects were undertaken by individuals captured under other occupations. Nous analysed job advertisements data to identify roles that required a similar skill set using cosine similarity. A weighting was then developed to apportion a share of Infrastructure Australia sub-classifications to the project manager sub-classification. Any ANZSCOs that contained less than one per cent of project management professional roles in its job advertisements were excluded from further analysis.

Assumptions

The following assumptions were adopted in defining infrastructure-relevant occupations:

1. Job advertisements are matched appropriately to ANZSCO unit groups in the Burning Glass data set.
2. All individuals covered by a mapped ANZCO unit group have skills relevant to public infrastructure.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. The workforce engaged in public infrastructure is diverse. Several occupations involved in pre-planning stages have been omitted from the analysis, such as construction lawyers, transport economists and policy analysts.
2. Infrastructure-relevant occupations are limited to those identified as working in the sector. Individuals outside defined occupations may share a sufficient base of skills to be relevant for public infrastructure. This is most likely true for labouring occupations such as general construction labour, riggers or operators of basic plant.

Defining the engaged, adjacent, trainable and distance share of the workforce

Methodology

Individuals were allocated to ANZSIC group segments by ANZSCO based on census data. ANZSIC groups were then classified based on those directly linked to the construction of public infrastructure and those that were not. ANZSIC groups identified as directly linked included ANZSIC E, 692, 942 and 529. These formed the basis of engaged and adjacent estimates, with trainable and distant drawn from the remaining ANZSICs.

Weightings were developed to apportion the share of workers engaged and adjacent to public infrastructure. Workforce-to-spend ratios provided by Infrastructure Australia were used to calculate public-private split estimates based on labour, rather than for the total value of projects by state and type of project. Occupational profiles by ANZSIC groups were then used to estimate which occupations were most likely to be working on public and private projects, allowing us to map the monetary public-private split data to the actual supply of labour for engaged and adjacent individuals.

For each ANZSIC group not identified as directly linked, a skills profile was developed using Burning Glass job advertisement data. This was compared to the profile for the same occupation in directly linked ANZSICs using cosine similarity analysis. Based on similarity score the ANZSCO-ANZSIC segment was allocated to either the trainable or distant category.

Assumptions

The following assumptions were adopted in defining the engaged, adjacent, trainable and distant shares of the public infrastructure related workforce:

1. Australian Bureau of Statistics data collections capture the full extent of government investment in public infrastructure.
2. ANZSIC E, 692, 942 and 529 account for most of the building and engineering construction activity.
3. Ratios provided by Infrastructure Australia to translate value to employment are consistent with industry practice.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Our definition includes work funded by all tiers of government (Australian Government, state and territory governments and local councils). We are unable to differentiate based on funder.
2. The Australian Bureau of Statistics expenditure data does not present any split within the private sector that can be used to estimate work done on private projects destined for private ownership but meant for public use. This relates to the caveat outlined in section 3.1.

Estimating historical and current labour supply for public infrastructure

Methodology

Bespoke estimates of workforce supply by ANZSCO unit and ANZSIC group for Infrastructure Australia-relevant occupations were developed by Nous. Estimates were developed for 2016 based on census data at ANZSCO 4 and Burning Glass job advertisement data. This approach was used due to Australian Bureau of Statistics perturbation of data where there is a risk of identifying individuals due to small numbers. Iterative proportional fitting was used to ensure that figures at the ANZSCO 6-digit level were consistent with higher level census results. A tailored Australian Bureau of Statistics request was used to validate estimates based on the ANZSCO unit by ANZSCO group level data provided.

Supply estimates were projected forward to 2022 based on results of Australian Bureau of Statistics labour force survey using iterative proportional fitting. The result was estimates for total workforce in infrastructure-relevant roles. This workforce was then apportioned based on weightings developed in the previous step to determine the number of engaged, adjacent, trainable or distant workers from 2016 to 2022.

Assumptions

The following assumptions were adopted to estimate the historical and current labour supply for public infrastructure:

1. The distribution of job advertisements by ANZSCO unit group is a reasonable approximation of the workforce under each ANZSCO minor group.
2. Individuals are classified in the same way under census, labour force survey and Burning Glass data.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Small variations in estimates may occur at sub-jurisdictional level from official statistics due to the approach adopted to overcome limitations in census microdata.

Estimating anticipated future workforce attrition

Methodology

Estimates of workforce attrition are based on changes to the age profile of the current infrastructure workforce between two consecutive Census surveys.

Age profiles of individuals in the current workforce were approximated using 2016 Australian Bureau of Statistics Census demographic data of individuals working in construction related industries, split by five-year age groups. The attrition rate was calculated based on movement between the 2011 Census and 2016 Census of consecutive five-year age groups for individuals older than 45 years old under the construction ANZSIC. The change between the two Census surveys and consecutive age groups captures mortality, retirement and career changes.

Nous then iteratively shifted the age distribution of the current workforce every five years, and applied attrition estimates to the respective five-year age groups. This produced attrition estimates by occupation and age to 2036.

Assumptions

The following assumptions were adopted in projecting workforce attrition:

1. The age distribution of the current infrastructure workforce is well approximated by the age profile of individuals working in construction related industries.
2. The change in workforce between the two Census surveys mostly captures mortality and retirement.
3. The change in workforce at an ANZSCO 6-digit level is well approximated by changes at the ANZSCO 4-digit level.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Estimated attrition ranges may vary within the ANZSCO 6-digit level compared to the ANZSCO 4-digit level.
2. We are unable to differentiate attrition by mortality, retirement or career changes.

Estimating future labour supply for public infrastructure

Workforce supply forecasts from 2022 to 2036 were developed by integrating current supply with education and migration inflows modelled from 2022 onwards. Inflows were modelled at an ANZSCO occupation level; neither education nor migration were modelled directly at the workforce (i.e., engaged/adjacent/trainable/distant) level. To estimate this breakdown, the current and historical supply were used to derive an average engaged/adjacent/trainable/distant workforce composition, and these proportions were applied to inflows.

Education inflow

New entrants via education were estimated based on the number of workforce-ready graduates across higher education and vocational education and training (including apprenticeships and traineeships, qualifications, and individual units of competency) in each year and mapped to infrastructure-related ANZSCOs. This was done in three steps:

Forecast population to 2036 by five-year age groups

Population projections derived by the Australian Institute of Health and Welfare (AIHW) were used to model population in five-year age groups at the Statistical Area Level 2 granularity up until 2032. Population projections between 2032 and 2036 were interpolated using the compound annual growth rate (CAGR) from 2027 to 2032.

Projecting the number of workforce-ready graduates (all pathways)

Domestic bachelor (higher education) commencements were calculated each year, by age group and translated to a ratio of commencements in each region, per age group, by its population. The commencement ratio was then combined with population forecasts to 2036 to obtain commencements into 2036. Commencements were then overlayed with estimated completion rates from the Department of Education, Skills, and Employment to project graduations. Estimates were then adjusted to account for students who may delay workforce entry to pursue further study.

Vocational education and training graduates were calculated in three parts – apprenticeships and traineeships, qualification completer, and part completers (people that may only undertake a few units of competency for occupational or high-risk licencing purposes). Apprentice and trainee completions were calculated with a similar approach used for domestic bachelor graduates, with completion rates based on prior Nous work. Our approach for non-apprenticeships or traineeship was adjusted to accommodate individuals who did not complete their full training but had completed all intended training to obtain the job they needed. The completion rates for non-apprenticeships and non-completers who had completed all intended training draw on data from the National Centre for Vocational Education Research (NCVER). To avoid double counting of individuals already in the labour market, both apprenticeships and non-apprenticeship graduates were filtered to only include individuals studying to get a job or to transition careers.

The workforce-ready graduates were mapped to Infrastructure Australia groups and Infrastructure Australia subclasses using Nous' proprietary concordance that link education to occupation.

Migration inflow

Migration inflows were projected using data supplied by the Department of Home Affairs. Data was broken down by visa subclass at an ANZSCO unit group level. Four visa subclasses were modelled that relate to permanent labour increases: 186 Employer Nomination Scheme; 187 Regional Sponsored Migration Scheme; 189 Skilled – Independent; and 190 Skilled – Nominated. Temporary visas were excluded to avoid double counting of the workforce. Migration figures were apportioned to regions based on existing distributions.

Assumptions

The following assumptions were adopted to estimate future labour supply for public infrastructure:

1. New supply is estimated on an annual basis and distributed evenly across the calendar year.
2. Population forecasts from 2032 to 2036 follow the compound annual growth rate of the AIHW's 2027-2032 population forecast.
3. The current rates of people commencing study is maintained to 2036.
4. The relationship between field of education and ANZSCO career outcomes are maintained.
5. 40% of commencing higher education students join the workforce after four years of commencing study. An additional 40 per cent join the workforce over the next four years (years 5–8).
6. 0.2% of bachelor completions move to postgraduate study each year and enter the workforce two years later.
7. 57% of apprentices and civil trainees join the workforce after four years of commencing study. An additional 8% join the workforce over the next four years (years 5–8).
8. 20% of non-apprenticeship students join the workforce after one year of commencing study. An additional 20% join the workforce in the following year.
9. 15% of all non-apprenticeship commencements are non-completers who have acquired the skills required to transition to the workforce. They join the workforce the following year.
10. VET students have been segmented into different categories based on reason of study. 'Skillers' and 'starters' (as identified through the student outcomes survey) are students who represent a net addition to the workforce. The ongoing proportion of 'skillers' and 'starters' maintains the same ratio as per student survey outcomes.
11. The visa classes of interest are: 186 employer nomination scheme; 187 regional sponsored migration scheme; 189 skilled independent; and 190 skilled nominated. These permanent visa classes represent a net workforce migration to Australia.
12. The 2018–2019 migration value for the above subclasses is assumed to be maintained from 2022 to 2036.
13. Perturbed data instances in the migration data which have a value of "<5" has been assumed to take on a value of three.
14. The distribution of migration to different states is assumed to follow the current distribution of infrastructure workers.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Education completion rates could vary due to factors including age, region, and field of study. This has not been individually estimated in this study.
2. Distribution of migrants to states could vary depending on external market factors. This has not been individually estimated in this study.

Identifying shortages based on modelled supply and demand

Methodology

Demand estimates provide by Infrastructure Australia were matched to Nous supply forecasts by sub-classification to estimate potential shortage or surplus at Infrastructure Australia group, classification, and sub-classification.

Assumptions

The following assumptions were adopted to estimate future labour supply for public infrastructure:

1. Occupational definitions are consistent for demand- and supply-side estimates.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Demand estimates are based on known infrastructure investment at 30 June, 2022.
2. Demand estimates do not incorporate demand from individual councils for public infrastructure.
3. Demand estimates are very limited outside of public infrastructure, so limited inferences can be made about private infrastructure and private non-infrastructure construction.

Identifying shortages based on labour market indicators

Method for occupational indicators of shortage

Each occupation has been assessed for signs of shortages using four independent methods which answer the following questions respectively:

1. Is the occupation in shortage on the National Skills Commission's Skills Priority list?
2. Do stakeholders show a belief that the occupation is in shortage, either in published reports or in consultations?
3. Does our supply and demand analysis of public infrastructure show a shortage?
4. Do the number and kind of job advertisements indicate a shortage?

An occupation is classified under 'Likely Shortage' if three or more of these assessments showed a shortage, 'Potential Shortage' if two showed a shortage and two did not or were unclear, and 'Unlikely Shortage' if only one or none of the assessments showed a shortage.

Assumptions

The following assumptions were adopted to identify shortages based on labour market indicators:

1. Movement in indicators reflects difficulties by employers in sourcing labour.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. A range of factors may contribute to movement in identified indicators. Consequently, indicators should be viewed in conjunction with other assessments of shortage to provide a fuller picture.

Developing skills profiles for identified occupations

Methodology

Burning Glass job advertisements were used to develop skills profiles by occupation and roles based on the Burning Glass skills taxonomy and text analytics algorithm.

Nous assessed each skill identified by whether they were general, or specialist as defined by Burning Glass and the distinctiveness of the skill – how likely a skill is requested in a job advertisement from a particular industry compared to the entire labour market. These combined to create the three categories – general, technical and specialist – outlined.

Nous also assessed the degree of change in mentions of particular skill. Two periods, 2016 to 2018 and 2019 to 2021, were compared to identify skills with increasing, declining or stable demand.

Assumptions

The following assumptions were adopted to develop skills profiles for relevant occupations:

1. Mentions of skills in job advertisements are representative of an employer's skills needs for a given occupation.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Sample sizes can be small for some occupations. To ensure sufficient samples all job advertisements were used for a given occupation, rather than restricting to those industries directly linked to public infrastructure.

Demographic analysis

Methodology

Detailed data tables were provided by the Australian Bureau of Statistics on Census 2016 employment figures. The tables provided employment data by gender, age, Statistical Area 3 (SA3) of residence, and ANZSCO 6-digit level occupation.

The figures were used to summarise age and gender distribution across occupations in scope for this report. The geographic indicators were used to explore the distribution of the infrastructure labour force across Australia.

The data used for these analyses required no modelling or estimation, just summary of custom tables, not publicly available.

Assumptions

1. Gender, age, and geographic distributions within infrastructure-specific occupations are consistent with broader industry trends and population estimates from 2016 to 2022.
2. Gender and age distributions for common job titles within the infrastructure industry do not differ significantly from distributions in other industries.

Limitations of analysis

Potential limitations identified in completing our analysis include:

1. Demographic information could not be explored by ANZSIC industry classifications because of (1) table size restrictions imposed by the Australian Bureau of Statistics data warehouse and (2) individual categories with small numbers, which the Australian Bureau of Statistics is unable to provide to protect individual privacy.
2. A key implication for analysis was the inability to accurately explore different segments of the infrastructure workforce (such as engaged, adjacent, trainable, and distant) by demographic breakdown. Only broader aggregations were possible.
3. Gender and age distributions could not be explored per geographic unit because the Australian Bureau of Statistics had to send the information in separate tables.

Public sector skills methodology

Proposed scope of public sector work

All ANZSCOs that were in scope for the overall infrastructure workforce skills supply assessment have been included in this assessment. This includes all identified relevant roles for project management professionals; engineers, scientists and architects; structures and civil trades and labour, and; finishing trades and labour.

An additional set of ANZSCOs intended to identify roles that support policy, regulation and government oversight in infrastructure. These are outlined below in Table 8. Note that only a subset of people employed in these occupations will be relevant to infrastructure.

Table 5: ANZSCOs included in policy and regulation occupation group

ANZSCO Major Group	ANZSCO Occupation	ANZSCO Code
Managers	Sales and Marketing Manager	131112
Managers	Public Relations Manager	131114
Managers	Finance Manager	132211
Managers	Policy and Planning Manager	132411
Managers	Supply and Distribution Manager	133611
Managers	Specialist Managers	139999
Professionals	Corporate Treasurer	221212
Professionals	Policy Analyst	224412
Professionals	Liaison Officer	224912
Professionals	Information and Organisation Professionals	224999
Professionals	Public Relations Professional	225311
Professionals	Graphic Designer	232411
Professionals	Urban and Regional Planner	232611
Professionals	Solicitor	271311
Community and personal service workers	Alarm, Security or Surveillance Monitor	442211
Clerical and administrative workers	Secretary (General)	521211
Clerical and administrative workers	General Clerk	531111
Clerical and administrative workers	Production Clerk	591112
Clerical and administrative workers	Inspectors and Regulatory Officers	599599
Sales workers	Property Manager	612112
Sales workers	Real Estate Agent	612114

Defining public sector infrastructure roles and occupations

Methodology

The first step to the public sector analysis is extending Infrastructure Australia's occupational and role taxonomy described in the Infrastructure Workforce supply comprehensive report. The original taxonomy includes 51 distinct infrastructure roles, grouped into four occupational groups. To adequately describe the public sector workforce, another occupational group was required, "Policy and regulation", expanding the framework to five occupational groups:

- Project management professionals
- Engineering, scientists and architects
- Structures and civil trades and labour
- Finishing trades and labour, and
- Policy and regulation.

Burning Glass Technologies Limited was used to identify appropriate roles and occupations to sit within the new group. The individual roles were identified using a multi-stage key-word search across all job advertisements listed by public employers at the local, state and central government levels. The search targeted skills listed for each job posting, job description text, and education qualifications.

The search used 41 key words and phrases identified through research and consultation. The list includes: 'civil construction', 'public infrastructure', 'major project', 'road and bridge', among others. Usage frequencies of these terms within job postings helped to indicate which ANZSCO categories were appropriate to include under the Policy and Regulation umbrella—as well as the proportion of individuals employed in the identified occupations to be considered in sizing the workforce (described further below).

The analysis resulted in a total of 21 additional roles to sit within the broader Policy and Regulation category. They include occupations of a specialist nature, such as urban and regional planners and policy analysts, as well as more general roles, such as finance and property managers.

Assumptions

The following assumptions were adopted in defining infrastructure relevant occupations:

- Job advertisements are matched appropriately to ANZSCO unit groups in Burning Glass data set.
- Proportions of job advertisements in key occupations are similar to proportions of those currently employed in those occupations.

Limitations of analysis

Potential limitations identified in completing our analysis include:

- While key phrases used to search through job advertisements to identify positions related to public infrastructure, vetted qualitatively, there has been only limited analytical testing to confirm the extent to which the search results either overestimate or underestimate proportion of advertised positions directly related to public infrastructure.
- Employers listed in Burning Glass advertisements are often not specific to individual government agencies; rather for example, they may be listed generally as "Australian Government". Thus, initial searches for relevant public employers had to draw from a large pool, which had to be narrowed down, but which still may exclude some employers.

Sizing the public sector infrastructure workforce

Methodology

Estimates of public sector workforce supply were developed using Australian Bureau of Statistics employment data. ANZSCO and ANZSIC classifications were considered for all Infrastructure Australia relevant occupations listed in the expanded public sector occupational taxonomy described above. The key ANZSIC categories used to define the public sector are 751 (local government), 752 (state government), and 753 (central government).

Estimates were developed first for 2016 based on census data at the ANZSCO 4 and ANZSIC 3 level. Burning Glass job advertisement data was also considered to determine the composition of employment in roles at a more granular level. This approach was used due to Australian Bureau of Statistics perturbation of more granular data, where there is a risk of identifying individuals due to small numbers. Iterative proportional fitting was used to ensure that estimated figures at the ANZSCO 6-digit level were consistent with higher level census results.

Supply estimates were projected forward to 2021 based on results of Australian Bureau of Statistics labour force survey using iterative proportional fitting. The result was estimates for the public sector workforce in infrastructure relevant roles filtering for the public sector ANZSIC codes mentioned above—as well as infrastructure workforce estimates for other sectors, based on employment figures for construction-related ANZSIC industry codes.

Assumptions

The following assumptions were adopted to estimate the historical and current labour supply for public infrastructure:

- The distribution of job advertisements by ANZSCO unit group is a reasonable approximation of the workforce under each ANZSCO minor group.
- Individuals are classified in the same way under census, labour force survey and Burning Glass data.

Limitations of analysis

Potential limitations identified in completing our analysis include:

- Small variations in estimates may occur at sub jurisdictional level from official statistics due to the approach adopted to overcome limitations in census microdata.

Understanding workforce composition

Methodology

Census 2016 employment figures at the ANZSCO-4 and ANZSIC-3 levels formed the basis of the demographic analysis of the public sector workforce, including disaggregation by gender and age. Burning Glass Technologies ltd was used to understand worker salary trends.

The data used for gender and age breakdowns required no modelling or estimation, just summarizing Census data using Table Builder Pro. Salary information from Burning Glass was pulled for the key occupational groups and averaged over time to determine trends.

Assumptions

- Gender and age distributions within infrastructure-specific occupations are consistent with broader industry trends and population estimates from 2016 to 2021.
- Gender and age distributions for common job titles within the infrastructure industry do not differ significantly from distributions in other industries.
- Advertised salary trends in job ads are reliable enough to represent the wages of those who are currently employed.

Limitations of analysis

Potential limitations identified in completing our analysis include:

- Demographic information could not be explored down to the ANZSCO-6 level because data at that granularity is not available in Table Builder Pro. This means that summaries for the occupations at the ANZSCO-4 level will include some extra information as they pertain to the Infrastructure Australia occupations framework.

- Salary information is available for only 25% of job advertisements on average, so while the overall sample size is sufficient to draw insight, salary trends at the occupation level should not be considered definitive.

Understanding workforce skills

Methodology

Burning Glass job advertisements were used to develop skills profiles by occupation and roles based on the Burning Glass skills taxonomy and text analytics algorithm.

Nous assessed each skill identified by whether they were general or specialist as defined by Burning Glass and the distinctiveness of the skill – how concentrated the demand for a skill is in specific occupations. These combined to create the three categories general, technical and specialist outlined in section one of the report.

Nous also assessed the degree of change in mentions of a particular skill. Two periods 2015—17 and 2018—20 were compared to identify skills with increasing, declining or stable demand.

Assumptions

The following assumptions were adopted to develop skills profiles for relevant occupations:

- Mentions of skills in job advertisements are representative of an employer's skills needs for a given occupation.

Limitations of analysis

Potential limitations identified in completing our analysis include:

- Sample sizes can be small for some occupations. Skills results at the individual occupation level are thus associated with some uncertainty and should be understood only as indicators. Further investigation using additional data sources would be needed to confirm exact trends.

Data sources and usage

A range of data sources have been used to support analysis for this report. These are outlined in Table 7.

Table 7: Data sources used and their purpose

Data source	Definition of occupations	Definition of public infrastructure	Estimation of current and historical supply	Estimation of current public workforce supply	Estimation of future workforce attrition	Estimation of future workforce supply	Modelled supply and demand shortages	Labour market indicators of shortage	Development of skills profiles	Demographic analysis
Burning Glass labour market data	x	x	x	x		x	x	x	x	
ABS Census 2011-2016[4]		x	x	x	x	x	x			x
ABS Building Construction Activity[5]			x			x				

Data source	Definition of occupations	Definition of public infrastructure	Estimation of current and historical supply	Estimation of current public workforce supply	Estimation of future workforce attrition	Estimation of future workforce supply	Modelled supply and demand shortages	Labour market indicators of shortage	Development of skills profiles	Demographic analysis
ABS Detailed Employment[6]			x	x						
ABS Payroll Jobs and Wages[7]			x							
ABS Labour Force Survey [8]				x						
Australian Institute of Health and Welfare[9]						x	x			
Department of Home Affairs migration data[10]						x	x			
Higher education completion rates[11]						x	x			
Higher education graduates[12]						x	x			
VET completion rates[13]						x	x			
VET student outcomes survey data[14]						x	x			
HEIMS enrolment data[15]						x	x			
NCVER Total VET Activity data[16]						x	x			
Infrastructure demand data[17]							x			

Appendix F: TraNSIT methodology

Overview of TraNSIT

TraNSIT is a modularised tool where data for each commodity is an input to the core engine, along with the operating characteristics of the infrastructure and regulatory environment associated with the movement and handling of the commodity. The infrastructure and regulatory attributes can be adjusted for the purposes of testing scenarios of interest. See Figure 2.

The core engine of TraNSIT simulates the number of vehicle trips per month moved between origin and destination enterprises. The goal of the TraNSIT model is to optimise transport route and vehicle selection along the transport network for each trip (from origin to destination), and then calculate the cumulative impacts at the enterprise or regional scale. Cumulative impacts can also be calculated at any other scale such as commodity, sector or network.

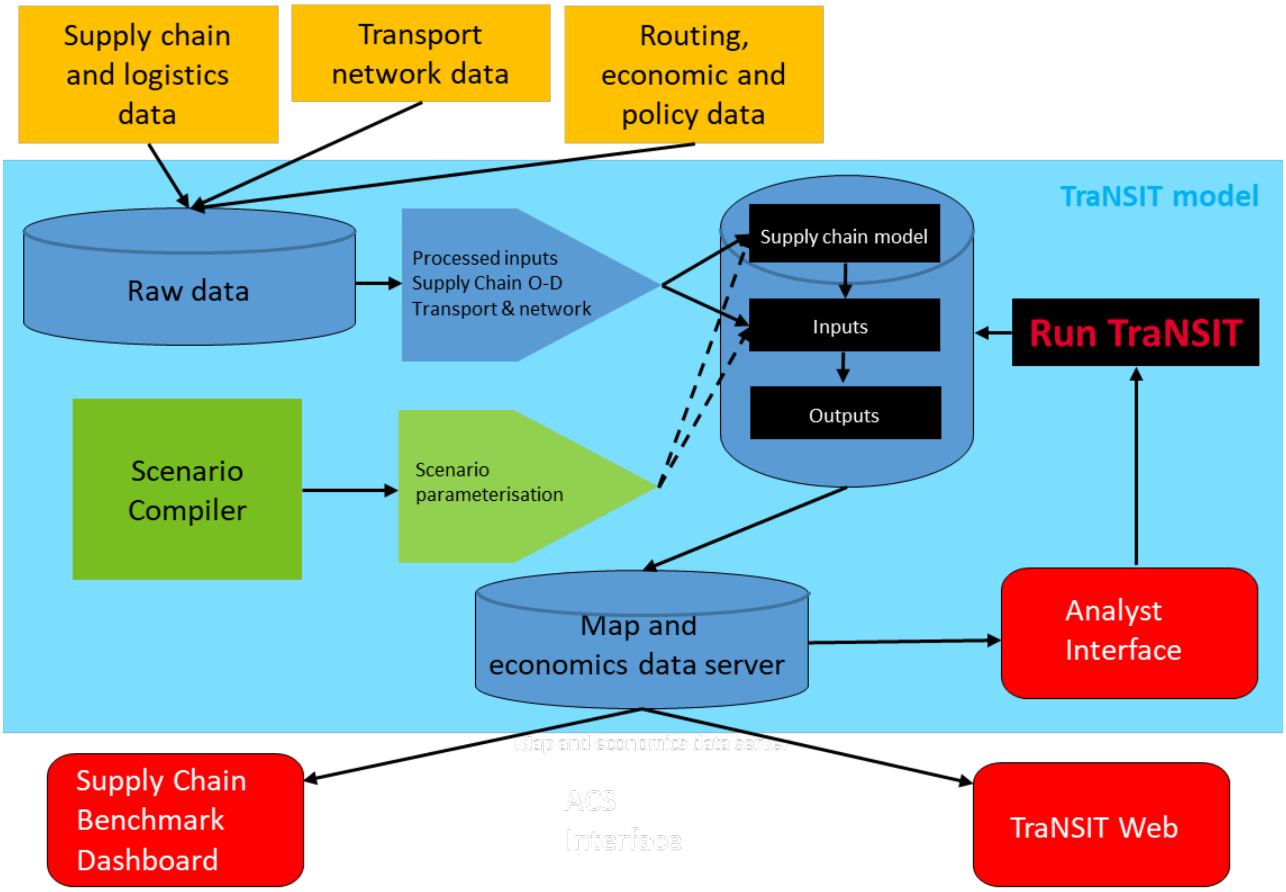
To determine the optimal road route, the analysis considers parameters such as costs, vehicle access and vehicle type according to the regulatory road class. TraNSIT will select/default to the lowest-cost vehicle combination based on heavy vehicle access restrictions throughout the journey from origin to destination. The optimal route selected may not necessarily be the actual route taken by the driver but rather the route that would be taken should the driver be seeking a least-travel-cost option.

To map rail movements the analysis also takes into account track standards (e.g., tonne axle load, siding lengths, gradients), train configurations, number and type of locomotives and rolling stock, and the location and type of handling facilities (e.g., intermodal terminals).

TraNSIT uses cost models to describe and model costs associated with the operation of heavy vehicles and trains, and with the handling of freight. These input costs are calculated from the ground up, rather than being actual freight rates/prices charged by transport and logistics service providers.

Two user-friendly web portals have been developed to analyse outputs from TraNSIT (Figure 2). TraNSIT Web allows various freight analyses along the transport network and is currently available to Australian and state/territory government agencies responsible for freight and logistics. The Supply Chain Benchmark Dashboard, released 15 October 2021, provides the capacity to analyse and compare freight trends between commodities and across each leg of the supply chain. The dashboard can be accessed at www.freightaustralia.gov.au/dashboard.

Figure 1: Process diagram of TraNSIT, comprising the stages from set up to running of each model component



Data inputs

TraNSIT is a knowledge-based tool, which means that the analytical capacity of the tool increases as more data becomes available and assumptions and unit cost estimates are validated by supply chain operators.

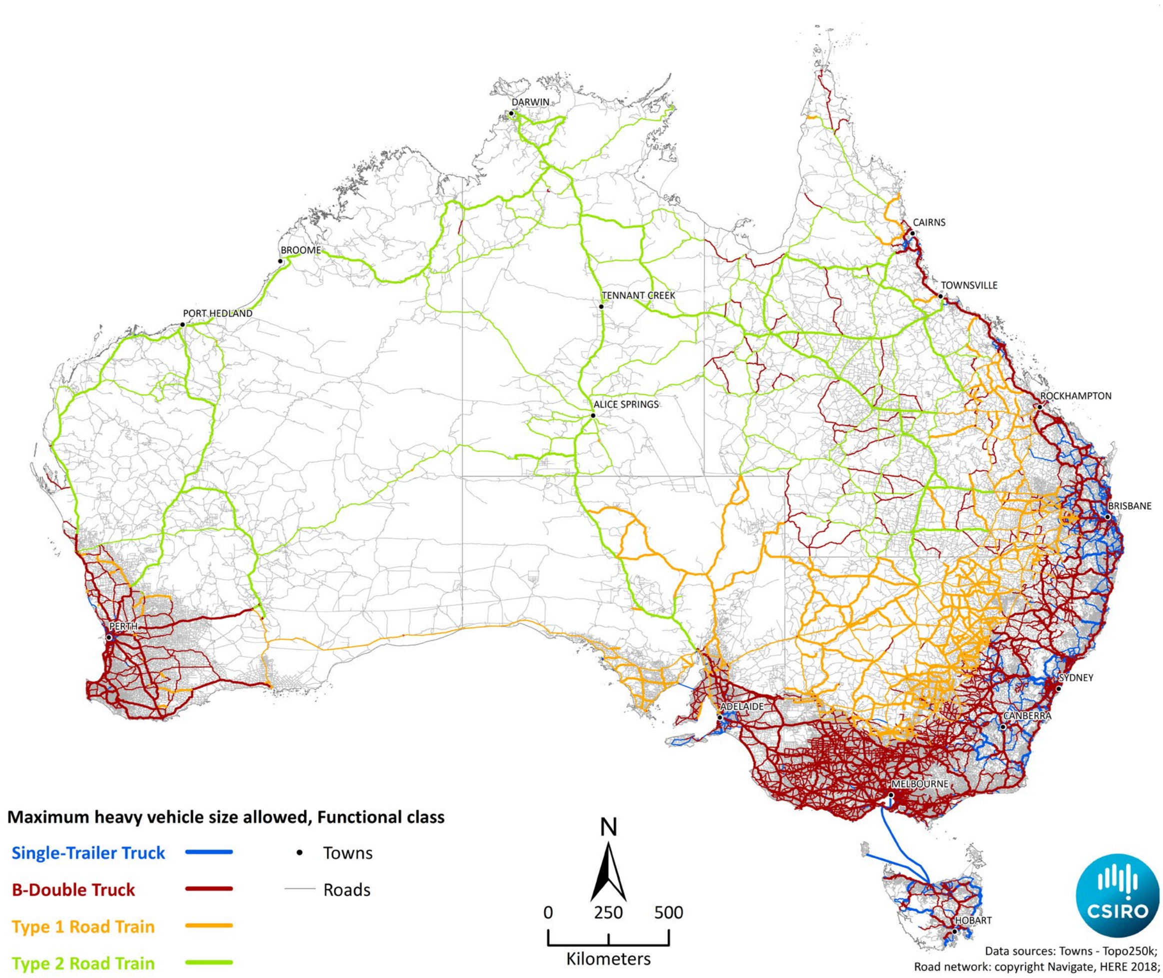
At the time of this report, June 2022, TraNSIT incorporated over 650,000 supply chain paths for 162 commodities between 530,000 enterprises. It comprised network modelling of over 20 million heavy vehicle and 9 million rail wagon movements per year. TraNSIT continues to be expanded with new commodities with currency updates for existing ones. Data used in the tool has been gathered from over 450 industry organisations, associations and government agencies since 2012. National commodity data is reviewed and updated every 2—3 years, or more frequently as a result of the application of TraNSIT to specific projects. For some commodities (e.g., grains), a representative production year is used instead of the most recent year.

An industrial enterprise is defined in our modelling as a site where a commodity (or commodities) is produced or consumed, i.e., transformed into a new commodity (e.g., a batching plant converting cement and aggregates into concrete).

Road network

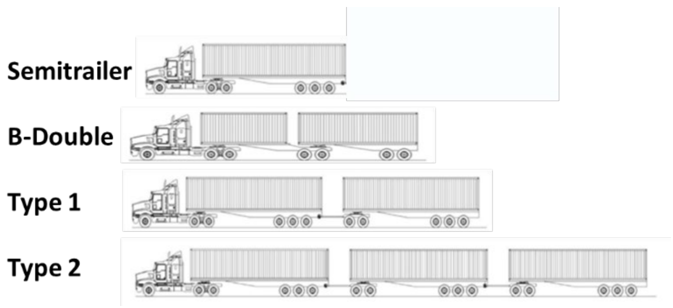
Road network data included in TraNSIT are ranked as primary, secondary and minor (including unsealed) roads. The road network, represented in Figure 3, was constructed using the HERE network (www.HERE.com), with additional road features incorporated from numerous other sources. These features include access restrictions and information on breakdown pads, biosecurity restrictions and rest stops. Spatial layers with different projections or coordinate systems were conflated to this road network using Artificial Neural Networks.

Figure 2: National baseline road layer used in TraNSIT showing heavy vehicle access



The National Heavy Vehicle Regulator www.nhvr.gov.au provides information on Performance Based Standard access limitations for different types of heavy vehicles across the road network. The PBS system is used for most of Australia (Western Australia uses a Restricted Access Vehicle system) to categorise permitted vehicle access for general mass limit combinations and for higher-mass limit combinations. Figure 4 shows four basic Performance Based Standard categories that accord with conventional truck and trailer configurations.

Figure 3: Typical Performance Based Standard road access vehicles



PBS Level	Heavy vehicle
Level 1	Single-Trailer Truck
Level 2A	B-Double Truck
Level 2B/3A	Type 1 Road Train
Level 4A	Type 2 Road Train

Within the TraNSIT road network, roads are also classified in terms of their relative importance, where Rank 1 represents major roads such as highways, a Rank 2 represents significant local roads and Rank 3 represents roads mainly used for local travel. Figure 3 displays roads of Rank 1 or 2. Rank 3 roads are excluded from Figure 3 to reduce overcrowding.

Roads are further separated into segments with attributes describing surface type, width, speed limit and any special limits (e.g., one-way bridges). All of these attributes affect average speed and transport cost per kilometre.

Operating cost model

TraNSIT uses operating cost models for road and rail that estimate the cost of operating the heavy vehicle or train from origin to destination, including backloading. The costs include track access charges (rail) as well as registration and fuel excise costs (road) that cover income for rail and road network managers. They do not account for costs of road or rail construction. Costs of transport can be translated to dollars per payload tonne or total costs for individual supply chains.

Transport costs in the *Infrastructure Market Capacity* eport are based on these cost models and do not represent freight rates (prices) charged for the transport service. Freight rates often differ from modelled costs depending on backloading, competition on different routes and market structures.

The operating cost model is used to calculate the cost of the vehicle trip from origin to destination, accommodating changes in road conditions (surface, speed, gradient, etc.) for every segment. The road cost model is based on published equations for vehicle operating costs (Tan *et al* 2012; QDTMR 2011). Additional vehicle types were incorporated to accommodate transport of different types of construction materials. Variables described in the model include:

- Vehicle type - four typical vehicle configurations based on PBS road access regulations, disaggregated further into more than 30 other vehicle types. These include AB triples (PBS3a) and BAB Quads (PBS4a)
- Fuel price
- Payload
- Fuel consumption - a function of incline, international roughness index, speed, tare, gross mass and vehicle type
- Travel distance and time, disaggregated for each segment along the route
- Driver costs
- Maintenance and tyre costs

- Fixed, capital and depreciation costs.

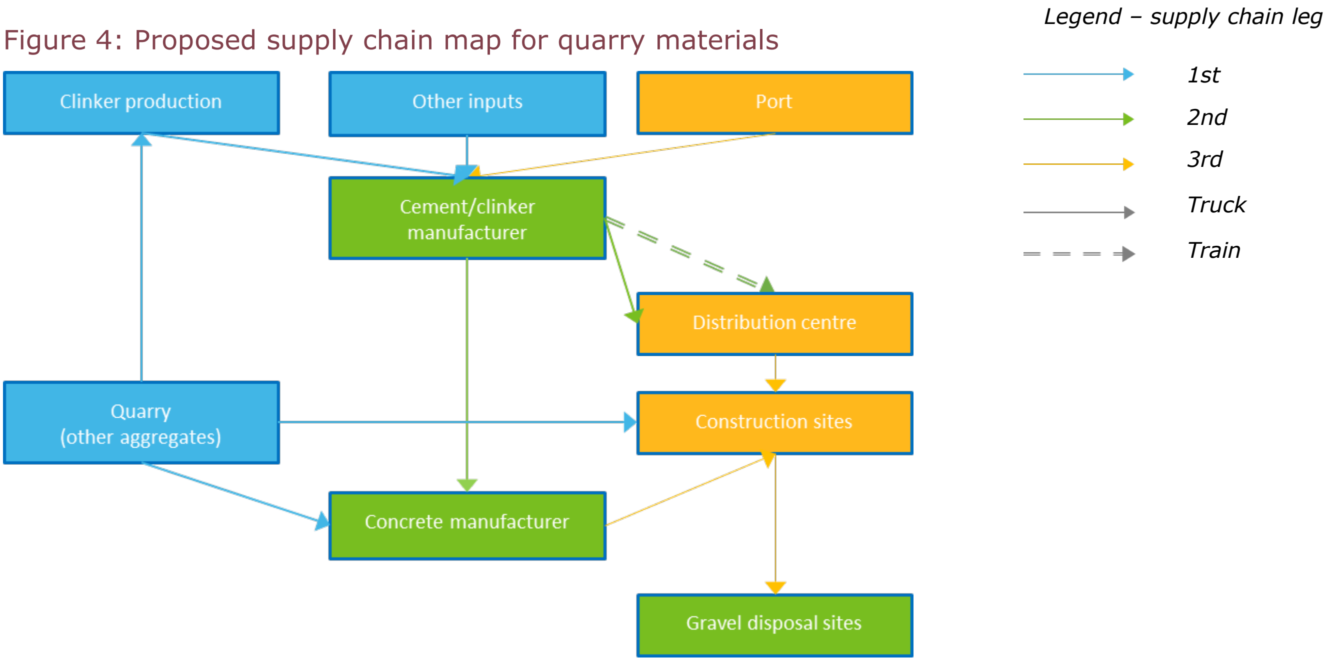
The total cost of the trip can be disaggregated into $/tonne, $/km or $/hr.

The operating cost models have been validated over the past six years with freight operators across Australia, who provided valuable knowledge to calibrate many of the input cost parameters.

Data collection

Data adequately representing each enterprise in the supply chain and flow of estimated materials is the key component of this project. The scope of the quarry materials supply chain is shown in Figure 5 and includes the cement/concrete supply chains. Both locally produced and imported inputs are included, where data could be gathered. Road and rail are included, as well as coastal shipping which is extensively used for transport of clinker and other materials. The scope initially included gravel disposal which represents a large percentage of the total freight for quarry materials, but was subsequently removed due to data inaccessibility.

Figure 4: Proposed supply chain map for quarry materials



Note: gravel disposal was not included in the modelling due to data inaccessibility

Unlike many bulk agricultural commodities that are supply-driven (i.e., large scale production pushed to exports and domestic markets), the supply chains for the construction sector are demand-driven. Gravel and concrete supplies are scaled up and down at different locations to meet the demand for construction material at the time. Insufficient supply at one location will require longer distance supply from other locations.

Demand mapping

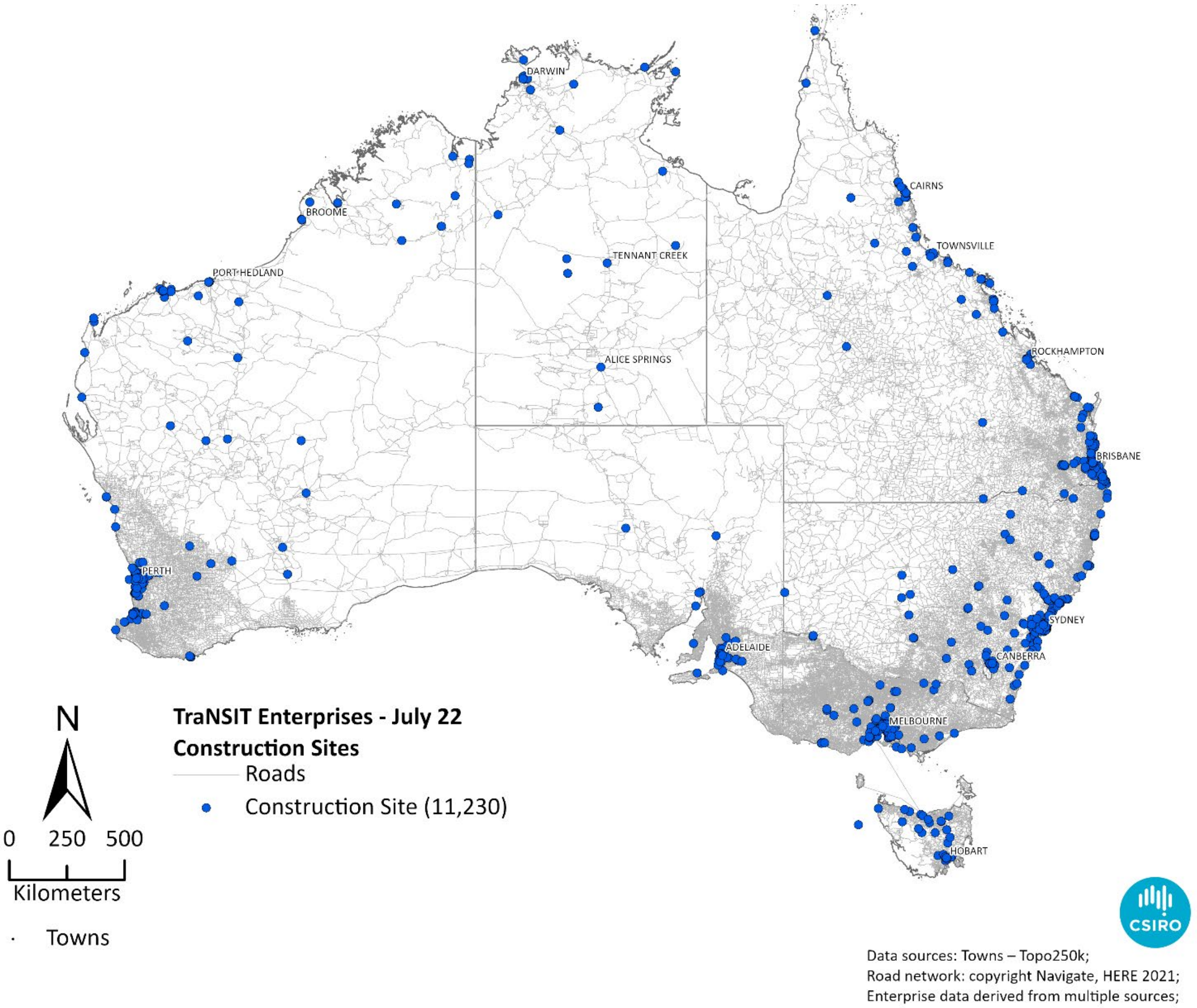
A list of construction sites was derived from GlobalData, which included the start and end dates of public and private construction sites across Australia from 2015 to 2031 dates valued at greater than $1 million. The initial analysis focused on public infrastructure construction only. For each construction site, Infrastructure Australia derived monthly material demands for the following resources:

- Steel
- Concrete – aggregates plus cement
- Asphalt
- Bitumen
- Rock/bluestone

- Timber
- Plasterboard.

Many construction sites such as road projects within the data set did not have latitude/longitude information. These had to be derived manually for use in the modelling. There were more than 2000+ construction sites across Australia for 2022—2023 used for the initial analysis (public construction sites only) - see Figure 6.

Figure 5: Location of the construction sites for 2022/2023, as used in the analysis



Material suppliers

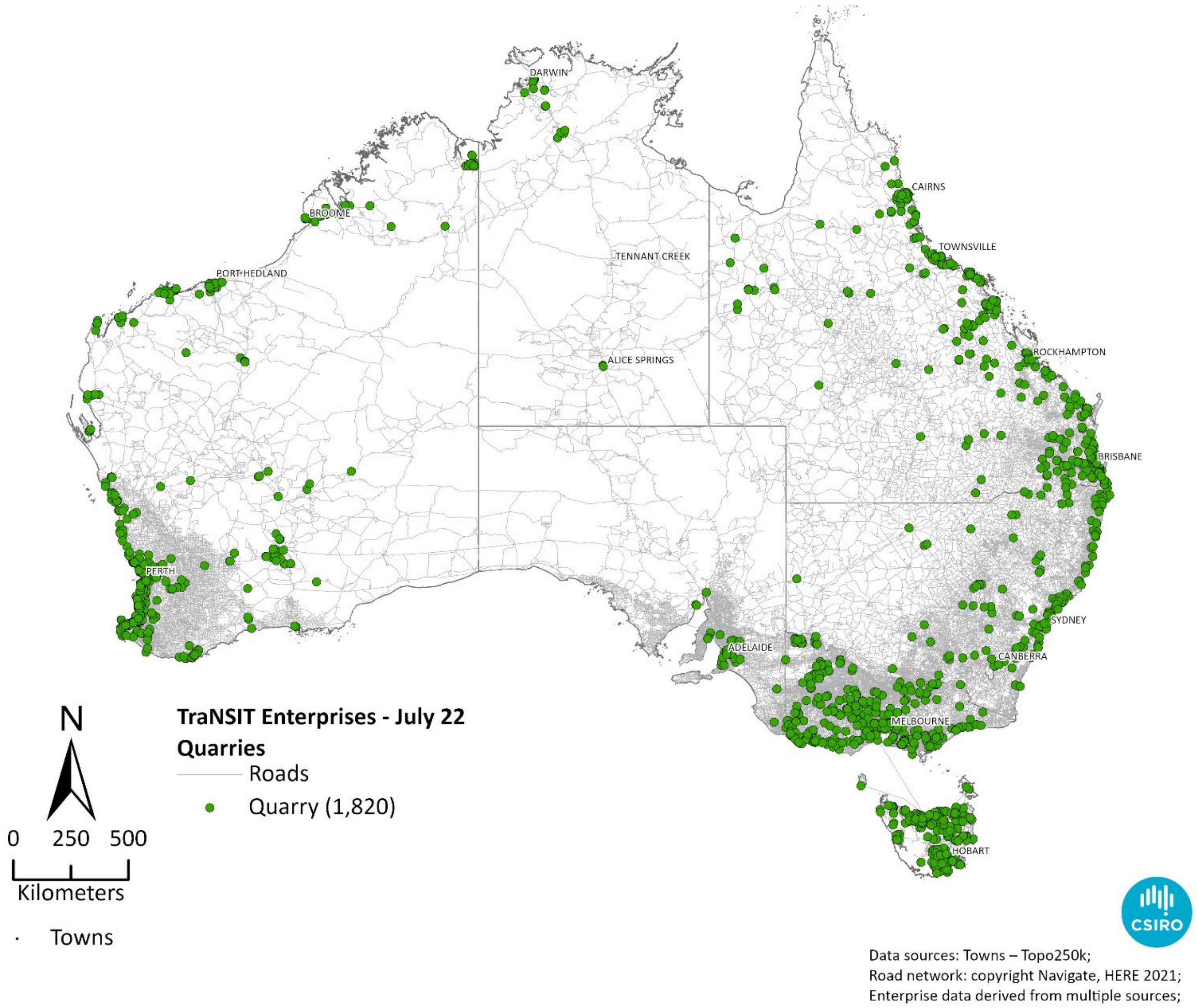
A challenge with mapping the supply points is the large number of companies which own the facilities, and the high sensitivity of industry data. Presentations to the Cement and Concretes Aggregates Association and individual companies (e.g., Boral) led to strong support for the project and recognition of its value in helping the industry reduce its supply chain costs. Despite this support, no industry data has been received to date. Disruptions to the construction sector due to COVID lockdowns have contributed to delays in data access.

Quarries

In the absence of industry data, quarry locations were sourced from mining and mineral agencies in each state and territory. See below for a summary of data sourced, along with its limitations. Data for each state and territory differed in format and quality. Datasets for Queensland and New South Wales were reasonable and differentiated the type of aggregates produced, including sand, gravel, rock, limestone and asphalt. Other states and territories had no or limited information on aggregates and differentiation between quarries and other types of enterprise (e.g., mines). None of the data sets had reliable information on the capacity of the quarries or supply tonnages per year.

Without reliable agency data for some states/territories, publicly available data was sourced to determine locations of quarries for the major companies such as Boral and Hansen. Overall, 1820 quarries were included in the initial TraNSIT analysis (Figure 7). However, a portion of these were either no longer active or very small.

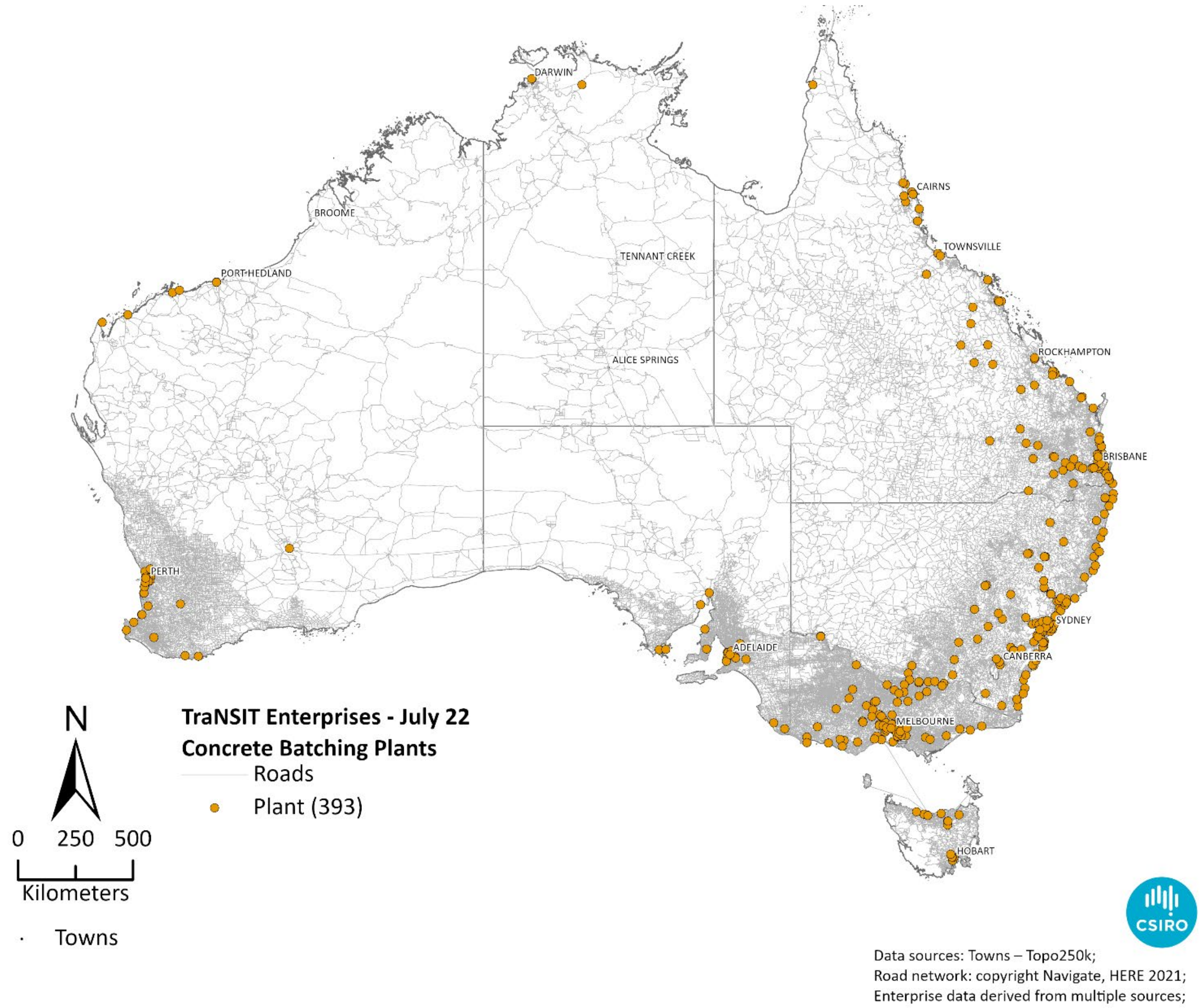
Figure 6: Location of quarries used in the analysis



Batching plants

Data on the location of 393 concrete batching plants represent Boral, Hansen and a few smaller operators, as shown in Figure 8. No information on capacity of annual throughputs were available. The batching plants are predominately located near the urban area and does not include temporary batching plants used for many remote large construction sites.

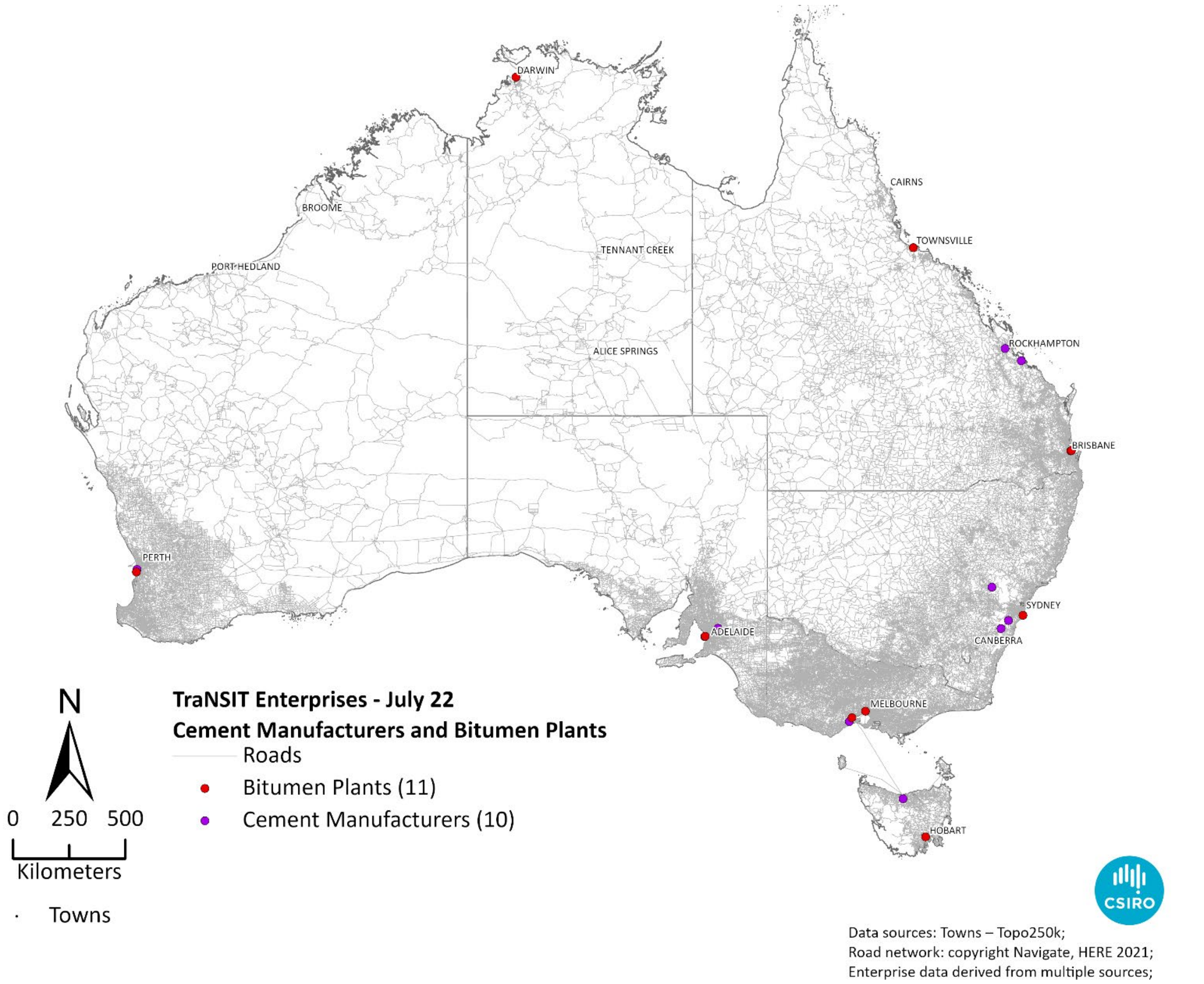
Figure 7: Location of concrete batching plants used in the analysis



Cement manufacturers

A list of the major cement manufacturers, their locations and annual production volumes was compiled and included in TraNSIT (see locations in Figure 9). There are ten plants including those for Cement Australia, Adelaide Brighton, Blue Circle and Cockburn. A considerable amount of movement of bulk cement occurs between and within the states and territories, with cement moved from production locations to distribution centres and batching plants. Coastal shipping has been used on some routes and was included in the analysis.

Figure 8: Location of cement and bitumen plants used in the analysis



Bitumen

The major bitumen plants are usually co-located at major ports. Eleven plants, particularly operated by Puma and Sami, were included in TraNSIT (Figure 9). Bitumen and asphalt are used in the road construction projects.

Steel

Steelworks and steel manufacturers have been added to TraNSIT, including many of the major companies such as Bluescope, Molycop, Liberty, InfraBuild and MetalCorp. Where the steel has been used for reinforcement, structural purposes and rail tracks, freight movements have been mapped from the manufacturers to the construction sites.

Plasterboard

Gyprock manufacturers and distributors are progressively being added to TraNSIT. Freight movements will be mapped from the distributors to the construction sites that have plasterboard requirements

Timber

The timber supply chain was previously incorporated into TraNSIT, and include freight movements of sawn timber to exports and domestic retailers. This current project added the supply chains from saw/panel mills to construction sites.

Quarry data gathered from each jurisdiction

Details of quarry datasets sourced and used in the TraNSIT modelling from each jurisdiction are provided below.

Overall the following issues were found:

1. The completeness of list of quarries varied between states. Queensland had a comprehensive and clean set, while data for NSW, NT and SA were very limited
2. Data for some states required a substantial amount of cleaning
3. The data sets did not contain information on the capacity or annual throughput of the quarry. This is very important to accurately map supply chain movements between the individual quarries, batching plants and the construction sites.

New South Wales

The primary dataset for New South Wales is operating quarries.[18] It contains location and some attribute information including size for a few limestone mines/quarries, but no information on gravel or sand mines. This limitation was overcome by finding the locations of Boral and Hansen quarries through an alternative online search. However, quarries of other companies are still missing.

Victoria

The dataset for Victoria is current extractive industry tenements.[19] This dataset has a good disaggregation by commodity type – sand, gravel, asphalt, clay etc. It also contains the area of the tenement, which we used as a proxy for relative quarry capacity. The dataset needed to be cleaned up to remove duplicates.

Western Australia

The dataset for Western Australia is the operating mines dataset, containing quarries disaggregated by sand, gravel, basalt etc. [20] There is no information on capacity. It is a large data set with over 600 quarries.

Queensland

The Queensland data set contains 300 entries on existing quarries, including contact details and an thorough breakdown by commodity type. [21] There is no information on capacity.

South Australia

A very limited dataset is available for South Australia, that had to be extracted from .pdf, as no electronic dataset was accessible. [22] The dataset lists 25 major quarries, with no breakdown by commodity. This limitation was overcome by finding the locations of Boral and Hansen quarries through an alternative online search, but some quarries are still missing from the data set.

Tasmania

The dataset for Tasmania has 249 quarries which seems large. There are many duplicates, probably a result of different parts of the quarry being separate entries. It has limited information on the ownership of each quarry, which made validation difficult. The data set has a field on the deposit size (small, medium, large). [23]

Northern Territory

The dataset for the Northern Territory has 51 entries with a large number of duplicates. [24] Many mainstream quarries are missing from the dataset and had to be looked up online to be found.

Appendix G: Replacement materials methodology

1. Detailed material supply chain overviews

Crushed recycled concrete and brick

Concrete is a structural material typically recovered from commercial demolition and civil works. Crushed recycled concrete can be used as a subbase under full depth asphalt or as a basecourse under low traffic local roads. Crushed recycled concrete may contain sand, brick, tile, asphalt, and recycled crushed glass. It is a high-strength and durable material that can reduce landfill volumes when used instead of limestone.

End of life bricks are mostly recovered from domestic demolitions works and typically contain hardened clay bricks and some crushed concrete and cement/lime mortar. Recycled crushed bricks are most commonly used in unbound and bound pavements as an alternative to natural and quarried aggregates and sand.[25]

In 2013, 8.7 million tonnes of demolition concrete was produced in Australia.[26]

A case study from the *National Waste Report* (2020) showed that crushed recycled concrete can offer superior performance compared to virgin aggregate when used in a hardstand application, as well as being cheaper and more environmentally friendly.[27] The carbon footprint of crushed recycled concrete is 65% less than that of the equivalent quarried material because it is softer and requires less energy to crush.

Figure 10 summarises the crushed recycled concrete material flow which begins with the recovery of end-of-life concrete from a demolition site. The recovered concrete is then sorted, separated and then reprocessed and crushed. The final product is then suitable for use in road infrastructure application and is sold to road construction companies. The process for recycled crushed brick is similar.

Figure 9: Material flow of crushed recycled concrete

Of the $70 per tonne required to collect, transport, and recover the materials, $40 is attributed to collection, with labour costs being a major component (interview conducted with Nik Comito, BINGO Industries 11 April 2022). As the materials are low value, transport costs are a significant part of this pricing, making proximity to the supply point important. Where there are shortages of virgin quarry materials, such as in and around Melbourne, crushed recycled concrete will be cost competitive with virgin materials.

Reclaimed asphalt pavement

Reclaimed asphalt pavement is asphalt that was previously used as an engineering material and is itself fully recyclable as a construction material. Reclaimed asphalt pavement can be used as a structural layer of asphalt pavement. End-of-life asphalt is removed from the pavement by milling and reprocessed for recycling by crushing and screening. Reclaimed asphalt pavement has strict specifications that can limit its use. For example, in some states, reclaimed asphalt pavement is not permitted in asphalt surfacing due to increased risk of cracking and lower skid resistance.

In 2005, almost 4 million tonnes of asphalt were disposed of in Australia[28]. If this total volume were commercially recycled, the energy savings would equate to 5 million households' energy requirements for a month. RAP can also reduce costs by reducing the need for virgin materials and transportation requirements and divert waste from landfill.

Recycled crushed glass

Australia's annual glass consumption is approximately 1.21 million tonnes with 90% being packaging (i.e. bottles and jars)[29]. Eighty-four per cent of glass is recovered, however around 20 million tonnes still ends up in landfill.[29]

Glass collected for recycling is primarily sourced from food and drink bottles and jars, and can be clear, green, or amber (brown). Glass sourced from drinking glasses and window glass are often unsuitable for recycling back into bottles or jars but may be suitable for use road applications.

Recycled crushed glass can be used as a natural sand replacement for many road applications including fill, drainage and retaining walls.

Every tonne of recycled crushed glass used in road applications can save approximated 560 kg of natural sand, 176 kg of soda ash, 176 kg of limestone and 64 kg of feldspar.[30]

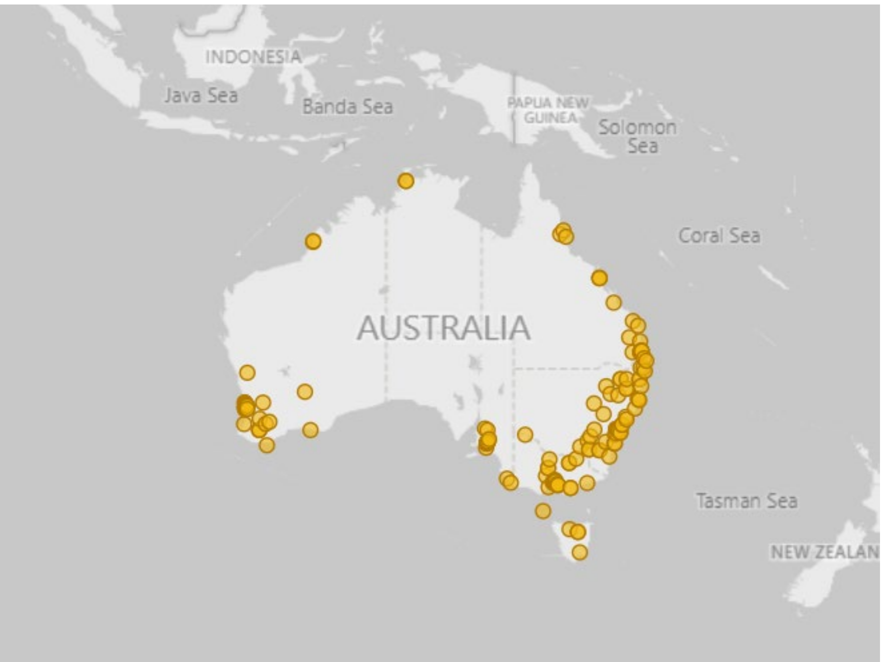
The material flow of crushed glass in asphalt is shown in Figure 11.

Figure 10: Material flow of recycled crushed glass in asphalt

Source: Transport for NSW (2020) [31]

Figure 12 shows the locations of glass recover and processing facilities in Australia.

Figure 11: Locations of glass recovery and processing facilities in Australia



Source: Department of Agriculture, Water and the Environment 2018[32]

The economic sustainability of crushed recycled glass and glass cullet need to be improved with a focus on reducing costs associated with milling the glass and washing it to remove contaminants (where required). A significant amount of energy is required to process the glass, so the cost of using this material is higher compared to raw materials.

The market value of recycled glass products (the end product) is estimated to be $100–149 per tonne delivered. When glass is used in roads, it can replace limestone, limestone costs are estimated at $30–38 per tonne, which is significantly cheaper.

Crumb rubber

Crumb rubber is sourced from the recycling of end-of-life vehicle tyres, and can be used in road infrastructure, especially in sprayed seals and asphalt. End-of-life tyres contain valuable polymers and carbon black that result in more durable roads when combined with bitumen. It also improves skid resistance, drainage performance, service life, resistance to crack reflection, and aggregate adhesion.

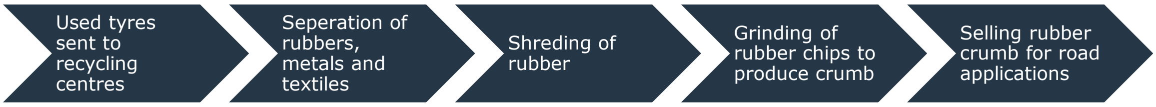
In Western Australia, 600–700 tonnes of crumb rubber are used annually for sprayed bituminous seals[33]. Western Australia imports its crumb rubber predominantly from Victoria, but suppliers are currently being established within the state.

In Australia, 51 million used tyres reach their end-of-life each year[34]. Only 5% of these are domestically recycled with the others being put in landfill, stockpiled or illegally dumped.

The most common sources of crumb rubber are truck tyres and off-the-road (OTR) tyres, as they have a higher concentration of natural rubber[35]. Processed crumb rubber has an estimated market value of around $700 per tonne.

Figure 13 outlines the processing steps for crumb rubber.

Figure 12: Supply chain of crumb rubber



Fly ash

Fly ash is a by-product of coal-burning, electricity-generating power stations[36] that is commonly used as a supplementary cementitious material. It can be used in cementitious materials, concrete and as a binder component in geopolymer concrete, which is concrete utilising alternative binders to ordinary Portland cement. Fly ash can also be used as a lightweight aggregate in concrete and for the stabilisation of fine-grained soils. The average amount of fly ash in cementitious material is 15–30%[37].

Using fly ash in concrete has many benefits including reducing costs, reducing greenhouse gas emissions, improving durability, and reduction in the heat of hydration[38].

Queensland recorded a reduction in up to 70% of greenhouse gas emissions from the use of fly ash[39]. Up to 35% of cement used in structural concrete can be replaced with fly ash and Queensland specifications require a minimum of 25% fly ash must be used.

Fly ash production is concentrated in black coal power-generating states of Queensland and New South Wales. In 2018–19, Australia's coal combustion generated 12.5 million tonnes of ash of which 90% (11.25 million tonnes) was fly ash[40]. Only 47% of the total ash generated was recycled.

Around 216 million tonnes of coal ash is stored or stockpiled in New South Wales. These stockpiles contribute up to 100 tonnes of leachate containing heavy metals and metalloids entering the waterways each year.

When used as a lightweight aggregate, fly ash is first collected from coal-fired power stations. The fly ash is then mixed with a binder and then formed into pellets using a pelletiser. After reaching the appropriate size, they are dried. The pellets are then sintered (compacting and forming a solid mass using heat or pressure) and finally cooled. The product is then ready to be used as a lightweight aggregate in the production of structural lightweight aggregate concrete.

Figure 14 shows the production and supply steps for fly ash as a lightweight aggregate.

Figure 13: Production and supply of fly ash

When high levels of fly ash are used in concrete it can lead to extended set times and slow strength development, which can delay rate of construction.[37] Extended set times can be advantageous in the case of cement stabilisation, where longer working times can allow more time to rectify construction issues or defects.

In addition, fly ash properties can largely depend on the composition of the coal. The variability of the unburnt carbon in fly ash in the market has a direct impact on concrete or cementitious materials' performance.

The leading supplier of fly ash in Australia is Flyash Australia Pty Ltd. The two major cement and concrete manufacturers, Boral Ltd and Cement Australia Pty Ltd, share ownership of this company. There is little incentive for power stations to facilitate users of fly ash to increase uptake as it is free for them to deposit fly ash in dams. Cement companies also have little incentive to use a large amount of fly ash as companies do not have significant competitors using large amounts of fly ash.[41]

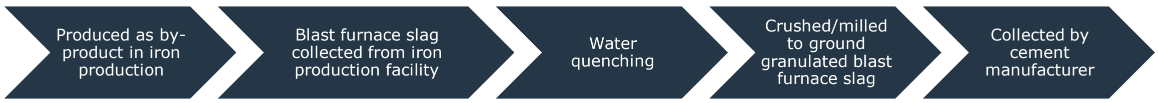
Ground granulated blast furnace slag (slag)

Blast furnace slag is a by-product from iron and steel production in a blast furnace[42]. Iron ore, coke, and limestone are fed into the furnace. The iron ore is reduced to iron and the remaining materials form slag. The molten slag and is then quickly cooled with fresh water to produce a granular product. This product is then crushed or milled to a fine particle size which has cementitious (pozzolanic) properties.

Ground granulated blast furnace slag's cementitious properties make it a suitable partial replacement for Portland cement. Ground granulated blast furnace slag is mainly blended with cement to manufacture concrete or as a direct supplementary cementitious material addition in concrete. Up to 60–70% of cement used in structural concrete can be replaced with ground granulated blast furnace slag[39].

Figure 15 shows the processing and supply of ground granulated blast furnace slag.

Figure 14: Processing and supply of ground granulated blast furnace slag



Bottom ash

Bottom ash is another industrial by-product from coal power plants[43]. These coarse particles fall to the bottom of the furnace during combustion. Bottom ash can also be generated from waste-to-energy incineration facilities.

Bottom ash can be used for several road infrastructure applications such as unbound and bound aggregate in the embankment fill, subbase layer, the capping layer of pavements or as a replacement for aggregate in structural concrete[44].

When compared to sand and gravel, bottom ash has a higher shear strength and is a suitable material for road base but due to its lower abrasion resistance, it is not recommended for full replacement of natural aggregates in base layers[45].

Of the total generated ash, 10% is bottom ash[40]. In 2018, ~1.34 million tonnes of bottom ash was generated in Australia, with only 47.6% being recycled[46].

Plastic

The most commonly found polymers in applications of plastics are high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), poly vinyl chloride (PVC) and polystyrene (PS).

Applications of recycled plastics in road infrastructure include the manufacture of plastic ancillary components, including roadside furniture, road cones, safety barriers, boardwalks, drainage covers. Higher percentages of recycled plastics can be used in this application compared to when used within a bituminous binder.

Using recycled plastics in asphalt has become a potential use of the waste product. Research is currently being conducted through a joint National Asset Centre of Excellence–Western Australian Road Research and Innovation Program project and a project done by the Royal Melbourne Institute of Technology on behalf of Austroads.[47]

Soft plastics can be used as an additive that melt to form part of the bituminous binder which bonds and waterproofs the aggregate. This means there would be no issue with microplastics. Asphalt commonly comprises of 95% aggregate and 5% bitumen binder.[48]

It has been found that the use of recycled plastics in roads may have limited impact on the current plastic waste stream so should be developed alongside other applications. If 6% by mass of waste plastic was added to the 800,000 tonnes of bitumen used in Australia annually, it would remove only 2% of the waste plastic generated in Australia per year. [49]

In 2018 the Downer Group partnered with Hume City Council, Close the Loop and REDcycle to develop Australia's first road using soft plastic and glass asphalt.[50] The plastics used in this application were soft plastics with 200,000 recycled plastics bags being used every 1 km of the two-lane road. In Victoria, around 170,000 tonnes of soft plastic waste is created each year and only about 10% of that is recovered. In comparison to regular asphalt, the modified glass and plastic asphalt has superior deformation resistance for withstanding heavy vehicle traffic. This research led to the commercialisation of the product and soft-plastic asphalt is now available across Australia. It is used by seven local governments in Victoria and councils in New South Wales and South Australia.

REDcycle collect plastic bags and other soft plastics with drop-off points in all major cities around Australia.[51] They collaborate with three Australian owned recycling and manufacturing partners who use these materials: Replas, Close the Loop and Plastic Forests. Replas and Close the Loop have been involved in projects that utilise recycled plastic in road infrastructure in Australia.

In 2018–19, 2.54 megatonne of plastic waste was generated in Australia.[52] Of this volume, just under 13% was recycled and the remainder was sent to landfill.

Figure 16 shows the flow of waste plastic through the supply chain.

Figure 15: Supply of plastics

Table 9 shows the number of plastic reprocessing facilities in Australia.[53]

Table 6: Plastic waste reprocessing facilities in Australia 2016–17

State/Territory	Number processing facilities
Australian Capital Territory	0
New South Wales	20
Northern Territory	2
Queensland	12
South Australia	12
Tasmania	2
Victoria	24
Western Australia	4
Total	**76**

Source: Locock (2017)[54]

Victoria and New South Wales have the largest reprocessing capabilities. These states reprocess ~30% of the recycled plastic that is recovered from each jurisdiction.

An issue with post-consumer plastics is they are often contaminated making them more complex to recycle. The recycled plastic must be carefully sorted to ensure it is not mixed with hard plastics and they must be cleaned to remove contaminants. This makes the process quite labour intensive. Plastic consumption has seen an increase of 10% while the recycling rates have decreased by 2%.[55]

Recycled solid organics

Recycled solid organics are products recycled from organic waste. Solid organics are sourced from plant or animal waste and can be used in road infrastructure, mainly in landscaping, erosion control, and biorientation and biofiltration applications.

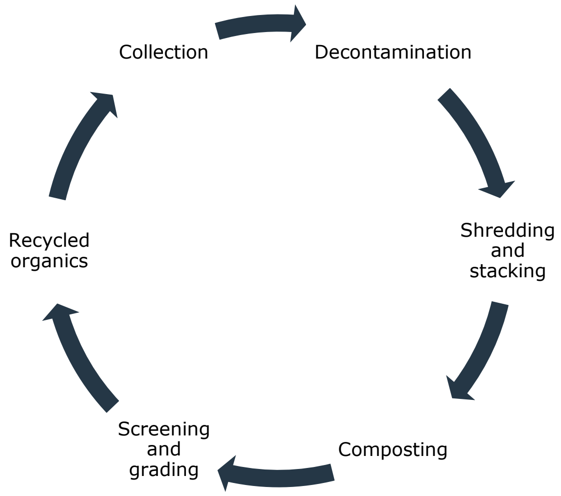
Recycled organics can add nutrients, act as a soil conditioner, improve water retention, and act as a seed suppressant.

Emissions largely consist of methane which is generated by the anaerobic decay of organic matter.[56] In 2020–21, waste accounted for 2.7% of the total emissions in Australia.

In 2018–19, 14.3 megatonnes of organic waste were generated in Australia of which around 7.4 megatonnes (51.5%) was recycled. According to the Australian Organics Recycling Industry Capacity Assessment 2020–21, the industry is capable of processing 82% of organic materials. This indicates there is untapped physical capacity of existing operations that can be utilised to achieve the National Waste Policy's target of halving the amount of organic waste sent to landfill for disposal by 2030.[55]

Figure 17 shows the recycling process of solid organics.

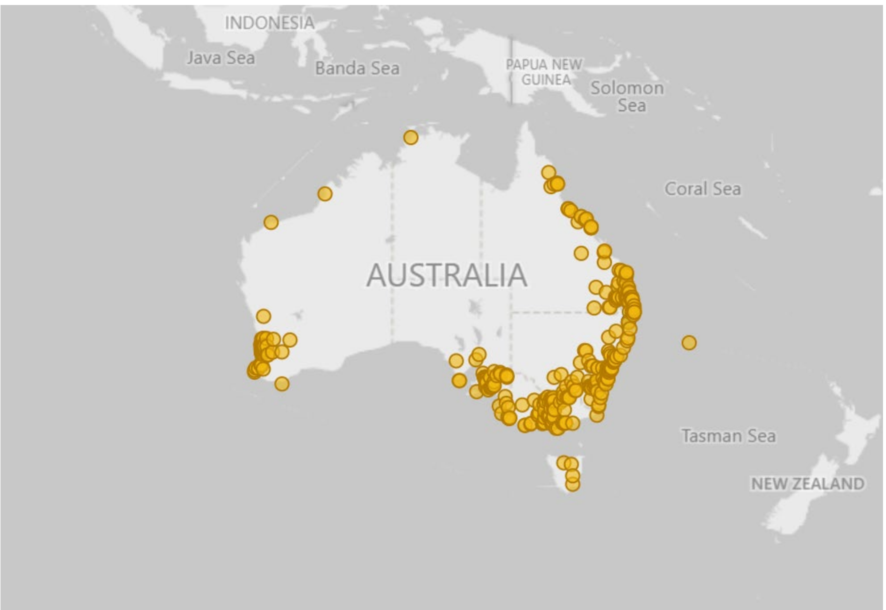
Figure 16: Solid organic waste recycling process



Source: Adapted from Suez (2017) [57]

Figure 18 shows the locations of organic recycling facilities across Australia.

Figure 17: The organics recycling facilities in Australia



Source: Department of Agriculture, Water and the Environment (2018)[58]

There are some key challenges related to recycled organics composting. The supply is directly related to the green waste collection and processing market. A sudden increase in supply due to rainfall or seasonality can be unmatched by demand as demand is controlled by economic growth, housing development timings and demand for gardening products. In addition, changes to supply can impact processing time which limits maturation time. This is directly related to quality so can cause greater variations between processors. Stockpiling is also limited by odour management regulations.

Contamination of recycled organics is also difficult to manage. It can be contaminated with plastic, glass, and other materials. In addition, products in this market can be very inconsistent with a varying price and volume making it challenging to pursue. Often most of the supply is in metropolitan cities, but the demand is in regional areas which can raise transportations costs.

There are future opportunities to address these challenges including fostering agricultural use, developing an overflow arrangement, and promoting urban amenity demand.

Food organics and garden organics is a kerbside collection service that enables food scraps and garden waste to be recycled into a top-quality compost.

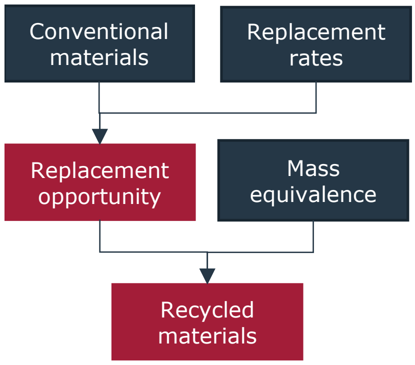
2. Technical notes for demand modelling

Overview

Background

Infrastructure Australia commissioned Australia Road Research Board and Ernst & Young to estimate the opportunity for replacing conventional materials and the potential demand for recycled materials for delivering major projects across the country. This report details the methodology, input and findings of the analysis.

Figure 18: Model map



Methodology

The modelling uses Infrastructure Australia's forecast conventional materials quantities (2015–31) and applies with analysis-derived estimates of replacement rates to estimate the quantity of conventional materials that could be replaced. It then applies mass and volume relativities between conventional and recycled materials to estimate the demand for replacement materials. The methodology of forecasting demand for replacement materials is depicted in Figure 19.

Findings

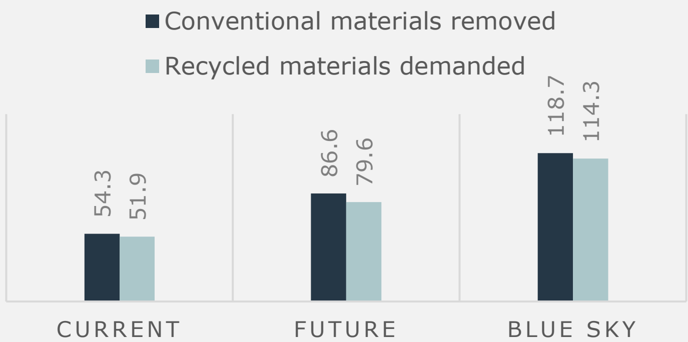
This report presents the findings for each of Infrastructure Australia's central case, low and high forecasts for conventional materials (**Figure 11**), based on the replacement scenarios of:

Current – existing science and technology, regulations and product allowable limits

Future – assumed advancement in technology and corresponding changes to standards

Blue-sky – a more bullish set of assumptions assuming further technical improvements and standards updates.

Figure 19: Central case forecast (million tonnes)



Compared to central case forecast above:

- Low forecast: −17%
- High forecast: +14%

Limitations

The accuracy of the conventional material demand forecast, quantities and type, underpins the robustness of the findings.

The broad aggregation of conventional material types and lack of information on the structures means generic assumptions are used when formulating replacement rates and mass equivalence factors.

Implications

There is significant potential for replacing conventional materials with recycled materials, with advancements in technology and the associated updates of standards presenting further opportunities. The scale of replacement realised will be affected by market appetite and supply.

Central case forecasts on the potential demand for recycled materials

Based on Infrastructure Australia's central case forecast for conventional materials demand.

- y-axis; groups of conventional materials that could be replaced
- x-axis: amount of recycled materials that could be used to replace each group of conventional materials.

Figure 21, Figure 22 and Figure 23 have been generated using a dashboard developed for this estimation project.

Figure 20: Forecast demand for recycled materials (tonnage) – current scenario

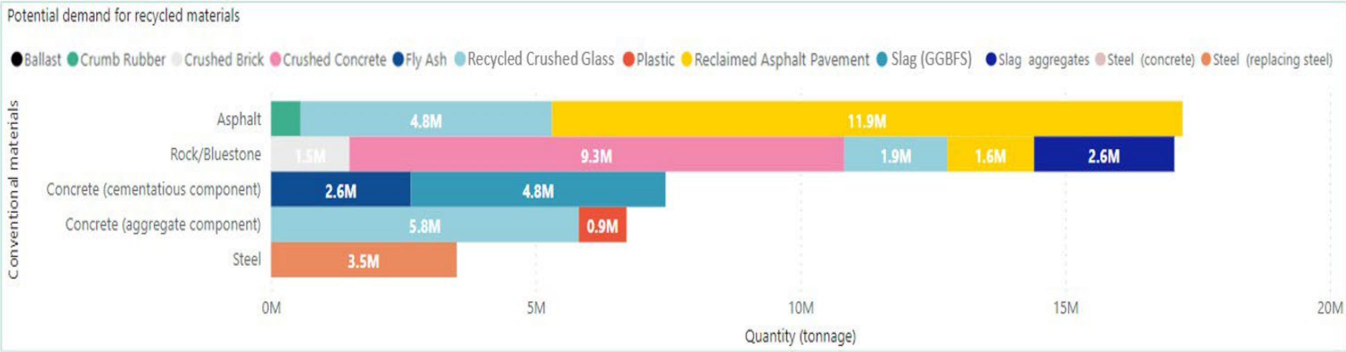


Figure 21: Forecast demand for recycled materials (tonnage) - future scenario

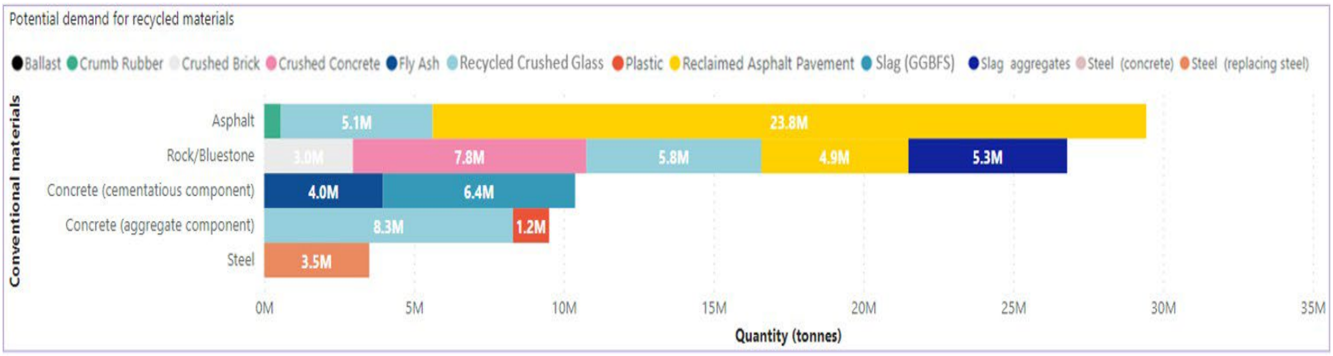
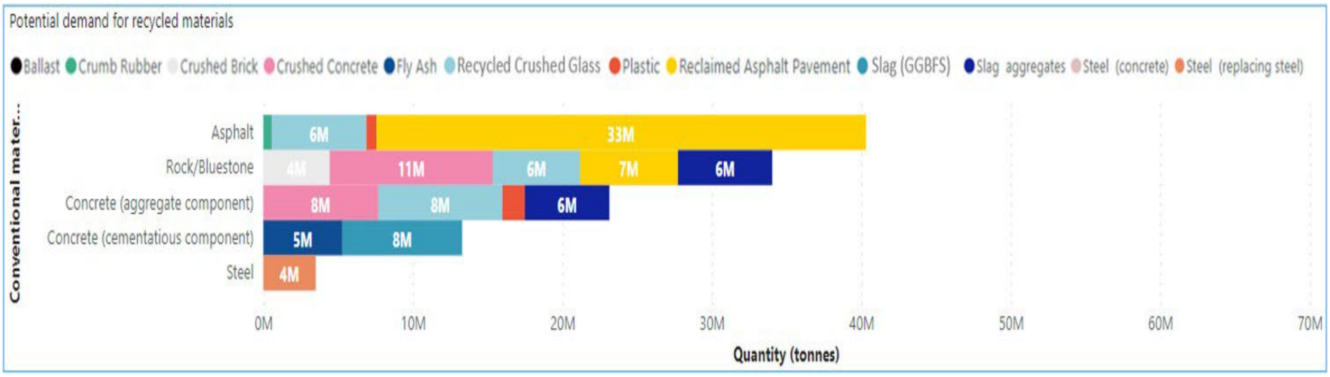


Figure 22: Forecast demand for recycled materials (tonnage) - blue sky scenario



Background

Purpose of this appendix

Infrastructure Australia commissioned Australia Road Research Board and Ernst & Young to estimate the opportunity for replacing conventional materials and the potential demand for recycled materials for delivering major projects across the country.

This appendix supports Section 3 Forecasting Potential Demand.

Contributors to the analysis

This report is the product of collaboration between Infrastructure Australia, Australia Road Research Board and Ernst & Young, with:

- Infrastructure Australia commissioning the technical work, providing the input data and overall steer on the analysis
- Australia Road Research Board managing the overall consulting engagement, providing input to the assumptions using its technical expertise in materials science, design and standards
- Ernst & Young providing the modelling support, using its experience in quantitative analysis including in the recycled materials sector.

The remainder of the appendix uses 'the consultant team' for noting actions undertaken by the joint Australia Road Research board and Ernst & Young team.

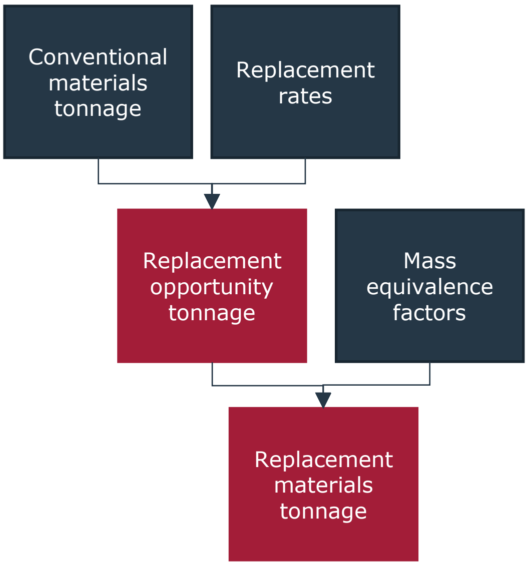
Methodology

Overview of approach and limitations

The approach

The following calculation steps have been developed for delivering the forecasts:

- Infrastructure Australia provided the quantities of conventional materials that are forecast to be required to deliver the range of projects under its analysis from across Australia.
- The consultant team formulated a set of replacement rates to estimate the opportunity for replacing each type of conventional materials with recycled materials.
- To account for the density differences between conventional and replacement materials, the consultant team applied a set of mass equivalence factors to estimate the mass (tonnage) of recycled materials needed to satisfy the requirements of infrastructure projects based on conventional materials.



The scenarios

Infrastructure Australia developed demand forecasts of conventional materials using a methodology based on assumptions on the resource demand intensity by project type (e.g., total labour and material demand per road tunnel project) and unit cost rates for labour and materials (e.g.,$/FTE steel worker and $/tonne of steel). To account for the uncertainties within these assumptions, Infrastructure Australia developed a set of forecasts under three scenarios that correspond to variations in these assumptions:

- Central case – demand forecasts under this scenario reflect the level of resource demand and unit cost rate based on the industry norm observed by Infrastructure Australia
- Low forecast – demand forecasts under this scenario are approximately 17% lower than the central case as it assumes a 25% lower resource demand intensity and 10% lower unit cost rate compared to the central case
- High forecast – demand forecasts under this scenario are approximately 14% higher than the central case as it assumes a 25% higher resource demand intensity and 10% higher unit cost rate compared to the central case.

The conventional materials forecasts were undertaken separately/outside this replacement materials analysis; they are external inputs to this analysis.

The replacement rates formulated consist of three scenarios:

- Current – replacement potential based on existing conditions in science and technology, regulations and standards
- Future – assuming a degree of technological and regulatory progress
- Blue-sky – providing an upper-limit set of potentials, with bullish assumptions for advancements.

The above scenarios are discussed further in the subsequent sub-sections.

Limitations

As with any model, the output is underpinned by the input. The forecast conventional materials in terms of the overall quantity, definition of material types and split between types, underpins the forecast replacement opportunities, what type of recycled materials are likely to be demanded and how much. The lack of structural details of projects in the input data provided means all conventional materials data are used 'as given', without understanding what the quantities of different types of materials are used for and how they are used. Therefore, general assumptions are made on the potential opportunities for replacement, and how much of recycled materials are likely to be required to replace the corresponding conventional materials. Overall, the accuracy and granularity of the input data underpins the robustness of the analysis.

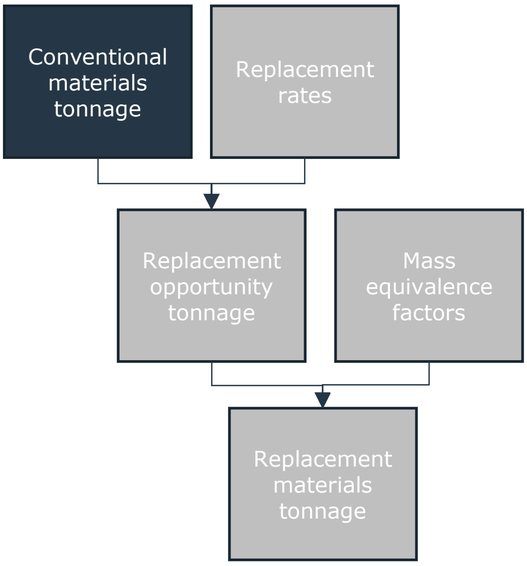
Input – conventional materials forecasts and scenarios

Data

Infrastructure Australia provided forecasts of conventional material demand from projects across the country (summarised in Table 10 below).

Table 7: Projects included in the analysis (2015–31)

Geography, jurisdiction	Number of Projects
Victoria	131
South Australia	48
New South Wales	191
Australian Capital Territory	11
Tasmania	80
Northern Territory	35
Queensland	362
Western Australia	140
Total	**998**



Infrastructure Australia provided three sets of forecasts of coneventional materials used on the projects – a central case set of figures, a low forecast and a high forecast. The quantities are shown in Table 11 below.

Table 8: Forecast conventional materials quantities (million tonnes)

Resource group	Low	Central case	High
Aggregate	48.8	58.6	66.6
Cement	14.7	17.6	20.0
Sand	24.8	29.8	33.8
Asphalt	45.5	54.6	62.0
Bitumen binders	4.2	5.0	5.7
Rock/Bluestone	26.0	31.2	35.4
Steel – structural elements	0.7	0.9	1.0
Steel reinforcement	2.2	2.6	3.0
Total	**166.9**	**200.2**	**227.5**
% vs Central case	*–17%*	*–*	*+14%*

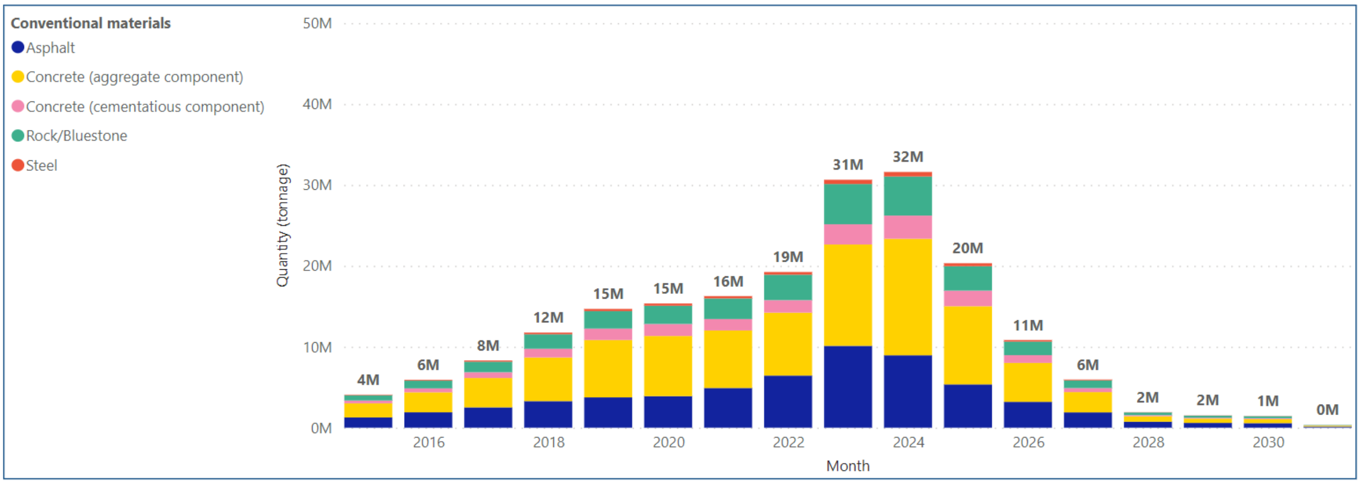
Grouping and profile

The conventional materials are grouped according to the table below, with this analysis splitting out concrete into aggregate and cementitious components to enable separate assumptions for replacement rates (discussed in the next section). This study-specific set of grouping is to achieve a reasonable balance between detail and ease of formulating assumptions. Profile of conventional material demand is shown in Figure 24, with grouping outlined in Table 12.

Table 9: Conventional materials grouping

Resource group	Grouping 1	Grouping 2	Grouping used in this estimation project
As provided by infrastructure Australia			Defined for this analysis
Aggregate	Concrete	Concrete	Concrete (aggregate component)
Cement	Concrete	Concrete	Concrete (cementitious component)
Sand	Concrete	Concrete	Concrete (aggregate component)
Asphalt	Asphalt	Asphalt	Asphalt
Bitumen binders	Bitumen binders	Bitumen binders	Asphalt
Rock/Bluestone	Rock/Bluestone	Rock/Bluestone	Rock/Bluestone
Steel – structural elements	Steel	Steel – structural elements	Steel
Steel reinforcement	Steel	Steel reinforcement	Steel

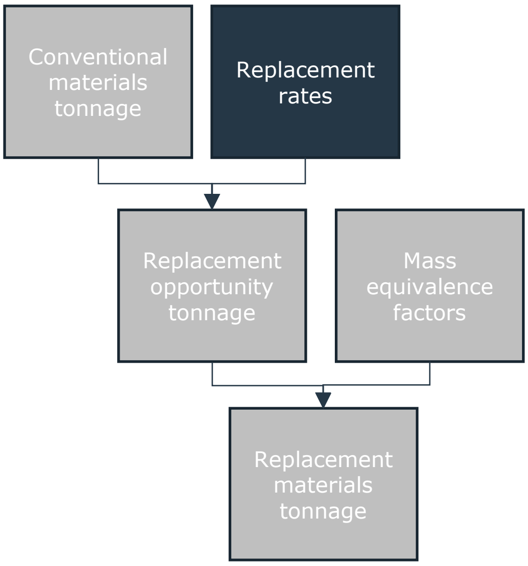
Figure 23: Conventional materials usage profile – central case forecast



Assumption rates and scenarios

Concept and methodology

A replacement rate is a percentage figure applied to a type of conventional material, to estimate the tonnage of that material which could be replaced by a recycled material.



The consultant team reviewed the following materials when developing the replacement assumptions:

- **Replacement rates in the ecologiQ model**. Major Road Project Victoria's ecologiQ team has developed replacement rates as a part of the material demand forecasting method for Victoria's Big Build projects. The replacement rates applied in the ecologiQ model are project-specific: they are developed based on the purpose, design, location, size, material availability and standards of specific infrastructure projects. These replacement rates are aggregated by material type to inform the demand forecast of recycled materials.
- **Standards and specifications of public road agencies**. A number of state, territorial and local road agencies regulate the extent to which recycled materials can be applied in road projects. Specifically, standards and specifications from the following agencies have been considered:
  - Department of Transport Victoria
  - Main Roads Western Australia
  - Queensland Department of Transport and Main Roads
  - Department of Infrastructure and Transport South Australia
  - Transport for New South Wales
  - Australian Local Government Association.
- **Australian and international research.** The developments of new recycled infrastructure materials and incorporation methods are an active area of research both in Australia and internationally. Related research produced by the following sources have been considered by the consultant team:
  - guidance and findings in Austroads publications
  - specifications developed by the Institute of Public Works Engineering Australasia
  - experience and knowledge collated from projects undertaken by Australia Road Research Board.

Through the above review, a set of rates were formulated to best reflect the current situation. Further, the consultant team developed assumptions to capture the potential effects from increasingly advanced technologies and corresponding standards updates. The scenarios are:

- **Current** – replacement rates in this scenario reflect the current usage of recycled materials by major projects in Australia
- **Future** – replacement rates in this scenario reflect the expected usage of recycled materials in a future when requisite infrastructure standards have been updated to accommodate the higher replacement potential supported by current research

- **Blue-sky** – replacement rates in this scenario reflect the highest replacement potential by recycled materials that may be achieved indicated by the latest research and Australia Road Research Board's professional opinion.

While the current standards and research provide references of replacement rates for individual recycled materials, there is a lack of existing knowledge on how multiple recycled materials may be applied as a composite replacement material. However, a composite replacement rate is needed to estimate the total demand of recycled material as a share of conventional material.

To address the lack of this knowledge, the consultant team has made assumptions for the total replacement rates under the three scenarios based on their knowledge of the properties of recycled materials in typical infrastructure applications. For example, collectively recycled materials will not replace more than 70% of the cementitious component in concrete application even when their individual replacement rates may sum up to more than 70%. Assumed total replacement rates are presented in Table 13 below.

Table 10: Total replacement rate by scenario

Conventional material	Current	Future	Blue-sky
Asphalt	30%	50%	70%
Concrete (aggregate component)	10%	20%	30%
Concrete (cementitious component)	50%	70%	90%
Steel	100%	100%	100%
Rock/Bluestone	50%	75%	100%

Summing to the total replacement rates for each conventional material group, Table 14, Table 15 and Table 16 present more detailed breakdowns of what each conventional material group could be replaced with, and the percentage replacement.

Replacement rates used

The replacement rates are presented below.

Table 11: Percentage of conventional materials that can be replaced by recycled materials – current replacement scenario

Current	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	20%	8%	0%	2%	0%	0%	0%	0%	N/A	N/A
Concrete (aggregate)	0%	0%	7%	0%	0%	0%	0%	0%	3%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	30%	0%	20%	0%	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	30%	5%	5%	5%	0%	0%	5%	0%	0%	N/A	N/A

Table 12: Percentage of conventional materials that can be replaced by recycled materials – future replacement scenario

Future	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	40%	8%	0%	2%	0%	0%	0%	0%	N/A	N/A
Concrete (aggregate)	6%	0%	10%	0%	0%	0%	0%	0%	4%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	40%	0%	30%	0%	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	25%	15%	15%	10%	0%	0%	10%	0%	0%	N/A	0%

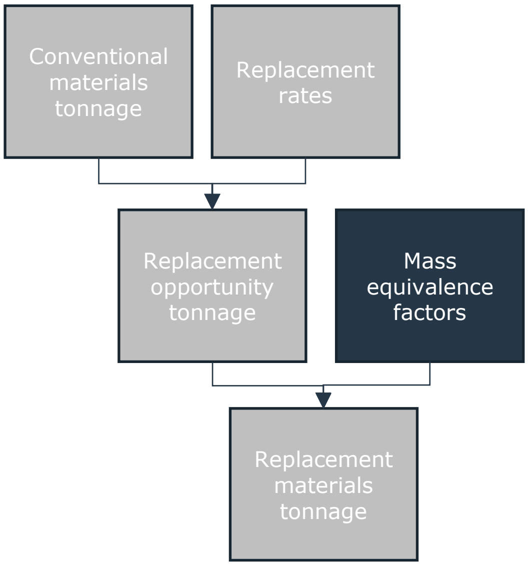
Table 13: Percentage of conventional materials that can be replaced by recycled materials – blue-sky replacement scenario

Blue-sky	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	55%	10%	N/A	2%	0%	0%	0%	3%	N/A	N/A
Concrete (aggregate)	10%	0%	10%	0%	0%	0%	5%	0%	5%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	50%	0%	40%	0	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	35%	20%	15%	15%	0%	0%	15%	0%	0%	0%	0%

Assumption – mass equivalent factors

Concept and methodology

Bringing input conventional materials forecast and replacement rates together generates the estimated mass of conventional materials that could be replaced. The next step is to estimate the corresponding mass of recycled materials that are required to replace them.



Doing so requires adjustments to account for the fact that recycled materials do not necessarily have the same density as the conventional material they replace which may result in more or less mass for the same volume of infrastructure material.

Mass of recycled materials are calculated by multiplying the mass of conventional materials with a mass equivalence factor which is the ratio of the density of recycled material over the density of the conventional material it replaces.

This method of calculating the mass of recycled materials assumes that conventional materials and the recycled materials occupy the same volume of space within each infrastructure application. For example, a pavement wearing course is assumed to have the same design dimensions – width, length, and thickness – with either virgin asphalt or reclaimed asphalt pavement.

Mass equivalence factors used

The factors used to 'convert' a tonne of conventional material to a tonne of replacement material are presented in Table 17 below.

Table 14: Mass equivalence factors

	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	–	1.00	1.06	–	0.47	–	–	–	0.38	–	–
Concrete (aggregate)	0.87	–	0.94	–	–	–	1.28	–	0.34	–	–
Concrete (cementitious)	–	–	–	–	–	0.91	–	0.75	–	–	–
Steel	–	–	–	–	–	–	–	–	–	1.00	1.00
Rock/Bluestone	1.00	1.05	1.25	0.95	–	–	1.35	–	–	–	–

3. Market analysis engagement program

The market analysis was informed by engagement program consisting of:

- a quantitative survey of the resource recovery and recycling industry
- facilitated workshops with the recycled materials supply chain and its customers
- one-on-one interviews with industry and government leaders.

Quantitative survey

Survey objective

The overall objective of the market survey was to understand material supply and supply chain constraints for recycled materials. In particular, the survey aimed to deliver hard data on the supplier market, including suppliers' capacity, their attitudes to and their experiences with recycled materials.

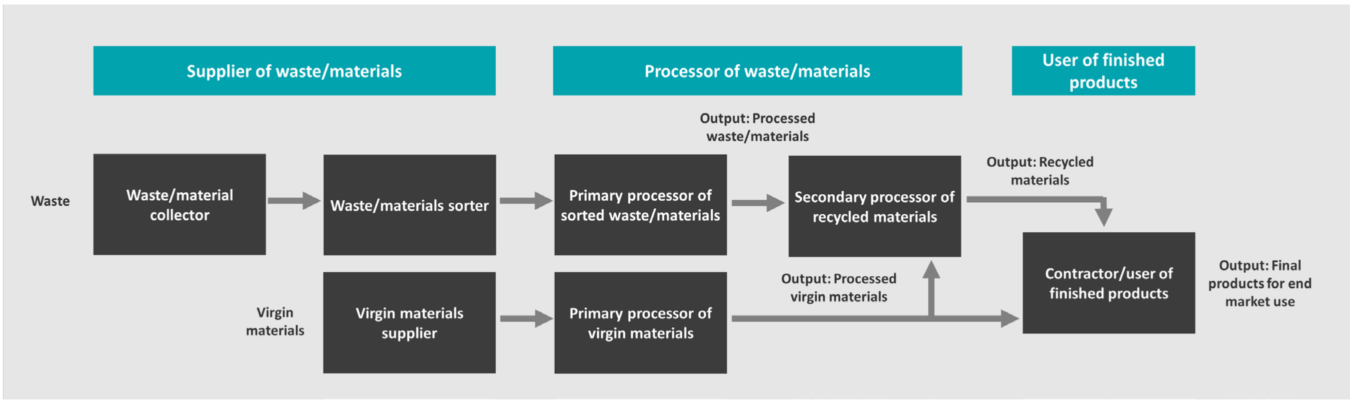
Methodology

The target audiences included a mix of organisations that currently are or would consider being part of the recycled material supply chain. To be eligible for participation, all respondents had to fall into at least one of these categories:

- supplier of waste/materials:
  - waste/materials sorter
  - virgin materials supplier
- current processor of waste/materials:
  - primary processors of sorted waste/materials
  - primary processors of virgin materials
- current secondary processors of recycled materials, including prospective secondary processors of recycled materials (i.e., considerers/non-rejectors).

This included a mix of businesses across material/product types, business sizes and geographies as illustrated in Figure 34 and Figure 35.

Figure 24: Quantitative survey industry participants



The survey was conducted from 16 March to 8 April 2022. It was administered as an online survey (main method) and via computer assisted telephone interviewing (supplementary method).

It took participants approximately 15–20 minutes to complete the survey. Participants were recruited via multiple sources, including:

- a purchased list of contacts from one of Ernst & Young's approved list brokers. A list of senior decision makers within the business was shortlisted based on their associated Australian and New Zealand Standard Industrial Classification codes
- a secondary list from Ernst & Young and Australian Road Research Board databases
- via Infrastructure Australia network affiliates/partners
- via Australian Road Research Board's website
- via the Infrastructure Australia social media platforms.

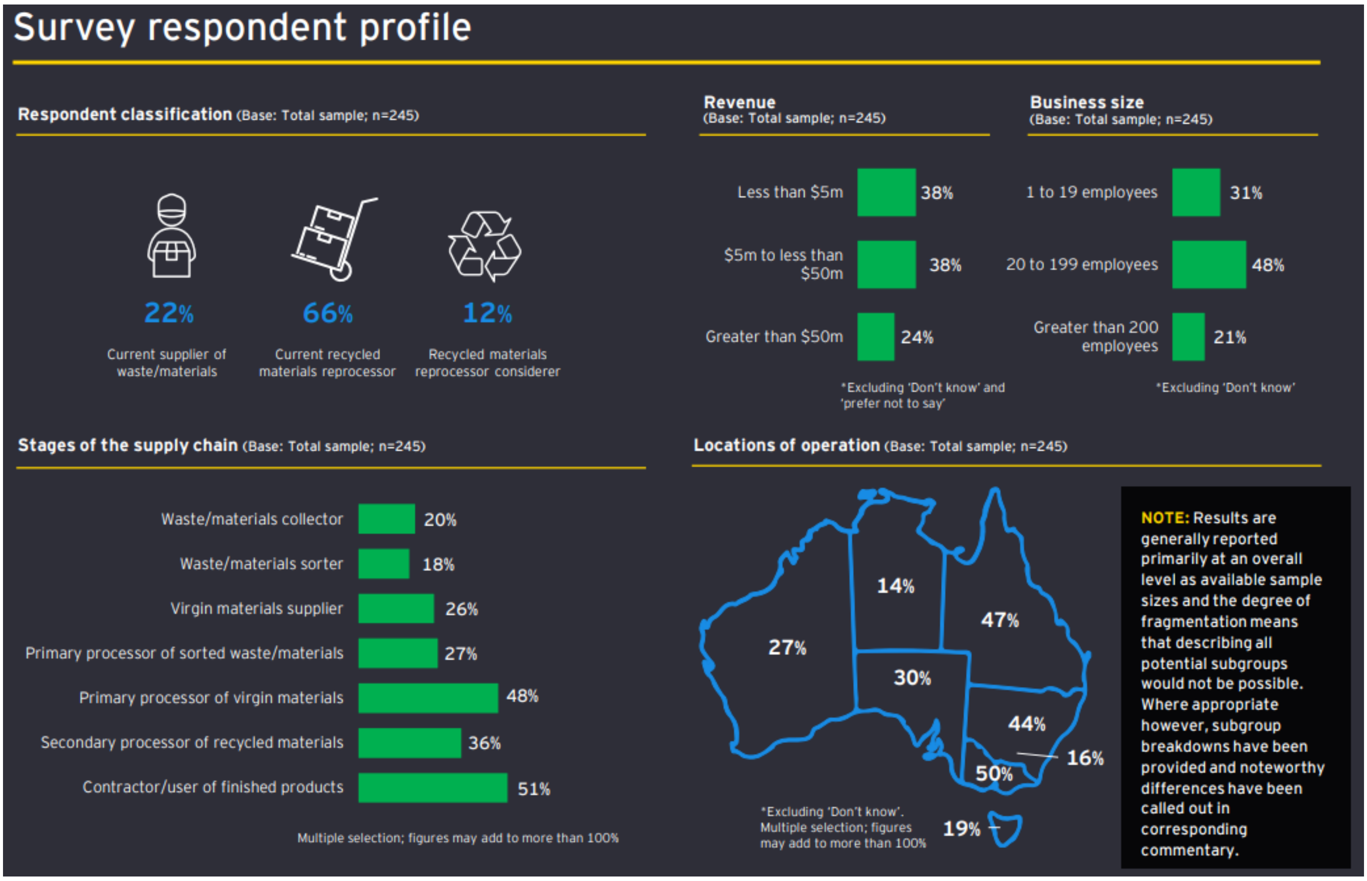
Where a list of contact names was available, EY Sweeney either emailed each contact a unique link to complete the survey online or completed the survey with them via computer assisted telephone interviewing. All other contacts were invited via a generic link, published by respective partners, websites and/or platforms (as described above).

A soft launch was conducted in the first instance on 16 March 2022, when 50 invitations were sent. A review of the soft launch data was undertaken before proceeding to the full launch, with the remaining invitations sent on 17 March 2022.

Survey respondent profile

A total of 245 businesses responded to the survey as shown in Figure 35.

Figure 25: Survey respondent profile



Key findings

The recyclable material supply chain is a diverse and fragmented market, which serves a mix of customers and locations across Australia

Participating businesses in the survey represent a mix of businesses within the waste and material supply chain ecosystem, who currently service a range of markets and customers.

- For-profit businesses in the private sector represent the largest customer base, with 87% of businesses surveyed selling products and services to these audiences. Government customers are the second-highest reported customer cohort (60%), followed by consumers/residential markets (52%).

- Businesses have multiple locations of operation, with 73% reporting that they have operations based on the eastern seaboard (86% compared to 42% non-east coast), across a mix of metropolitan (73%) and regional (67%) areas
  - government makes up a larger proportion of the customer base for businesses operating in regional areas, where 7 in 10 (69%) businesses sell products and services to government
  - this figure is slightly lower for those operating in metro areas (57%).
- The geographic reach of where their customers are based is diverse, although at least half tend to service customers on the eastern seaboard.
- Over three-quarters (77%) of participating businesses currently service road sector customers. Current reprocessors of recycled materials are more likely to sell products or services for road projects, with 7 in 10 (72%) indicating they do so.
- Businesses that participated in the survey are typically small (31% with 1 to 19 employees) to medium (48% with 20–199 employees) in size, with an annual turnover of < $5 million (38%) and $5–50 million (38%). High turnover businesses ($50 million+) are more likely to have customers in Victoria (77%).

A sizeable proportion of businesses within the supply chain sell recycled materials for road projects, although opportunities exist to expand production and revenues

The use of recycled materials for road projects readily exists in and around Australia, with 62% of survey participants saying they process recycled material into road project materials. This tends to be a more common occurrence among large businesses and those operating in regional areas. Crushed concrete, in particular, has the highest reported production for use in road projects.

Revenues from these projects are however relatively low, with two in five (41%) current reprocessors reporting a revenue of 1 to 20% through such projects. This may partly explain why a large proportion (72%) of current reprocessors of recycled materials are also in the business of processing/producing virgin materials.

Consideration of expanding materials produced for road projects is mixed, and opportunities exist to make recycled materials a more attractive supplementary option. Just over half (54%) of current recycled materials reprocessors surveyed would consider producing other recycled materials in the future, although a sizeable proportion (33%) of participants do not know what new materials they would produce. One in five (20%) would never consider producing other recycled materials, a more common trend among small businesses. Small businesses are also more likely to indicate they are uncertain about future production types, with around one in two (46%) businesses with less than 20 employees indicating this.

Implications

Support businesses by educating them about the range of recycled materials (e.g.,a database of products and their application), educational collateral and case studies. Policy development that improves the price competitiveness of recycled materials, and which provides clear demand signals to support profitability and production would be beneficial.

Recycled materials are viewed positively largely due to the environmental and practical advantages offered

There is a sense of willingness within industry to produce and use recycled materials, which is largely driven by a host of environmental and practical benefits.

Most commonly, recycled materials are viewed positively as they help reduce waste sent to landfill which is the most common driver to produce recycled materials (43%). Primary suppliers of waste/materials are most likely to cite reducing waste sent to landfill as a driver (61%), followed by current producers of recycled materials (50%). Seventeen per cent also acknowledge that there is increasing technology/innovation, which supports the production of replacement materials.

There is also a sense of responsibility among businesses to do their part for the environment by reducing emissions, with a higher proportion of current reprocessors of recycled materials mentioning this (24%).

While current producers of virgin materials reported similar patterns in relation to drivers as current reprocessors, proportions within each driver are lower, possibly suggesting a lower overall resonance with recycled materials.

Notwithstanding, survey participants also acknowledge the practical sides, with the supply of traditional quarry materials becoming increasingly constrained due to a depletion of natural resources. Using recycled materials reduces the reliance upon and use of non-renewable materials (16%), and encourages more efficient use of natural resources (11%). Similar proportions also recognise that virgin materials are becoming increasing costly to use (10%), which is likely dampening the market demand for raw materials, vis-à-vis recycled materials, with a growing trend noted both currently and in the future.

Implications

Build up the momentum for the production and use of recyclable materials by focussing on the environmental credentials and the lifecycle cost of such materials compared with virgin materials.

Perceived performance, cost and compliance issues are leading barriers to businesses producing recycled materials

Despite growing confidence in the use of recycled materials overall, the widescale construction of roads and pavements with recycled materials do present challenges in the minds of businesses, some of which are more nuanced among different cohorts.

Primary suppliers of waste/materials are most commonly concerned with the economic barriers acknowledging that virgin materials are cheaper to use (28%). It is also perceived to be unhelpful with low demand in the market (28%), and subsequently low uptake of the products and low returns on investment.

In contrast, current reprocessors of recycled materials are more likely to cite misperceptions and predispositions among industry towards recycled materials. This includes perceptions around the poorer quality of recycled materials (23%), which is largely a sentiment noted among their customers (44% having come across this always/most of the time/sometimes compared to a 38% average). Those who service customers in the road sector are more likely to have customers believing that products made from recycled materials for road projects perform worse than products from virgin materials (50% always/most of the time/sometimes compared to a 36% average). It appears that a fear of the unknown and a lack of confidence among customers is likely to influence business inertia to produce more recycled materials. These concerns are further compounded by unfavourable regulatory conditions (21%) that do not necessarily support the demand and supply for replacement materials, as well as a lack of government incentives/grants (19%).

Current producers of virgin materials are more similar to primary suppliers of waste/materials, where there is a greater focus on economic concerns. Some 31% feel that it is cheaper to use virgin materials than recycled materials, offering quicker returns on investment. While 50% of survey participants who currently do not process recycled materials (n=83) would not reject the idea of processing/producing recycled materials in the future, a similar proportion say they would not consider the possibility at all (n=41).

Of these future considerers, both suppliers of waste/materials and producers of virgin materials appear to have a higher degree of confidence and trust in virgin materials. This confidence is primarily based around the belief that virgin materials are cheaper to use raw materials in locations where their supply is consistent. This belief exacerbated by a poor understanding of the benefits of recycled materials as well as a lack of conviction about the real impact they have on the reduction of emissions.

Overall, the survey identifies various concerns, including:

- misperceptions and predispositions, particularly around the quality and performance of products made with recycled materials, as perceived by customers and businesses not currently reprocessing these materials, as well as a lack of interest among customers
- regulatory barriers associated with a lack of regulatory policies to support the transition toward the use and production of replacement materials, as well as an unfavourable financial/incentive system
- market barriers, which appears to be influenced by the lower price of virgin materials, high(er) upfront investment costs which can reduce profitability, and limited standardisation for the use and production of recycled materials.

Encouragingly, there is some acknowledgement of the increasing technology/innovation that supports the supply of remanufactured products, as noted previously. Further activities are necessary to ensure that recovered materials meet the quality requirements demanded by customers, which will likely require the review of activities and processes, and the development of new technologies.

Implications

Educate the sector as well as customers to ensure adequate knowledge about recovered materials and their characteristics, which is fundamental for overcoming the misperceptions about the quality and durability of products that potentially raise such barriers.

Establishing standards and regulatory conditions that support the optimal performance of recycled materials would be valued

Prioritisation of the development of national standards and specifications is called for… of which 92% would find this to be a very/somewhat attractive measure to supporting their business' decision to continue, or consider, producing recycled materials for road projects.

The survey suggests there is still a degree of ambiguity around the perceived quality and performance of recycled materials, which are generally viewed to be on par with virgin materials. This belief is evident even among existing reprocessors of recycled materials, with one in two (48%) of these businesses believing that recycled materials is similar 'quality', and 54% thinking they 'perform' the same as virgin materials. A relatively high proportion are vague about the relative quality and performance of recycled materials, even among current reprocessors (28% for quality and 27% for performance), indicating further education is needed.

Developing specifications that stipulate the use of different recycled materials in road projects can provide producers greater clarity and guidance in producing optimal performing products. This can provide product performance guarantees to customers, which help address some of the cultural barriers towards products made with replacement materials.

As part of this process, early engagement with stakeholders and decision makers who have responsibility for standards and certifications needs to be fostered to ensure that recycled materials are fit-for-purpose and accurately reflect both policy objectives and technical needs.

Implications

The development of a common standard for the production of recycled materials provides businesses greater assurance of the production of high-quality recycled materials for road projects. This in return can help shift existing mindsets and reservations around the quality and performance of recycled materials among customers and stakeholders across the supply chain.

A call to review government specifications in procurement processes and practices is noted

An opportunity exists to review government specifications in procurement processes and practices, with 88% of participating businesses in the survey recognising the attractiveness of this measure.

Exploring this possibility further may be valuable, as businesses acknowledge that current procurement conditions relating to recycled products do not necessarily drive current procurement of products containing recycled materials, with 13% of current reprocessors identifying this factor to be a barrier to greater production.

Including recycled content specifications in tenders and contracts may help drive the demand and subsequently supply for replacement materials. Business case examples may also be helpful in educating procurement stakeholders to see how recycled content products can be adapted to their needs, including information on performance, cost and reliability in specific applications.

This in part may involve increasing the technical skills and expertise of procurement stakeholders such as government members, so they are informed buyers in the process, are conscious of the material choices, cost and wider benefits, and are in a position to challenge standards to enable innovation and drive efficiencies. Training may need to be introduced to enable procurement stakeholders to understand how best to integrate recycled content into their procurement planning and strategy, including sourcing suppliers and product availability.

Implications

Reviewing procurement guidelines, including educating procurement stakeholders about recycled material choices, helps ensure buyers are informed purchasers. This in return could promote end markets for recyclable materials in building demand and uptake of such materials.

Opportunity exists to provide businesses with financial assistance to make recycled materials a more attractive proposition

Initiatives to help make the production of replacement materials more price competitive and financially sustainable for businesses are appreciated… with survey findings revealing that concerns are present around the costs and profitability associated with the production of replacement materials.

While drivers for businesses' willingness to produce recycled materials largely centre around the environmental impacts that they can bring, uncompetitive pricing conditions and low market demand for recycled materials can also hinder businesses from transitioning to the production of replacement materials.

Businesses require assurances that the operating cash flows from producing recyclable materials will be sufficient to repay their initial investments. External drivers such as financial incentives can help promote its uptake by helping businesses address expenditure needs, such as upfront capital costs (with 98% valuing financial assistance to help reduce costs associated with infrastructure setup), talent sourcing (83%), and staff training (80%). Some have explicitly mentioned the value of marketing support and development grants to help them expand their customer base and markets.

Coincidentally, about half (52%) of businesses surveyed have invested in, or are planning to invest in, new technologies; 40% have not. Larger businesses are more likely to be new technology adopters, which is likely influenced by the availability of financial support.

Implications

Interventions that are focussed on intrinsic motivations, as well external drivers such as measures using financial stimuli can both support each other and together, may increase positive impact of businesses uptake of replacement material production.

Workshops

Infrastructure Australia hosted three workshops facilitated by Australian Road Research Board and Ernst & young. Over 100 individuals representing the following government agencies and industry organisations participated in the workshops.

Government

- Australian Local Government Association
- Austroads

- Department for Infrastructure and Transport, South Australia
- Department of Agriculture, Water and the Environment, Australian Government
- Department of Environment and Science, Australian Government
- Department of Environment, Land, Water and Planning, Victoria
- Department of Infrastructure, Transport, Regional Development and Communications, Australian Government
- Department of Jobs, Precincts and Regions, Victoria
- Department of State Growth, Tasmania
- Department of Transport, Victoria
- Department of Transport, Western Australia
- ecologiQ, Major Transport Infrastructure Authority, Victoria
- Environment NSW
- Environmental Protection Authority, New South Wales
- Green Industries South Australia
- Infrastructure NSW
- Infrastructure SA
- Infrastructure WA
- Local Government Association of South Australia
- Main Roads Western Australian
- Major Road Projects Victoria
- Mitcham Council
- Northern Territory Government
- Office of Projects Victoria
- Queensland Transport and Main Roads
- Southern Sydney Regional Organisation of Councils Standards Australia
- Sustainability Victoria
- Transport for New South Wales
- Wyndham Council

Industry

- AECOM
- AI Group
- Alex Fraser
- Arcadis
- Australian Packaging Covenant Organisation
- Australian Society for Concrete Pavements
- Boral
- Cement Concrete & Aggregates Australia
- Cleanaway
- Close The Loop

- Construction Material Processors Association
- Downer
- EcoDynamics
- Fibrecon (Enviromesh Pty Ltd)
- Fulton Hogan
- Hanson Downer Group
- Hyder Consulting
- Infrastructure Sustainability Council
- Institute of Public Works Engineering Australasia
- Pact
- Pipa
- Repurpose IT
- ResourceCo-Tyrecycle
- Roads Australia
- Smartlite
- Tyre Stewardship Australia
- Waste Management & Resource Recovery Association

Interviews

The following organisations participated in the one-on-one interviews:

Government

- Australian Local Government Association
- Infrastructure Tasmania
- Main Roads Western Australia
- Major Projects Canberra
- Queensland Transport and Main Roads
- Sustainability Victoria

Industry

- Alex Fraser
- Australian Council of Recycling
- Australian Society for Concrete Pavements
- Bingo
- Boral
- Cement Concrete & Aggregates Australia
- Fulton Hogan
- Pact
- ResourceCo-Tyrecycle
- Veolia

AustStab and IPWEA Australasia also provided written responses.

Workshop and interview commentary

The workshops and interviews provided invaluable insights from many, diverse government and industry stakeholder organisations to inform the report. Recorded comments were consolidated and categorized into four key topics and many sub-topics. The following figures (Figure 36, Figure 37, Figure 38, Figure 39 and Figure 40) and tables (Table 22, Table 23, Table 24, Table 25 and Table 26) show the breakdown of comments by category and sub-category. This analysis gives an indication of the relative level of interest or concern for each category and sub-category.

Figure 26: Share of engagement comments by topic

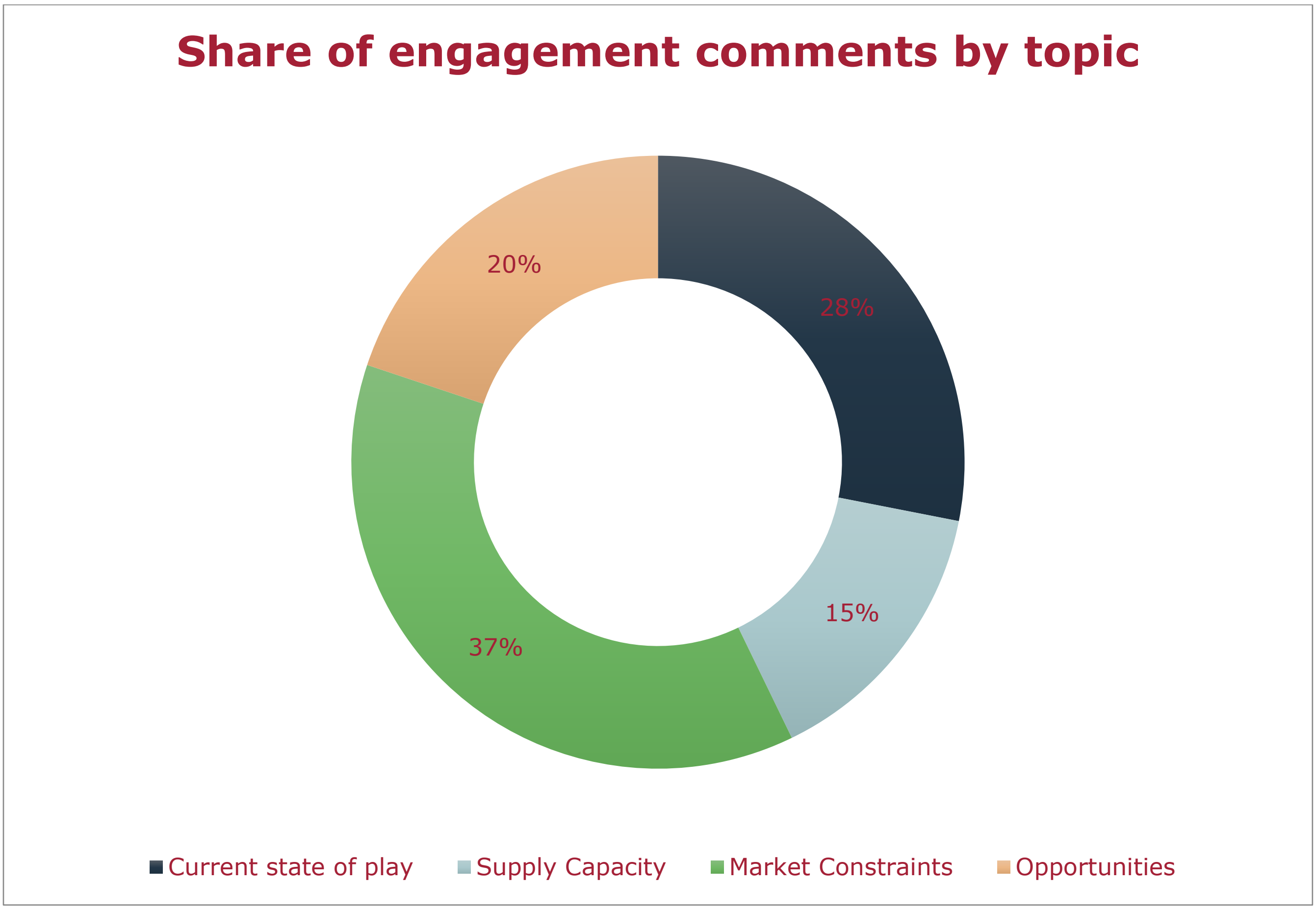


Table 15:Share of engagement comments by topic

Topic	No. of recorded comments	Percentage of total comments
Current state of play	82	28%
Supply capacity	43	15%
Market constraints	109	37%
Opportunities	52	20%
	286	**100%**

Figure 27: Share of current state comments by sub-topic

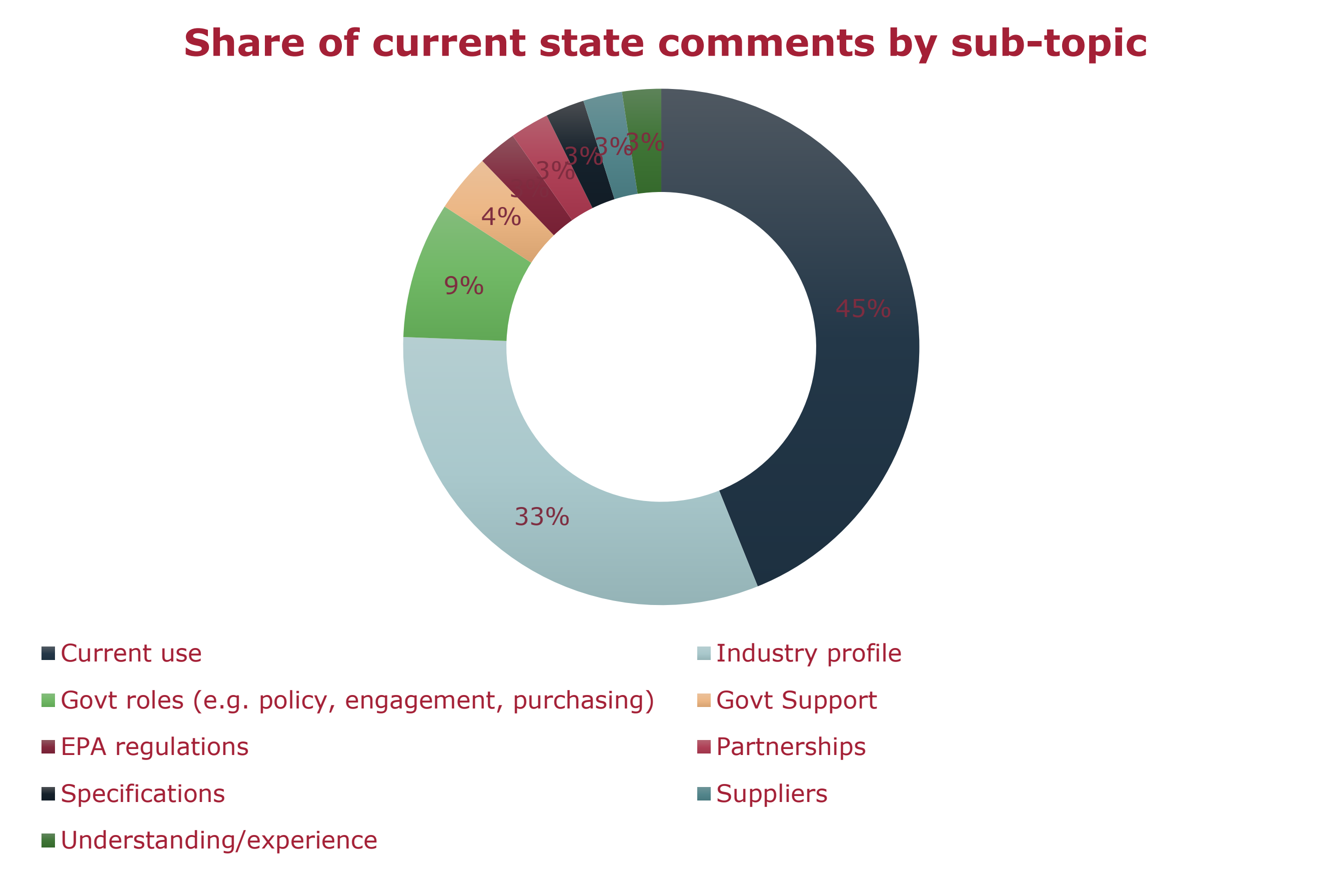


Table 16: Share of current state comments by sub-topic

Sub-topic	No. of recorded comments	Percentage of comments
Current use	36	45%
Industry profile	26	33%
Govt roles (e.g., policy, engagement, purchasing)	7	9%
Government support	3	4%
EPA regulations	2	3%
Partnerships	2	3%
Specifications	2	3%
Suppliers	2	3%
Understanding/experience	2	3%
	82	**100%**

Figure 28: Share of supply capacity comments by sub-topic

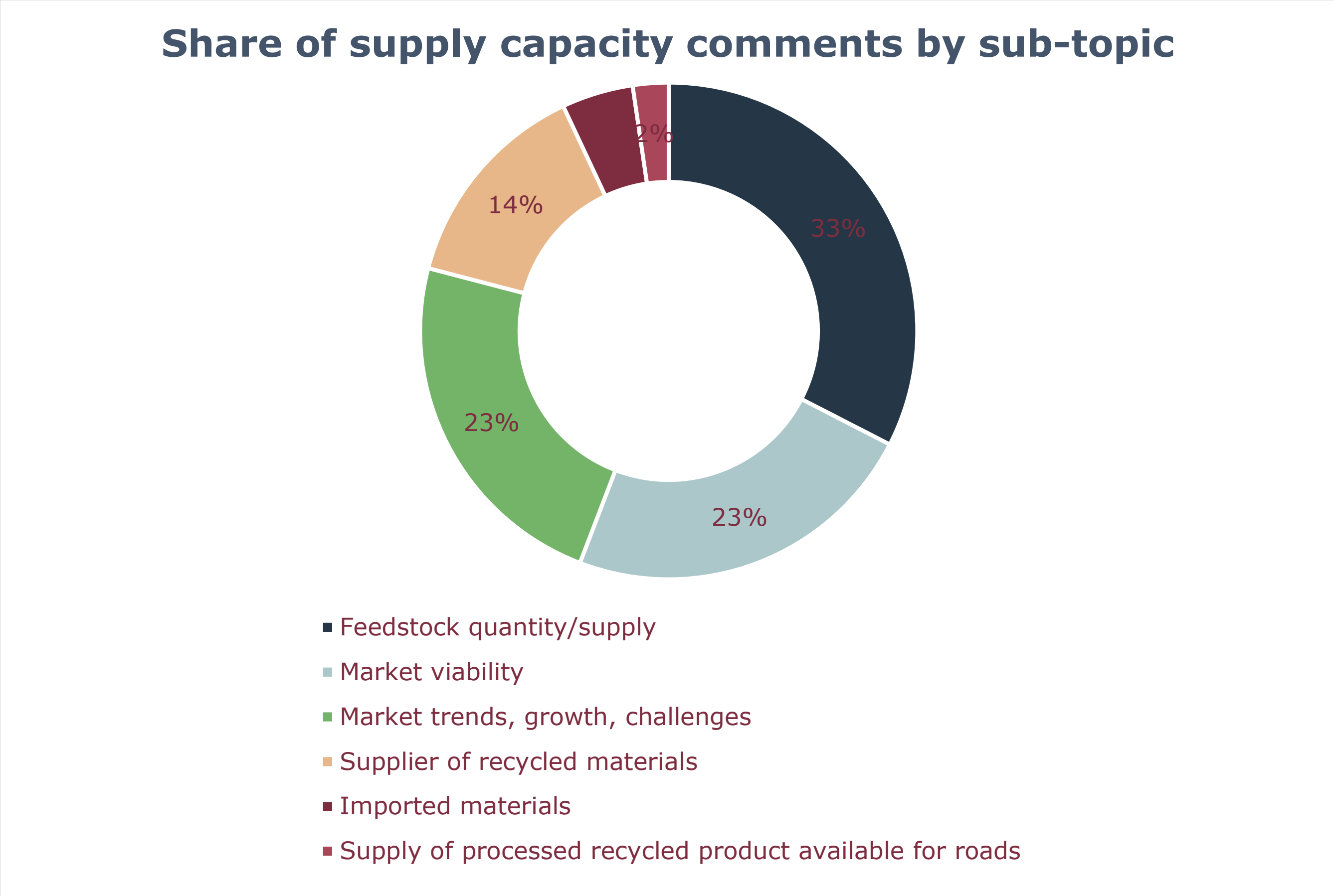


Table 17: Share of supply capacity comments by sub-topic

Sub-topic	No. of recorded comments	Percentage of comments
Feedstock quantity/supply	14	33%
Market viability	10	23%
Market trends, growth, challenges	10	23%
Supplier of recycled materials	6	14%
Imported materials	2	5%
Supply of processed recycled product available for roads	1	2%
	43	**100%**

Figure 29: Share of market constraints comments by sub-topic

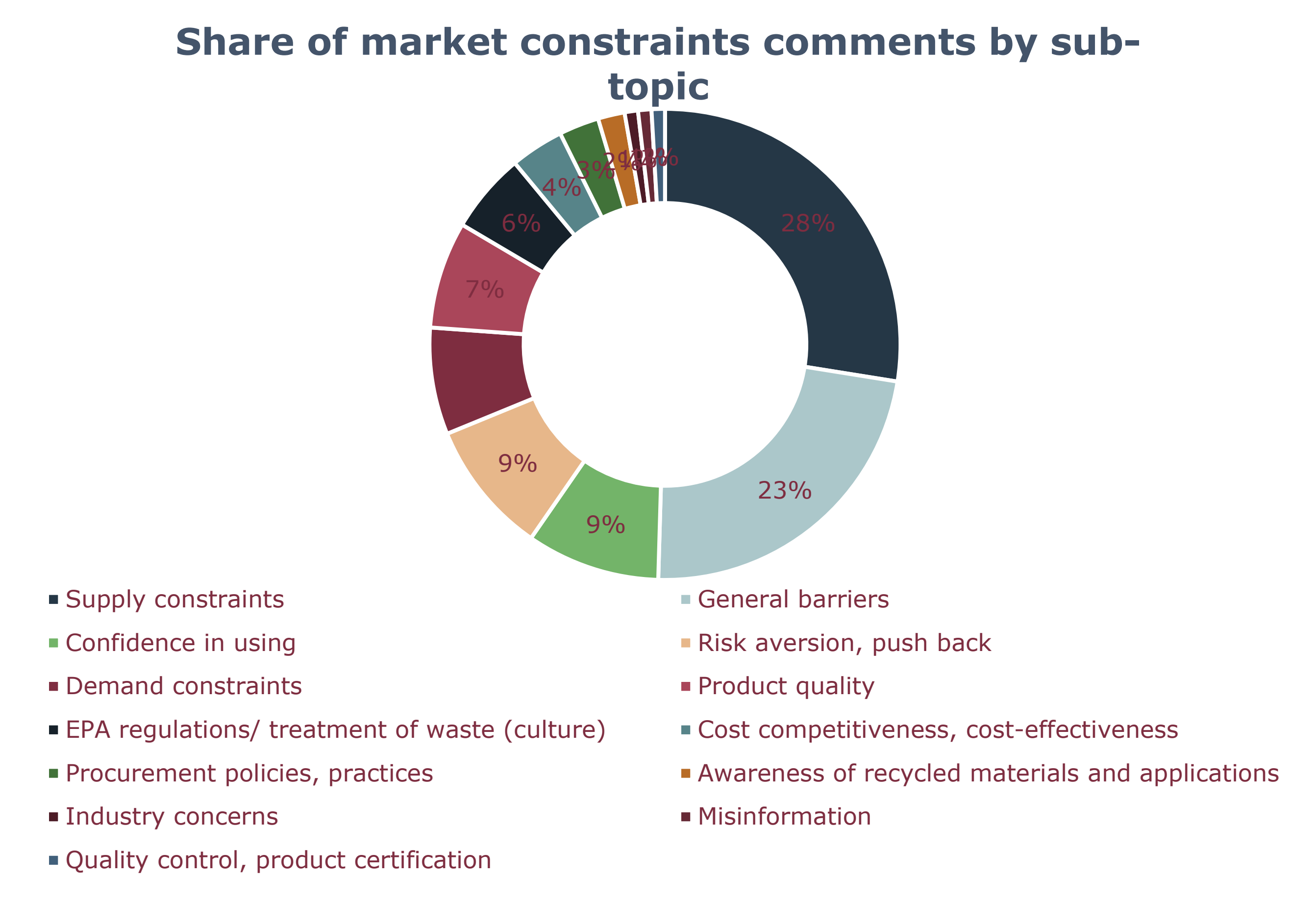


Table 18: Share of market constraints comments by sub-topic

Sub-topic	No. of recorded comments	Percentage of comments
Supply constraints	30	28%
General barriers	25	23%
Confidence in using	10	9%
Risk aversion, push back	10	9%
Demand constraints	8	7%
Product quality	8	7%
EPA regulations/treatment of waste (culture)	6	6%
Cost competitiveness, cost-effectiveness	4	4%
Procurement policies, practices	3	3%
Awareness of recycled materials and applications	2	2%
Industry concerns	1	1%
Misinformation	1	1%
Quality control, product certification	1	1%
	109	**100%**

Figure 30: Share of opportunities comments by sub-topic

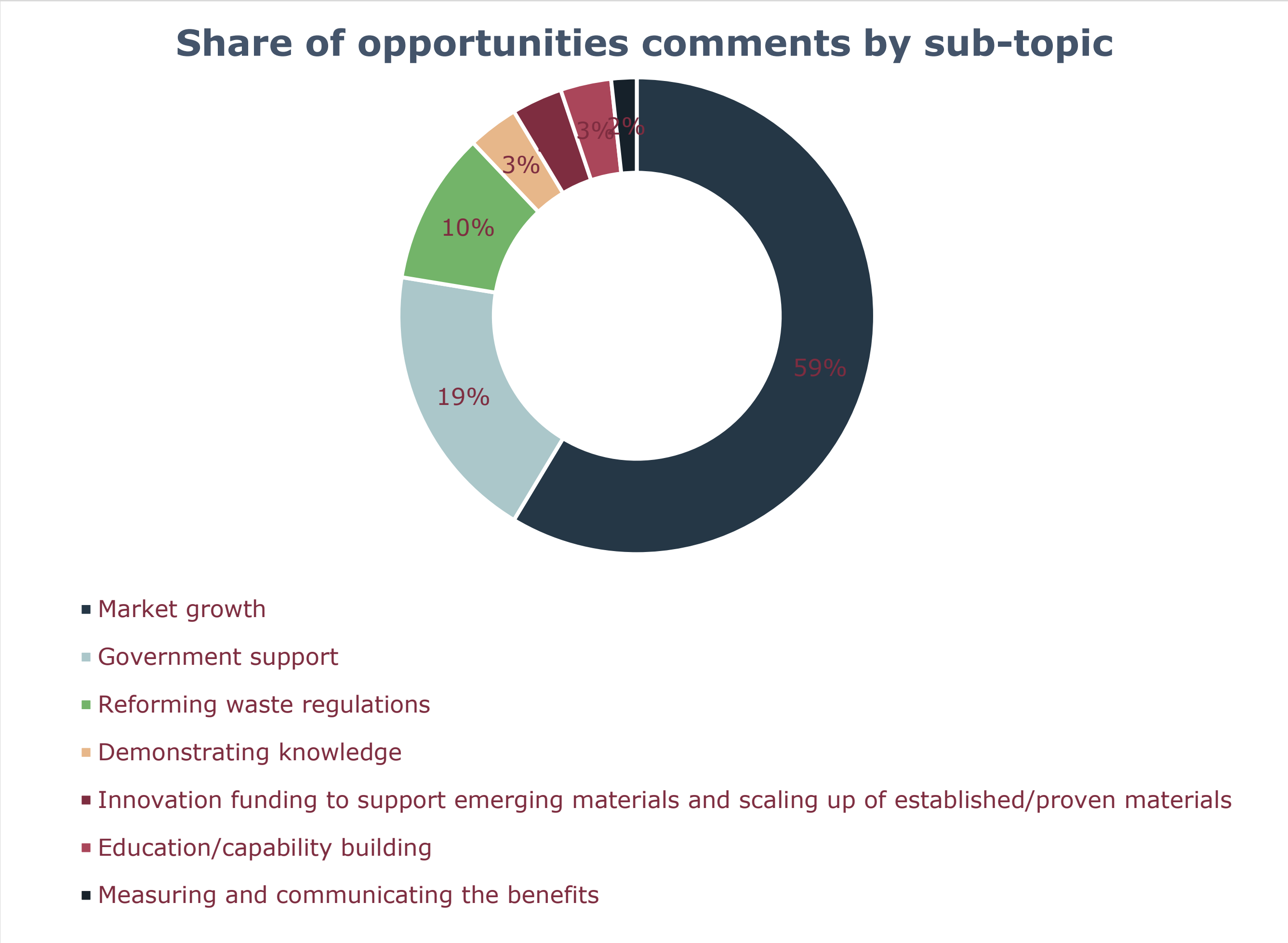


Table 19: Share of opportunities comments by sub-topic

Sub-topic	No. of recorded comments	Percentage of comments
Market growth	34	59%
Government support	11	19%
Reforming waste regulations	6	10%
Demonstrating knowledge	2	3%
Innovation funding to support emerging materials and scaling up of established/proven materials	2	3%
Education/capability building	2	3%
Measuring and communicating the benefits	1	2%
	58	**100%**

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