Austroads

Research Report
AP-R574-18

Australia and New Zealand Roads Capability Analysis

2017-2027

Australia and New Zealand Roads Capability Analysis 2017-2027

Prepared by

Adrian Hart & Rachael Logie

Project Manager

Tracy Jenkinson

Publisher

Austroads Ltd.
Level 9, 287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 8265 3300
austroads@austroads.com.au
www.austroads.com.au

Abstract

This is the Final Report of the Australia and New Zealand Roads Capability Analysis 2017-2027. This report combines recent quantitative (workforce gap) and qualitative analysis (industry consultation) undertaken for this study to explain how 'traditional' and 'non-traditional' skills demand will form for roads agencies over the coming decade, what will be the key threats to workforce capability in the roads sector, and what positive steps roads agencies can take to respond to meet the short and longer term challenges ahead to 2037.

In defining the skills considered here, use was made of the 'skills cluster' framework developed by Foundation for Young Australians (FYA), where 'traditional' road agency skills are defined as those skills come from artisan and designer clusters and 'non-traditional' skills come from informer and technologist clusters. Through this, and extensive stakeholder and industry engagement, this workforce capability analysis has a much broader scope than previous analyses and presents a richer tapestry of capability threats and potential solutions for consideration by road agencies in Australia and New Zealand.

Keywords

Workforce capability, skills shortages, labour supply and demand, education, migration, road construction, road maintenance, network operations, asset management, project delivery, technology, data, disruption

ISBN: 978-1-925671-65-0

Austroads Project No. CSP6502

Austroads Publication No. AP-R574-18

Publication date July 2018

Pages 207

About Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies.

Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research that underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:

- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Australian Government Department of Infrastructure and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

Acknowledgements

BIS Oxford Economics would like to acknowledge the assistance and support from the Austroads Capability Working Group in preparing this analysis, comprising Tracy Jenkinson, Anita Curnow, Belinda Halling, Hayley Rose, Ken Marshall, Kym Foster, Neville Willey; Sandra Butcher; Sophie Ader, Trudi Mares, Maria Drinkwater, Mary Trestrail, Clare Rosso and Margret Dornan.

This report has been prepared for Austroads as part of its work to promote improved Australian and New Zealand transport outcomes by providing expert technical input on road and road transport issues.

Individual road agencies will determine their response to this report following consideration of their legislative or administrative arrangements, available funding, as well as local circumstances and priorities.

Austroads believes this publication to be correct at the time of printing and does not accept responsibility for any consequences arising from the use of information herein. Readers should rely on their own skill and judgement to apply information to particular issues.

Summary

Following previous workforce capability studies undertaken in 2006, 2009 and 2013, Austroads engaged BIS Oxford Economics to undertake a new workforce capability analysis for member authorities based on planned and forecasted infrastructure development requirements in Australia and New Zealand over the next 10 years, with implications and recommendations to be provided encompassing the next 20 years to 2037.

The analysis undertaken for this report indicates that roads agencies will face a convergence of challenges across the coming one to two decades: rising levels of transport infrastructure investment at a time of rapid changes in technology, funding and the very economic role and function of agencies themselves.

Through expansive stakeholder and industry engagement – as well as gap analysis including extensive data analytics – this report seeks to explain how traditional and non-traditional skills demand will form for roads agencies over the coming decades, what will be the key threats to workforce capability in the roads sector, and what roads agencies can do to respond to the meet the challenges ahead. This far broader scope differentiates the current report from previous workforce capability studies undertaken by Austroads that tended to focus only on quantifying the demand for traditional civil engineering based occupations.

The key messages from the analysis undertaken for this report are:

- **Agencies are already experiencing skills shortages**, with transport analysts, planners and a range of designer cluster skills (engineers, surveyors, spatial scientists, cartographers and procurement managers) rated as being very difficult to source now.
- **Existing roads workforce will be under threat from rising activity in other sectors.** Many, though not all, existing roads skills are transferable to other sectors such as rail. As such, a major threat to traditional agency capability is not meeting rising roads demands, but retaining the existing skills base during this period of heightened demand from other sectors.
- Technologies that are expected to mature in coming decades will impact on agency roles and functions – and drive demand for new or expanded skills. While happening now, this process will accelerate in coming years. In an increasingly technologically-oriented world, agencies will face stern competition for these new breeds of ‘hard’ and ‘soft’ skills in coming decades. Conversely, new technologies will also see demand for some existing skills drop away.
- **Agencies are likely to have time to adapt to some of the new technological developments.** But, as indicated in the recommendations to this report, much needs to be done now and in coming years to place agency workforce capability on a sustainable path.

Identifying the risks and providing positive solutions to meeting the ‘triple threat’ facing roads agencies is a key objective of this report. Through the findings of this workforce capability analysis, both quantitative and qualitative, a range of actions have been identified which can assist roads agencies in navigating risks to workforce capability, now and through the coming decades. These include measures aimed at making the greatest use of available skills now, whilst also putting forward recommendations aimed at developing and sustaining the skills agencies are expected to need in coming years and decades.

Central to achieving sustainable workforce capability, however, will be consistent long term engagement with the education sector – as well as the broader industry – to ensure the right mix of skills is being developed, that roads agencies are well positioned to compete for these skills, and that agencies seek optimal ways to partner with other sectors to leverage their skills whilst retaining in-house capability to be ‘informed buyers’ of technological solutions. These are skills in their own right. In the words of one agency: “*the answer may be… to identify ways we can bring in others to solve problems. We can be a good broker, rather than trying to do it all.*”

Contents

Tables

Figures

1. Introduction

In 2006, 2009 and in 2013, BIS Shrapnel (now known as BIS Oxford Economics) prepared reports for Austroads detailing the outlook for road construction and maintenance activity and the implications for the workforce capability of its member authorities in Australia and New Zealand. These reports focused on the capability of the engineering skills sector to meet forward demand over a 10 year horizon.

In July 2017, Austroads engaged BIS Oxford Economics to undertake a new workforce capability analysis for member authorities based on planned and forecasted infrastructure development requirements in Australia and New Zealand over the next 10 years (as outlined in Project Brief CSP6052 Australia and New Zealand Roads Capability Analysis 2017-2027), with implications and recommendations to be provided encompassing the next 20 years to 2037.

Given the timeframe of the analysis, in conjunction with potential changes in technology and funding capability through the next two decades, it is recognised that workforce capability analyses need to look beyond engineering skills and consider more broadly skills in areas such as project, contract, commercial and business management, data analytics and control engineering and the impacts of new technologies including Cooperative ITS and Connected and Automated Vehicles (as well as others). The research looks beyond state road agencies and includes local government, industry, educational institutions and other Government Departments.

In doing so, BIS Oxford Economics has adopted a new occupation cluster structure set out by the Foundation for Young Australians (FYA)[1] that groups occupations according to the portability of skills within clusters. As such, the new analysis heavily expands upon previous workforce capability studies to consider skills across 'non-traditional' clusters including Informers (e.g. data analysts and economists) and Technologists (e.g. ICT professionals), as well as Artisans (e.g. construction labourers), on top of 'traditional' Designer occupations (e.g. civil engineers) which were the exclusive focus of previous workforce studies

The analysis undertaken for this Report indicates that roads agencies will face a convergence of challenges across the coming one to two decades: rising levels of transport infrastructure investment at a time of rapid changes in technology, funding and economic role/function of agencies themselves. Identifying the risks and providing positive solutions to meeting this 'triple threat' is a key objective. In turn, this also differentiates the current Report from previous workforce capability studies undertake by Austroads (also with BIS Oxford Economics) which tended to focus only on quantifying the demand for traditional civil-engineering based occupations.

Using both quantitative and qualitative approaches – including a literature review of previous and current work undertaken, expansive stakeholder and local government engagement and gap analysis including extensive data analytics – the analysis seeks to explain how traditional and non-traditional skills demand will form for roads agencies over the coming decades, what will be the key threats to workforce capability in the roads sector, and what roads agencies can do to respond to the meet the challenges ahead.

Recommendations and findings resulting from this research allows road agencies to work collaboratively across the road sector and with all levels of educational institutions to ensure mid to long term strategic workforce planning needs are identified and addressed. Potential benefits resulting from this project include providing a national strategic approach to road agency capabilities, allowing planned, visionary and innovative decision making for the future, providing greater links between road agencies, industries, educational institutions and other government departments to ensure the future workforce has the right skill sets, providing a clearer landscape for future national training, development and capability initiatives linked to planned future infrastructure investment.

1 Foundation for Young Australians & AlphaBeta (2016), 'New Work Mindset: 7 new job clusters to help young people navigate the new work order', at https://www.fya.org.au/wp-content/uploads/2016/11/The-New-Work-Mindset.pdf

1.1 Structure of this Report

Following this Introduction:

- Section 2 provides a description of the methodologies used in this Report and a description of the forecasting model used in the quantitative analysis (in Section 5). Section 2 also shows how we translate future roads activity into skilled labour demand and how the model is augmented to include supply-side issues such as the ageing of the existing workforce. Concepts used in this report such as 'workforce gaps' and 'capability deficit or surplus' are defined. Limitations of the forecasting model, and key assumptions made in the analysis, are made also made explicit.
- Section 3 provides a global review of the published literature regarding workforce capability analysis in the roads sector (acknowledging that there may yet be a range of unpublished material held internally by roads agencies and/or governments across the world). It is noted that there, in fact, very few published capability studies for the roads industry matching Austroads' own pioneering efforts in this space during the 2000s.
- Section 4 then presents a 'State of Play' summary of BIS Oxford Economics' outlook for the Australian and New Zealand economies and their construction and maintenance sectors, including the roads sector. These forecasts are taken from various BIS Oxford Economics reports, and is an important driver of demand for skills in the quantitative model of roads industry labour demand (outlined in Section 5), particularly for the traditional engineering roles.
- Section 5 presents the output of the quantitative workforce gap model for Australia and New Zealand, including a comparison of the total roads industry and the publicly-funded roads sector. Apart from modelling workforce gaps under a base case, the quantitative analysis considers two alternative scenarios driven by changes in technology and possible responses to this. These scenarios see changes in the proportional mix of skills demanded across Designer, Artisan and other (Informer and Technologist) skills clusters, with implications for Australian and New Zealand roads agencies.
- Teasing out the workforce capability issues, risks and challenges further is the core objective of the qualitative analysis presented in Section 6. Using extensive stakeholder and industry engagement through survey and interview, this section identifies the core themes and challenges regarding capability that are either now emerging in the roads industry, or expected to emerge in the coming two decades.
- Section 7 summarises these challenges and presents a roadmap – with potential solutions – for roads agencies to consider in meeting the workforce capability challenge, along with a list of recommendations.
- References used in this report then follow, along with Appendices detailing the quantitative modelling output (Appendix A) and the stakeholder and industry survey used (Appendix B).

2. Methodology

2.1 Introduction

Austroads has engaged BIS Oxford Economics to produce this workforce capability report for member authorities on planned and forecasted infrastructure development requirements in Australia and New Zealand over the next ten years. This project focuses on the *traditional* and *future* skills and capabilities required by road agencies in Australia and New Zealand.

Such an analysis is timely for the following reasons:

- The broader transport industry in Australia and New Zealand is in the midst of a substantial phase of investment in new infrastructure and maintenance (see Section 4) which has implications for 'traditional' agency skills across construction, maintenance and design.
- New technologies such as Cooperative ITS, Connected and Automated Vehicles (CAV), and Mobility as a Service (MaaS) are now emerging that may influence future transport user behaviours across all transport modes. With this comes the need to manage these behaviours effectively so that the use of roads (and broader transport assets) are optimised.
- Advances in fuel and energy technologies represent a threat to future funding of transport infrastructure. With CAV also likely to be electric vehicles (and hence not subject to fuel taxes), new sources of funding will need to be tapped to cover the costs of building and maintaining transport systems including roads. At the very least, roads agencies will likely need to be able to do more with less, and be willing to partner more with the private sector, which is itself a skill.
- Meanwhile, new advances in "big data" coupled with infrastructure funding reforms are likely to encourage the discipline of asset management at a broader level encompassing roads, railways and other transport systems. Consequently, the existing role and function of roads agencies will likely evolve in coming years as they play an increasingly important role in holistic transport network management – the existing strategic and operations roles of roads agencies may be increasingly integrated with that of broader Transport agencies. As roads technologies evolve, the regulatory role of agencies may well move away from current prescriptive practices to 'outcomes based' or 'performance' approaches.

In assessing the simultaneous impact of these developments on workforce capability, BIS Oxford Economics has embarked on a multi-faceted approach. As well as undertaking a quantitative analysis (Section 5) our methodology revolves around industry liaison, via both survey and interview (Section 6), aimed at gathering views from various industry players – across the private sector, education, government agencies and roads agencies themselves – on what they see as the looming threats, limitations and challenges in ensuring roads agency workforce capability in the coming decades. In these soundings, industry stakeholders had both positive and negative feedback regarding the current state of roads workforce capability, the outlook and opportunities for various skills, where the greatest risks to capability lay, and what actions could be undertaken by roads authorities to help minimise capability risks and leave a positive legacy for the future.

2.1.1 Industry Liaison

For this Report, BIS Oxford Economics has drawn upon its extensive network of industry contacts to conduct 'soundings' of industry leaders and participants. This has been used to gauge their concerns about a range of factors and risks affecting workforce capability, as well as glean their positive ideas for improvement. These issues include:

- Current and future roads agency roles
- Factors affecting capability of roads agencies now

- Occupations and skills where capability gaps may already exist
- Potential future scenarios which agencies should plan for
- Risks to capability from other industries through the outlook period
- How technological disruption will impact on agency capability
- Supplying appropriate domestic skills through education
- Future skills that agencies will need
- Other key risks to capability
- Potential solutions that can mitigate against capability risks

As we 'took the pulse' of the industry we gained invaluable insight into industry concerns, as well as uncovering opportunities for better ways of sustaining or building roads agency workforce capability.

Altogether, BIS Oxford Economics interviewed 21 non-agency organisations through September-November 2017 (including four from New Zealand), on top of 11 separate interviews with roads agency staff covering functions such operations and networks, capital works programs, new technologies, and workforce planning – making a total of 32 interviews. Most interviews were conducted by phone over 1-1.5 hours, but several were also conducted face to face in BIS Oxford Economics' Sydney offices, as well as on location at the interviewee's premises where existing travel plans allowed.

The breakdown of industry participation in the consultation program by type of organisation is shown in the following table.

Table 2.1: Industry Consultation by Organisation Type

Organisation Type	Number of Interviews
Industry Associations	3
Professional Bodies	2
Universities	5
Non-University Education	3
Private Contractors	3
Councils	2
Government Agencies	3
Total Non-Agency Interviews	**21**
Roads Agency Interviews	11
Total Interviews	**32**

In this Report we do not identify or attribute any comments or views expressed in these interviews back to individuals or organisations. We have simply published the issues raised and the thoughtful contribution participants have generally made toward planning and policymaking for ensuring roads agency workforce capability in Australia and New Zealand.

2.1.2 Industry Survey

As well as industry interviews, BIS Oxford Economics designed an industry survey to obtain quantitative feedback on various issues concerning roads agency and industry workforce capability in Australia and New Zealand.

The survey instrument generates quantitative ratings of industry opinion and complements the qualitative feedback from industry interviews.

Questions and ratings surveyed include:

- The level of difficulty in recruiting staff by occupation, and why
- Occupations most likely to see skills shortages over the next 10-20 years
- Key risk factors to roads agency workforce capability over the next 5-20 years and why
- Key risks to roads agency workforce capability through technological change and why
- Initiatives that should be undertaken to reduce risks to workforce capability

Roads agencies and the broader industry responded to these questions in the survey. On top of this, all Austroads roads agencies were surveyed on their existing functions and staff structure across the occupations considered for this report. The latter questions included not just their existing structure in terms of numbers of people and age profile, but also the number of retirements across all occupations and the age group of retirement, the number of redundancies by occupation and age, the number of new hires by occupation over the past three years, the source of new hires (graduates, other industry sectors etc), and the near term outlook for road construction and maintenance expenditure. Responses from these questions were useful in developing quantitative modelling for Section 5 of this Report.

The survey form responded to by both roads agencies and broader industry are provided in Appendix B. The survey was designed so that broader industry and roads agencies could respond to the same questions so that their responses could be compared. There were additional questions for roads agencies that were important in gathering information on the size and composition of the existing roads workforce to assist with the quantitative modelling. In addition to set questions, space for free-form comment was also provided to respondents, and these are noted where applicable.

2.1.3 Quantitative Analysis

As per previous workforce capability studies undertaken for Austroads, this Report also provides estimates of the public sector workforce by skills cluster required to meet demand from road construction, maintenance and operations activity over the ten year period to 2026/27 for Australia, New Zealand and for the Australian states and territories (see Section 5). The report also looks at the expected ‘workforce gap’ for each skills cluster annually over the forecast horizon taking into consideration demand, workforce attrition and productivity growth.

At a national level it also reflects on the likely ‘capability gap’ – the difference between skills demand and supply – over the forecast horizon for the different clusters. This supply analysis suggests that competition for civil engineers over the forecast horizon will be less tight than over the previous decade at the national level in both Australia and New Zealand. However, there is a key limitation to this analysis, which is the assumption that new graduates can provide the necessary experience required to meet demand. There will be continued strong demand for highly experienced civil engineers across other construction sectors over the forecast horizon and these sectors will also experience attrition of their existing highly experienced workers. Further research is required to investigate the likely skills gap at different experience levels for the design skills cluster in the road sector over the forecast horizon and also the potential for net migration to fill any potential shortfall.

The methodology used in the quantitative involves, firstly, the estimation of a skilled (road) labour ‘usage coefficient’. This is the amount of labour that is currently required to perform a certain volume of road-related activity. Then, projections of end use sector activity over the decade to 2027 have been translated, using these coefficients, into forecasts of future skilled labour demand.

Given the timeframe of the study, attrition of the existing workforce through ageing (e.g. via retirement and death) also becomes an important issue. The existence of workforce attrition means that the total additional skilled labour workforce requirement will end up higher than the total labour demand estimated by changed end use sector activity alone. This is because skilled labour also must be found to replace existing skills lost because of the ageing workforce.

The second step therefore involves the comparison of the expected demand for skilled labour with our projected levels of the existing workforce. The difference between the total labour demand and the size of the existing workforce is referred to as the 'workforce gap'. This gap, when positive, will need to be met by additional supply if projected levels of end use sector activity (road construction and maintenance) are to be achieved.

The final part of the methodology relates to estimating the potential new workforce supply. The estimated workforce gap less the supply of additional skilled labour via new graduates is defined in this report as the 'net capability position'.

2.2 Defining the Roads Sector

The task of identifying a skilled roads workforce remains complicated by the fact that there is no precise definition of a "roads industry" sector within the Australia and New Zealand Standard Industrial Classification.[2]

While Australian and New Zealand Census data does have "road and bridge construction" (Class 3101) as an industry category, the reality is that not all persons working in the roads sector will record this industry sector on their Census forms. Indeed, using only Census data from this industry sector would, in our view, severely underestimate the size of the skilled roads workforce given (i) a range of other industry and agency skills that are utilised outside of this segment and (ii) other industry sectors that use the same skills.

For instance, those employed by the large state road authorities (e.g. the Department of Roads and Maritime Services in New South Wales) may identify their industry sector as being State Government, while those employed by councils could list their industry as Local Government. Meanwhile, those working for large private construction companies, whose businesses encompass a wide range of activities including roads, may identify their industry more broadly as Non-Building Construction. Finally, some occupations such as engineering consultants, who again work across various sectors, including roads, could correctly identify their industry as a part of Professional, Scientific and Technical Services.

Consequently, BIS Oxford Economics considers that the "roads sector" not only includes the 'Road and Bridge Construction' subsector but also a proportion of people employed in State and Local Government, Total Non-Building Construction and Professional, Scientific and Technical Services. We have made reasonable assumptions to estimate these proportions for successive Censuses, including the most recent (2016) Census in Australia. For New Zealand, we have estimated a breakdown by extrapolating from the previous Censuses (latest being 2013), guided by known changes in industry sector activity.

2.3 Defining the Roads Workforce Capability Skill Sets

For this roads workforce capability project, BIS Oxford Economics has moved beyond previous Austroads studies in adopting the 'job cluster' framework for grouping skill sets that are highly transferable with each other. This framework derives from the Foundation for Young Australians (FYA, 2016) *The New Work Mindset* report which, based on an analysis of millions of job advertisements, asserts that more than 1,000 different occupations in Australia can be grouped into seven distinct job clusters.[3]

2 Australian Bureau of Statistics and Statistics New Zealand (2013), Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Revision 2.0), Cat. No. 1292.0.

3 Foundation for Young Australians & AlphaBeta (2016), 'New Work Mindset: 7 new job clusters to help young people navigate the new work order', at https://www.fya.org.au/wp-content/uploads/2016/11/The-New-Work-Mindset.pdf

The key idea is that occupations within the job cluster require similar skills that are often portable within that cluster. The portability of skills, in the context of this workforce capability, is vital given the outlook for disruption in the roads industry (whether technological, economic or both) and the need for a range of multidisciplinary and 'soft' skills sets which will enable roads agencies and the broader roads industry to negotiate change. From the perspective of employers and employees, such a framework is important, given the increasing trend for employees to change roles or employers regularly throughout their careers instead of training for an 'occupation for life'. The framework also allows for analysing which clusters (and hence occupations) are likely to lose or benefit from the increasing automation of work, a trend which the roads industry is likely to be heavily exposed to in coming years.

The clusters developed by FYA are:

- **Generators** – comprises jobs that require a high level of interpersonal interaction in retail, sales, hospitality and entertainment. For roads agencies, this may include occupations centred around front line services.
- **Artisans** – require skills in manual tasks related to construction, production, maintenance or technical customer service. In the roads industry, occupations in this cluster focus around construction and maintenance skills, including construction labour, tradespersons and plant and machine operators.
- **Carers** – seeks to improve the mental or physical health or well-being of others, including medical, care and personal support services. Occupations in this cluster have not been included in this analysis for the roads industry.
- **Coordinators** – involves repetitive administrative and behind-the-scenes process or service tasks. For the roads industry, this would include administration and back-house functions.
- **Designers** – involves deploying skills and knowledge of science, mathematics and design to construct or engineer products or buildings. Occupations here are highly STEM focused, and for the roads industry would include the full range of engineering skills.
- **Informers** – involves professionals providing information, education or business services. For roads agencies and the broader roads industry, this would include analysts, economists, legal and behavioural occupations.
- **Technologists** – requires skilled understanding and manipulation of digital technology. For the roads industry, this would include occupations that establish and maintain critical data platforms, as well as online services and cyber security.

This study expands on the scope of previous Austroads workforce capability research in that it considers occupations not just in the Designers cluster (and, particularly, civil engineering based skills within this cluster) but also a range of other occupations from other clusters considered critical to agency function. In particular, this project also reports on occupations from the Informers, Technologists and Artisans clusters, as well as a broader range of occupations in the Designers cluster than previously considered.

A detailed mapping of occupations drawn from the Australian and New Zealand Standard Classification of Occupations (ANZSCO) into the clusters undertaken for this analysis is provided in Appendix A, but a brief categorisation is provided below.

Occupations included in this analysis from the **Designer**s cluster include:

- Professionals
  - Project managers
  - Civil engineers
  - Mechanical engineers
  - Surveyors and spatial scientists
  - Other engineering professionals

- Associate Professionals
  - Civil engineering associates
  - Mechanical engineering associates
  - Surveying and spatial science associates
  - Other construction associates
- Others
  - Contract, program and project administrators
  - Procurement managers
  - Natural and Physical science professionals.

Occupations included in this analysis from the **Artisans** cluster include:

- Tradespersons
- Mobile plant operators
- Construction and mining labourers.

Occupations included in this analysis from the **Informers and Technologists** cluster include:

- Urban and regional planners
- Information and organisation professionals
- Welfare professionals
- Social professionals not elsewhere classified (nec) including transport analysts
- ICT professionals.

Because of the broader range of occupations considered for this analysis, the measured population of the roads industry is significantly larger than in previous Austroads workforce capability studies and is not – with the exception of a small number of civil engineering and spatial sciences roles – directly comparable with those studies.

3. Review of Existing Literature

This Section looks at comparable workforce capacity and capability studies undertaken in Australia and overseas. There are very few examples of studies exclusively looking at the roads sector, so the review has been broadened to include studies for the overall construction sector, as well as for the transport & logistics sector. It should be noted that there may be significantly more detailed or advanced research available within the 'grey literature' of roads agencies and other government bodies which are not available to the public.

3.1 Previous Austroads Analyses by BIS Shrapnel

Austroads first commissioned BIS Shrapnel to prepare its Australia and New Zealand Roads Capability Analysis study in 2006, with updates subsequently prepared in 2009 and 2013. The BIS Shrapnel study analyses the capability of the Australian and New Zealand roads workforce to meet projected infrastructure requirements over a 10-year forecast horizon.

For the study, skilled labour demand is estimated by applying a skilled labour usage coefficient to future projections of end-use activities, e.g. volumes of road construction or road maintenance. The skilled labour demand projections are then compared to future skilled labour workforce projections, calculated by applying attrition rates to the existing workforce and supplementing it with the projected supply of new engineering graduates. The model is thereby able to specify a capability deficit or surplus in terms of personnel numbers per occupation type. The model is not, however, able to identify impacts associated with the attrition of highly experienced workers or a shortage of particular skills within an occupation class.

The findings of the 2009 report formed part of the Austroads submission to the 2012 Senate inquiry into the shortage of engineering and related employment skills.

3.2 Transport Systems Catapult (2016), Intelligent Mobility Skills Strategy

The Transport Systems Catapult (TSC) is the UK's innovation centre for Intelligent Mobility. In 2016, TSC released a report as a 'call to action for government, academia and industry to invest in a skills strategy that enables the UK to achieve global industry leadership in the rapidly growing field of intelligent mobility (IM)', where IM refers to the optimised movement of people and goods.

TSC's report was delivered through reviewing over 30 reports, interviewing 40 key stakeholders and using an IM skills industry workshop with over 20 industry participants from SMEs and large corporates. Industry specific skills initiatives were also examined to assess overlaps and potential synergies. Using this approach, a cross-sectoral IM skills matrix and skills gap assessment was created identifying the IM skills demand forecast to 2025.

The key findings of the report were:

- 'Disruptive' high value digital skills were in short supply
- Transport industry experts strongly prefer higher degree apprenticeships to address the IM skills gap
- A range of traditional and disruptive interventions would be required to address the IM skills gap, from early education to post graduate training, while supporting transfers and skills growth from across other sectors
- Proactive efforts would be required to attract women with IM skills to the transport industry

- There was a potential for the UK to adopt rapid, low cost ways of developing people with IM skills by taking advantage of emerging digital training opportunities from the ed-tech sector.

3.3 Highways UK (2017), Highways skills shortage: the ticking time bomb

This study published in 2017 came on the back of two earlier studies, The National Infrastructure Plan for Skills launched in 2015 and the Transport Infrastructure Skills Strategy published in 2016.

The earlier studies highlighted the significant increase in demand for skilled workers that would be required to meet planned investment in the UK roads sector (and other infrastructure sectors) over the five years to 2020-2021.

The UK roads sector, like the Australian sector, is faced with an ageing workforce, and through a combination of worker attrition and a significant ramping up in roads activity faces a major workforce capacity shortfall in the near term.

For this study, Highways UK undertook a survey of the roads sector to try to understand where the skills shortages were most acute and when they were likely to start to bite.

Key findings from the survey include:

- The availability of people with supervisory and management experience was the area of most concern
- In terms of service provision, respondents identified the main blockages to be in core engineering design and ancillary design
- Careers in other industries were considered to be more attractive to STEM graduates and apprentices
- The sector attracts people stimulated by technical challenges, but career progression is generally through non-technical routes
- Only 7 per cent of respondents thought the sector had the technology skills required to support the emerging use of autonomous vehicles on the network
- Only 28 per cent of respondents thought the sector had the skills set to make collaborative working successful, e.g. professionals in the built environment and infrastructure industries working on designing road networks in cities
- Despite the lack of diversity in the road sector workforce, most respondents did not consider this to be a significant barrier to retaining talent

Survey respondents were asked to rank which of seven given skills initiatives would deliver the greatest benefit, but no stand out initiative was identified. The top three ranked initiatives were a national skills academy, greater standardization in baseline qualifications and a national competency assessment.

3.4 Infrastructure NSW (2017), NSW Construction Delivery Assessment

In 2016/17, Infrastructure NSW engaged BIS Oxford Economics to produce a report identifying capability or capacity gaps in the New South Wales construction sector and the reasons for these gaps. The analysis was largely based on stakeholder consultation and surveys with commercial organisations in the construction sector. This expert report is now published alongside the release of Infrastructure NSW's 2018 State Infrastructure Strategy.

The report included a survey in which over 60 per cent of respondents indicated that the availability of both professional and trade skills was a short-term risk (within 5 years), while over a third of respondents considered the availability of these skills to be a long-term risk (within 5-20 years).

Industry soundings revealed that the greatest capability risks were associated with the availability of onsite construction skills and, particularly, high quality site managers.

The projected ramp up in road and rail projects both in NSW and nationally was expected to create challenges in meeting demand for high quality skills in tunnelling and tunnel fit-out, which was already creating pressures in the “off-site”, pre-construction phases, including design and procurement.

At the design and prefeasibility stages, the industry soundings suggested that lessons had been learned after dealing with previous extraordinary cycles in work during the resources boom, with consultants able to use technology to shift design work interstate (as well as internationally) where there had been spare capacity to deliver.

At the procurement stage, the demand for offsite professional skills was found to have been particularly acute, with offsite skills pressures highly focused towards quality resources – in particular those engineers and other professionals’ skill sets that have accumulated substantial experience. Part of the reason given for the pressures on procurement skills was competition for private sector skills from the public sector itself.

Other findings include:

- A lack of transferability of many skills between sectors
- A perceived government agency roadblock in insisting engineering teams bidding for tenders had previous experience on similar jobs, e.g. major road projects
- A lack of mobility of workers, to a large extent related to the high cost of relocation
- Difficulties in attracting skilled workers to regional areas
- The loss of industry capability through an ageing workforce
- A focus on importing skills at the expense of upskilling local workers
- A shortage of qualified tradespeople and low uptakes of vocational training programs
- A strengthening supply of engineering graduates, but with a low female representation

3.5 Transport & Logistics IRC (latest edition 2017), Skills Forecast

The Transport and Logistics Industry Reference Committee (IRC) develops four-year skills forecasts for the Transport & Logistics Industry which are used to inform the development of the TLI Transport and Logistics Training Package, which provides nationally recognised Vocational Education and Training qualifications for occupations relating to Road Transport, Logistics, Warehousing and Ports.

The IRC skills forecast identifies the priority skill needs of the Transport and Logistics industry through a research and stakeholder consultation process. Emerging issues and future trends are identified through this process; in some instances, these trends are already having a significant impact on workforce requirements, e.g. the automation of port operations and the use of autonomous vehicles by the mining industry; however, other technologies, such as drone deliveries, are in the very early stages of commercial application; and technologies such as driverless road vehicles are still under development and the extent and timing of their impact is uncertain.

The findings of the research and stakeholder consultation process are used to review the existing TLI Transport and Logistics Training Package and to inform training delivery over the subsequent four-year period to ensure that the training qualifications offered closely align with skills requirements.

A number of Australian jurisdictions have undertaken reviews into how enhance workforce capability in the road freight sector including Victoria and Tasmania. The road construction and transport & logistics sectors face similar issues with respect to ageing workforces and changing skills requirements associated with increased automation and the penetration of disruptive technologies.

3.6 Literature Review: Summary of Findings

An ageing workforce, low productivity and barriers to attracting new skilled labour, particularly woman, were already creating skills capability and capacity issues in the roads sector prior to emergence of technologies requiring new skills sets. These trends were similarly impacting on workforce capability and capacity across other construction sectors, as well as the transport & logistics sector.

The fast rate of technological innovation and uncertainty over the speed and extent to which it will impact on these sectors makes it difficult to project skills requirements. The studies' recommendations largely centre around adopting measures to meet near term skills shortages, boost productivity and increase the attractiveness of working in the industry at all education levels.

4. Current State of Play

In undertaking research and analysis for this workforce capability study, it is important to consider the current economic and industry environment in which roads agencies are competing for skills and resources. Crucially, large waves of investment continue to play out across Australia and New Zealand, leaving economic ripples in their wake and creating new patterns of demand for skills across industries and regions. In particular, the mining investment boom has given way to a boom in housing, commercial and industrial building and the renewed development of economic and social infrastructure in the 'non-mining' regions as population and economic growth recovered. By contrast, economic and industry conditions have been much tougher in the former 'mining boom' regions where resources investment was most focused.

In some cases, this re-balancing of investment has been supercharged by new infrastructure finance (such as decisions to undertake long term asset leases in New South Wales and Victoria) which has amplified the recovery in non-mining investment and economic growth. Despite this, unsynchronised cycles of investment over the next few years is expected to keep overall economic growth (and growth in construction activity) constrained, although the renewed focus on infrastructure investment – and particularly transport – presents clear challenges to roads industry workforce capability.

4.1 Economic Trends and Outlook

4.1.1 New Zealand

New Zealand's economy is expected to grow at a healthy pace over the coming years. While residential and non-residential construction is expected to cool, rising levels of public spending and continued strength in export volumes will continue to support growth in the future.

New Zealand remains one of the smallest OECD economies and is still reliant on exporting commodity products to distant markets – it has, for instance, 60 million sheep and accounts for 70 per cent of the world's wool trade. Exports are equal to about 30 per cent of GDP. China is now the country's largest export market destination for over 20 per cent of total sales, having overtaken Australia in 2013.

The global financial crisis in 2008/09 hit the economy hard, with the combination of falling commodity prices and high levels of household indebtedness weighing on GDP. As a result, the economy experienced its worst recession for 30 years, with GDP falling in 2008. Yet similar to Australia's economy, the New Zealand economy returned to modest growth relatively quickly. GDP growth averaged 2.9 per cent over the six years to 2016.

New Zealand has a robust economic outlook, with GDP forecast to grow by 2.7 per cent in 2018. Growth will be supported by accommodative monetary policy, a new wave of fiscal stimulus and healthy levels of business and consumer confidence. Much of the political uncertainty, a by-product of last year's election, has abated with the formation of the new government and the outlining of its policies.

Exports have stabilised after recent strength. Solid momentum in the global economy will continue to support New Zealand's key exports, notably dairy and meat products. Overall export volumes are expected to grow 3.9 per cent in 2018. Tourism remains a key service export, has benefitted from the depreciation of the NZ$ and will continue to be supported by the growth in Asia's middle class. In the medium to long term, the currency is likely to appreciate gradually, driven by a recovery in commodity prices and the economy's relatively strong performance. Import growth remains solid, driven by healthy domestic demand.

Civil engineering sector growth is expected to pick up in the two years to 2020/21.The Labour Government intends to invest more in the renewal of Christchurch, with plans to build a stadium and other priority infrastructure, facilitated by an additional injection of NZ$300m. Moreover, an extra NZ$200m to develop regional ports should bolster engineering construction.

The rise in residential investment in 2018 and 2019 is expected to be relatively modest compared to the gains seen in 2012-16 (when annual growth in residential investment averaged 6.1 per cent). Investment is expected a reach a peak in 2018/19. Meanwhile, non-residential construction, which has recently been buoyed by strong levels of tourist and education arrivals, is expected to cool as oversupply appear in some non-residential sectors such as office building and factories.

There is a sound investment outlook given healthy business investment intentions. Most firms are likely to continue to expand capacity, given the high level of capacity utilization and the decrease in political uncertainty. In addition, the terms of trade have improved (agricultural prices have increased since mid-2016), which is also supporting business spending.

The outlook for consumer spending is improving. Wage growth, having been subdued in 2016, edged up to over 2 per cent pa in the first half of 2017. Aggregate household spending will also be supported by healthy employment growth and low interest rates. However, jobs growth is expected to moderate from the rapid pace seen during much of 2016 and first half of 2017, so consumer spending growth will likely slow in 2018.

CPI inflation is unlikely to reach 2 per cent until mid-2018 when the government's planned minimum wage increase takes effect and the impact of reduced migration starts to be felt. As such, monetary policy will remain accommodative. The cash rate is expected to stay at 1.75 per cent until the second half of calendar 2018, before a process of gradual rate normalisation is implemented.

The new government recently announced its intentions to cut immigration figures by 20,000-30,000 per year, especially student visas. Lower immigration may dampen growth potential. Another risk to the future growth of the economy exists in the potential for a slowdown in the Chinese economy, a downside that may eventuate if Chinese authorities decide to rein in credit growth.

4.1.2 Australia

The Australian economy grew by just 2.1 per cent in 2016/17 – the weakest rate of growth since 2008/09. While a weak outcome, this result extended Australia's long period of uninterrupted economic growth to 26 years – a new world record.

Large slices of luck and lessons learned from the last recession (in 1990/91) has helped successive Australian governments and the Reserve Bank of Australia (RBA) steer the economy through the 1997/98 Asian crisis, the 2000/01 downturn, the global financial crisis (GFC) in 2008, and a large bust in resources investment since 2012/13.

Overall, however, the Australian economy has been unable to sustain economic growth above 3 per cent since the peaking of the resources investment cycle in 2012/13. Much of this weaker economic performance is due to very weak growth in domestic demand during the period, which has been negatively impacted by the ongoing decline in resources investment.

While partially cushioned by a boom in residential investment since 2013/14 and, more recently, by a recovery in public infrastructure investment, economic growth has also been hampered by record low growth in wage incomes, with households spending more of what they earn and reducing savings to maintain just moderate household expenditure growth. Weak wage growth has also driven weaker than budgeted tax revenues for governments, lengthening the time horizon required to return to sustainable budget surpluses, and limiting the firepower of governments to counter weak private investment with higher public investment without further increasing public debt.

Unlike many other resources-exporting economies, Australia did not experience a recession in the wake of the resources investment bust. Strong growth in mining production and exports from world class, competitive deposits, and supercharged by a much lower Australian dollar – which also stimulated other exports of goods and services, such as tourism, education services, agriculture, manufacturing and business services – has helped offset some of the pain from weaker demand growth. Economic growth (which includes net exports) has generally been higher than growth in domestic demand.

The challenge for Australia is that mining exports, particularly, are highly capital – rather than labour – intensive. Stronger, sustainable growth in employment requires stronger growth in local expenditures (i.e. domestic demand). In turn, this requires the return of growth in non-mining business investment, which stalled following the onset of the GFC.

The problem for non-mining industry sectors has generally been weak growth in demand, weak profits and excess capacity. In that environment, it has been foolhardy for businesses to invest ahead of requirements, straining cash flows and locking in additional costs before they had the revenue to support them. Most businesses remained in cost cutting mode, preserving cash and deferring investment until demand recovered. Low interest rates in this environment had relatively little impact. While there was plenty of funds available, the business environment was anathema for investment.

The next growth phase in the Australian economy will be driven by non-mining business investment. When it does recover (and the signs are currently positive), it will be to service growing demand, driven by a growth logic (evidenced by rising profits, which is now occurring) and augmented by a technology catch-up. In turn, this will have a strong multiplier through business services into the rest of the economy. While the profit share of income is at high levels, it is still too early to say that businesses are confident in the path of future demand and profits and are willing to make the psychological shift from caution to a ‘go for growth’ investment mentality.

Part of the reason for this is that nationally, by region and industry, growth and profitability is highly fragmented. Very strong economic growth has returned to New South Wales and Victoria, after spending much of the mining boom years suppressed. But growth in demand is still very weak in many other regions. In some states such as Western Australia and Queensland, State Final Demand (SFD) has outright declined in recent years, placing strains on their respective State Governments to finance infrastructure investment.

There remain challenges ahead for the Australian economy, too, which are likely to keep business confidence and investment constrained. Wage growth, except for skilled professions and trades in some sectors and states, is likely to remain relatively weak, affecting retail trade and household expenditures. Politics is highly adversarial, with major political parties unable to forge a workable consensus on many important policy areas surrounding taxation, energy security, and the environment.

But, more importantly, investment cycles across Australia are likely to remain highly unsynchronised over the next few years – keeping overall economic growth constrained at or under 3 per cent per annum.

These unsynchronised investment cycles include:

- Residential investment – a key driver of economic growth in recent years – which is expected to decline over the next year three years, with particularly large declines expected in the volatile high density apartment market
- Mining investment is now entering the final year of an expected six year decline, with further significant declines to come over the next 18 months as the LNG investment boom finally runs its course. This will see mining construction fall around 78 per cent from the 2013/14 peak to the 2018/19 trough, although mining equipment purchases and exploration have started to recover across most commodities (indicating the initial stages of the next upturn)
- Public investment finally started to recover in 2015/16 (after five years of decline), surging 14 per cent in 2016/17 alone. Growth in public investment is being supported by new transport infrastructure, but will be offset in part after 2017/18 by falling investment in Australia’s largest public infrastructure project – the NBN. Total public investment is expected to be flat or falling (and hence be a drag on Australia’s economic growth) by the end of the decade

- Non-mining business investment is currently showing only modest growth but is expected to strengthen from late decade as higher profitability, demand and capacity utilization (in turn supported by a slightly weaker Australian dollar) drive in change in psychology

Consequently, domestic demand and to improve markedly late in the decade, as the declines in mining and residential investment bottom out and start showing signs of recovery. Capacity constraints and expected improvements in business confidence are predicted to drive an acceleration in non-mining business investment. But until that time, economic growth and inflation is expected to remain relatively subdued, with the Reserve Bank unlikely to be in a strong position to raise interest rates until 2019/20.

Vast differences between Australian states

Differences in the timing and magnitude of investment cycles by region are creating large differences in economic performance (and industry activity) by state across Australia, with implications for workforce capability in each region. Strong pipelines of infrastructure projects, relative undersupply in housing, higher population growth and private sector confidence to invest is driving a construction-led upswing in New South Wales and Victoria, which in turn is spilling over into broader industry growth. In turn, recent Census data reveals a significant shift in interstate migration towards Victoria and New South Wales since the end of the resources investment boom, with many people moving from former boom states (particularly Western Australia and Queensland) in search of employment opportunities.

By contrast, investment and construction activity remains relatively weak in the former resources boom states of Queensland and Western Australia. These states are now generating strong growth in mining production and exports as a direct consequence of the previous resources investment boom, boosting Gross State Product (GSP). However, growth in State Final Demand (SFD, the sum of household consumption, government consumption and investment – both public and private) has been very weak or negative in recent years. This is important, as growth in SFD tends to be a greater driver of demand for skills, growth in employment and incomes than growth in (capital-intensive) mining exports.

These large differences in state economic drivers and performance means that economic policy prescriptions are also quite different by state. For New South Wales, the challenge will likely be to smooth out what is a tremendous cycle of investment and construction work (particularly in Sydney and Melbourne) to avoid looming capacity and capability challenges that may threaten project costs and timings as well as the financial health of the construction industry.

For states such as Western Australia and Queensland – which will need to run down an excess supply of residential and commercial space in the wake of resources and residential construction booms (and now weaker population growth) – the challenge will be to maintain a steady pipeline of productive infrastructure investment to sustain local industry and employment, boost efficiency and competitiveness, and ‘crowd in’ private sector confidence and investment by providing a long term economic development plan.

4.2 Construction Industry: Trends and Outlook

Apart from broader macroeconomic impacts, investment cycles across Australia and New Zealand have significant direct impacts on the construction industry as well as related industries including manufacturing, professional and business services and transport.

New investment in buildings (both residential and non-residential) and civil infrastructure (encompassing transport, utilities, recreation and mining and heavy industry) have important consequences for roads workforce planning given its potential call on similar skills and occupations that are relevant across roads and other sectors – from designer cluster skills (engineering, project management, procurement), artisans (construction labour, plant operators) to informer skills (analysts, economists and others) and technologists (ICT professionals).

4.2.1 New Zealand Construction

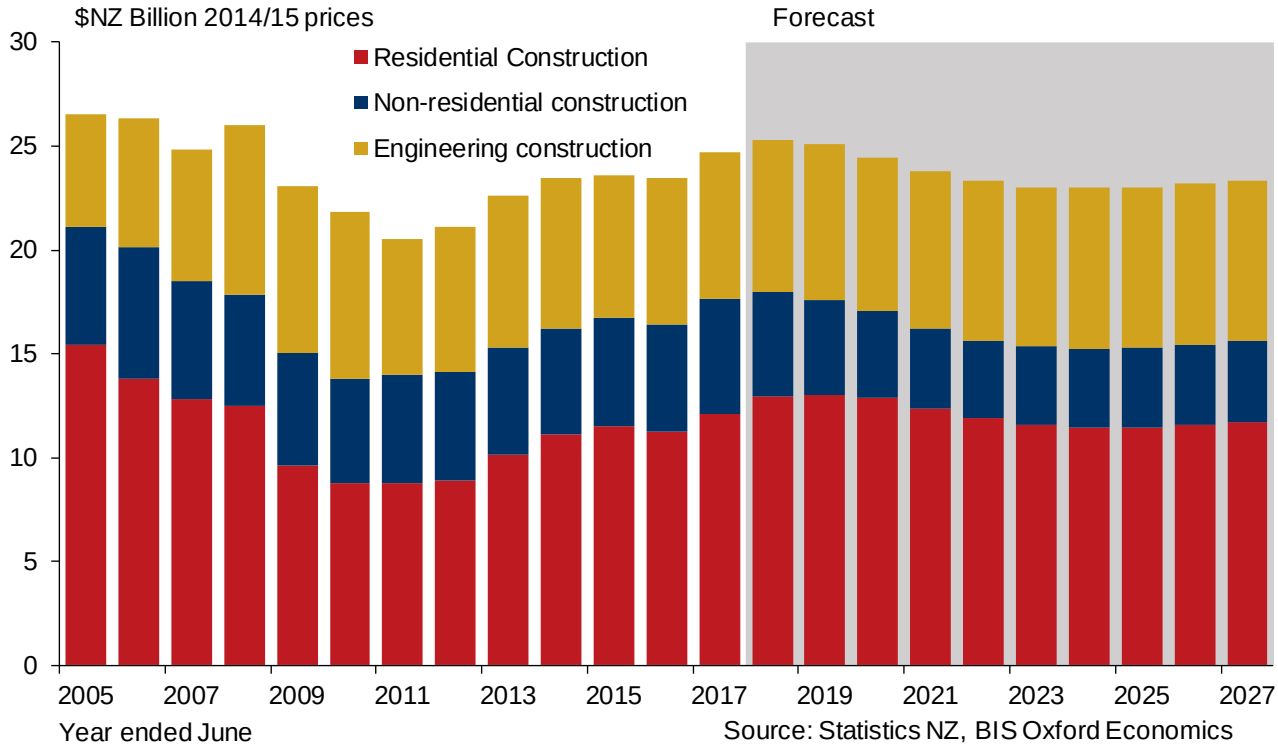
New Zealand Building Activity

Over the seven years to 2017 residential construction grew at an average of 4.9 per cent per annum. High levels of net migration drove population growth to record levels and underpinned demand for new dwellings, as well as rebuilding effort after the 2011 Christchurch earthquake. Growth in residential investment is expected to continue over the next two years to 2018/19, albeit at a slower pace than levels seen in recent history. Activity will peak in 2018/19 before cooling over the subsequent years.

Despite the new Labour-led government's NZ$2 billion KiwiBuild program to build 100,000 units over the next 10 years, residential building is expected to be held back as fundamental drivers and constraints for residential building will remain challenging over the short to medium term.

Emerging oversupply in some pockets of non-residential building is also expected to drive some cooling in this market, which has been strong in recent years. However, building activity is expected to be sustained at reasonable levels over the outlook period given relatively strong growth forecasts for the New Zealand economy and the strong tourism sector. Furthermore, with bank lending rates expected to remain at lower levels for a longer period before reaching its normalisation level, this should help to boost domestic consumption and business investment.

Figure 4.1: Total construction work done, New Zealand, $Millions, 2015/16 prices



Average annual authorisation value over the outlook period is forecast to remain at a relatively high level of over NZ$9 billion, backed by modest growth in residential building and relatively high non-residential building activity in the North Island. Both residential and non-residential building activity in the South Island is trending down to underlying demand levels over the outlook period as the Canterbury earthquake rebuilding gradually winds down.

New Zealand Engineering Construction Activity

BIS Oxford Economics continues to expect New Zealand civil engineering construction to expand moderately over most of the forecast period. The new Labour-led government is expected to continue spending on infrastructure. Power, rail and communications related expenditure will be moderate. Rail related infrastructure spending is likely to get a boost from the new government's commitment to spend NZ$800 million on two railway projects in Northland region – a new line to Marsden Point port and the modernisation of the Auckland-Whangarei railway line. Budget 2017 has allocated NZ$984 million investment to support national and urban rail, although much will depend on the timing of the proposed Auckland City Rail Link project.

4.2.2 Australia Construction

For more than a decade, the resources investment boom radically changed the profile of the construction market in Australia. This investment wave helped drive annual construction work done in Australia from $82 billion in 2000/01 to a peak of $226 billion in 2013/14. During the period, engineering construction grew almost four times, while non-residential and residential building activity grew around 90 per cent and 60 per cent respectively. Although population growth and domestic demand fuelled higher levels of building activity, the resources investment boom also underwrote a recovery in non-resources construction activity through the strong increases in tax revenues (through higher profits, wages and royalties) at the Federal and State level.

Sharp declines in commodity prices in 2011 triggered the collapse in resources investment that has coloured total construction activity to this day. While this was mostly felt in the mining-focused engineering construction segment, it also impacted on parts of the building market and population and employment growth become re-oriented away from the resources states.

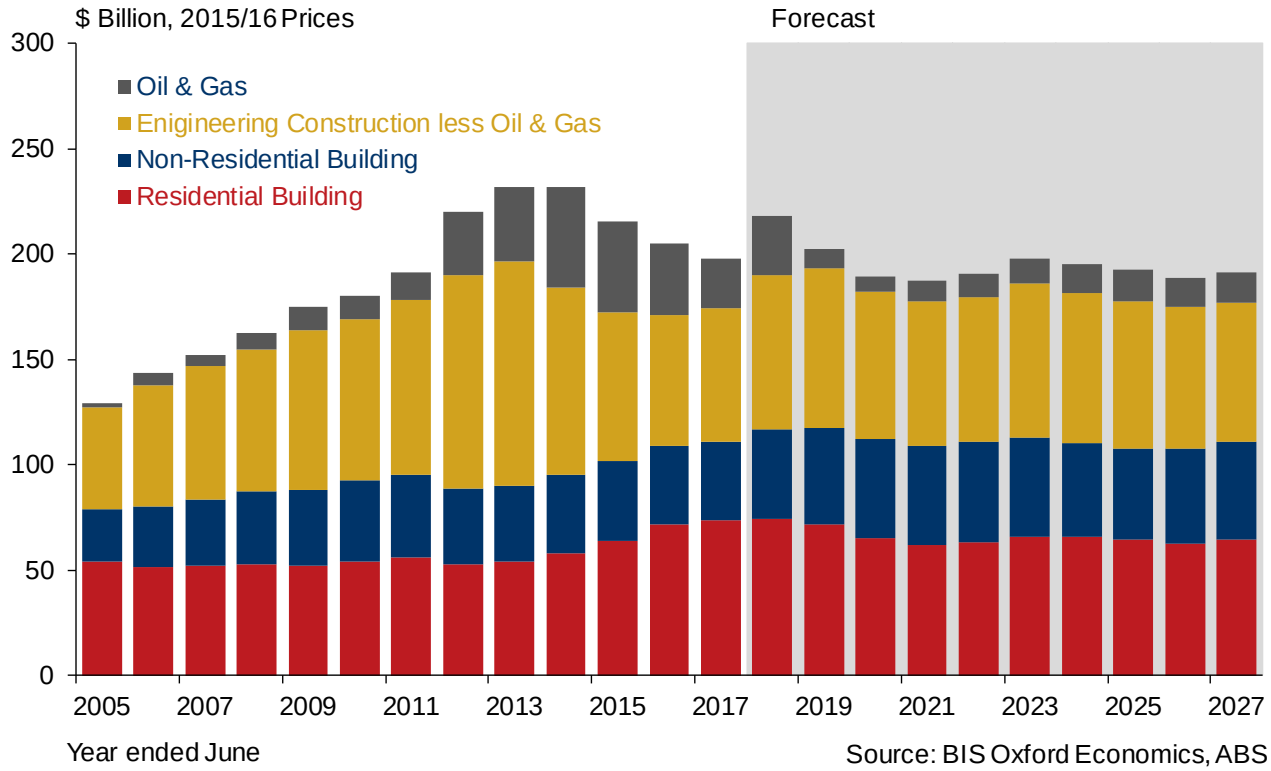
Australian Building Activity

Residential building in Australia has boomed over the past five years, with work done increasing by around 40 per cent to around $72 billion in 2016/17. Historically low interest rates, a sizable dwelling stock deficiency nationwide, and significant interest from foreign investors and developers in the Australian property market have all helped drive the upturn, with Sydney and Melbourne being the strongest performers. However, the current upswing in residential building work is near a peak and is expected to fall back significantly in coming years. particularly in the investor-focused high-density apartment market.

Although BIS Oxford Economics anticipates a continuation of the low interest rate environment until 2019/20, this is not expected to assist new residential building. Investors are already withdrawing from the market due to tighter lending requirements locally, stricter capital controls on foreign capital, and higher interest rates for investor loans. With the residential market moving into oversupply in most states (with the exception of New South Wales and Victoria, where population growth is now strongest), and population growth nationally weaker than it was, total residential building work done is expected to peak in 2017/18 but fall 17 per cent per over the subsequent three years.

Non-residential building in Australia has been somewhat patchy by segment and state since the Building Education Revolution (BER) stimulus supported a peak of $38.1 billion in work done through 2010/11.

Figure 4.2: Total construction work done, Australia, $Billions, 2015/16 prices



The resources investment boom drove strong increases in commercial and industrial building in the resources states (Western Australia and Queensland) but the high dollar suppressed economic activity and non-residential building in the non-resources states, particularly New South Wales and Victoria. More recently, the lower Australian dollar (compared to that during the resources boom) has triggered a new wave of investment in commercial and industrial building, particularly in retail, accommodation, and offices – the latter now booming in New South Wales and Victoria. By contrast, office building activity is likely to remain weak in Western Australia and Queensland where the markets are now oversupplied.

Social and institutional non-residential building is expected to increase gradually over time, supported by new projects across education and health (underpinned by strong growth in both aged (>70 years) and younger (5-19 years) populations), as well as defence, prisons and aged care projects.

Overall, across the period to 2020/21, non-residential building activity is forecast to fluctuate between $39 billion and $41 billion, with growth in New South Wales and Victoria more than offsetting weaker activity in the former boom states of Western Australia and Queensland over the next few years.

Australian Engineering Construction Activity

Engineering construction activity has been falling in Australia since 2013/14 as mining investment has subsided. In 2015/16 and 2016/17 the decline was predominantly driven by collapsing oil and gas construction as a $200 billion phase of liquefied natural gas (LNG) construction across Australia – encompassing no less than seven separate multi-billion LNG production “trains” – continued to wind down.

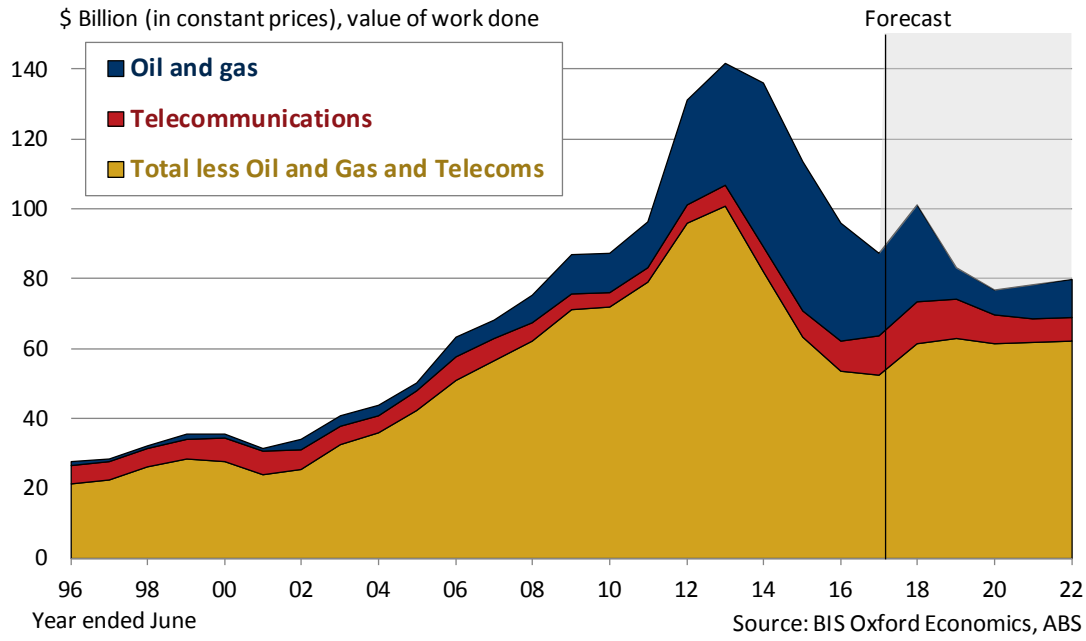
Scratch below this surface and important differences begin to emerge. Whereas the fall in engineering construction work done was widespread (by sector and state) in 2014/15, by 2015/16 new growth sectors and regions had already begun to emerge and by 2016/17 strong growth in roads, rail, water and the telecommunication sub-sectors helped stem the collapse in investment elsewhere. A sudden spike in oil and gas construction in the September 2017 quarter (driven by the arrival of the Prelude floating offshore LNG platform in Western Australia) will help drive a 10% rise in measured engineering construction work done in Australia for 2017/18. But this is largely illusionary as the full value of the Prelude LNG platform – which was fabricated overseas – overstates the call on local engineering skills and resources. In any case, non-oil and gas engineering construction is on the rise in Australia, driven mainly by public infrastructure investment across telecommunications (the NBN), roads and rail.

Looking ahead, the one-off Prelude spike will drive a renewed downturn in measured engineering construction activity over the next few years, with BIS Oxford Economics forecasts now suggesting the bottom of the cycle will not be until 2019/20, with annual work done bottoming out at around $76 billion (in constant 2015/16 prices). This compares to the $141 billion in work done at the peak of the cycle in 2012/13.

This outlook remains heavily impacted by the ongoing collapse in oil and gas construction in Australia. However, it should be noted that this sector is heavily dominated by imports of LNG modules for oil and gas construction, which is currently the largest sub-segment of the mining and heavy industry construction sector. In 2016/17 work done in this sub-segment was $24 billion – around 27 per cent of the entire national engineering construction market (down from 38 per cent in 2014/15 and up from just a 2 per cent share of the market in the late 1990s / early 2000s). While many large LNG projects in this segment have already moved to completion (including the three large facilities in Queensland and the aptly named Gorgon LNG project in Western Australia), the completion of further projects will strip around $16 billion in measured construction work out of the market over the two years to 2019/20 – not including the temporary spike in activity in 2017/18 driven by the arrival of the Prelude platform.

The sheer scale of this decline on top of the declines experienced in the previous years is likely to keep the path of total engineering construction work (as measured by the Australian Bureau of Statistics) on a downward trend through these years, despite significant rises other parts of the engineering construction market, notably roads, railways, water and electricity.

Figure 4.3: Engineering construction work done, Australia, $Billions, 2015/16 prices



4.3 Roads Industry: Trends and Outlook

4.3.1 New Zealand

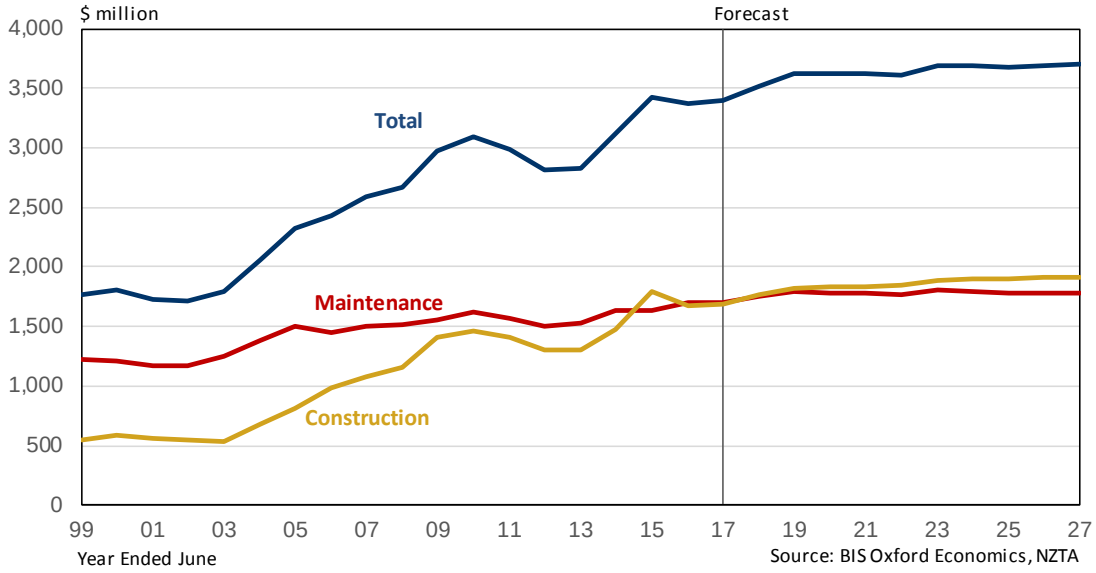
New Zealand Road and Bridge Activity Outlook

Over the past decade, total road construction in New Zealand has grown at an average rate of 2.9 per cent per annum. Work done leaped 10.2 per cent in 2014 and 9.9 per cent in 2015, but activity has since levelled off. We expect total road activity will be much more stable over the decade to 2026/27, flattening off at a level above NZ$3.5 billion per annum. Regional improvements, public transport investment and the roads of national significance will support activity.

We have used the Government Policy Statement on Land Transport – in particular the planned expenditure on Roads of National Significance – as the basis of the outlook for New Zealand roads activity. These figures are augmented with our own estimates of locally funded construction and maintenance activity. We have also deflated this series to take into account of rising construction costs.

A number of major projects were completed in 2017, including the $2.4 billion Western Ring Route and a NZ$630 million component of the Wellington Norther Corridor Road of National Significance. Road construction activity is likely to remain strong. The 2017 Budget allocated NZ$812 million to reinstate State Highway 1 between Picton and Christchurch following the Kaikoura earthquakes. Over the next four years, a total of NZ$9.17 billion will be invested to deliver key roading projects around the country.

Figure 4.4: Road construction and maintenance work done, New Zealand ($M 2015/16 prices)



4.3.2 Australia

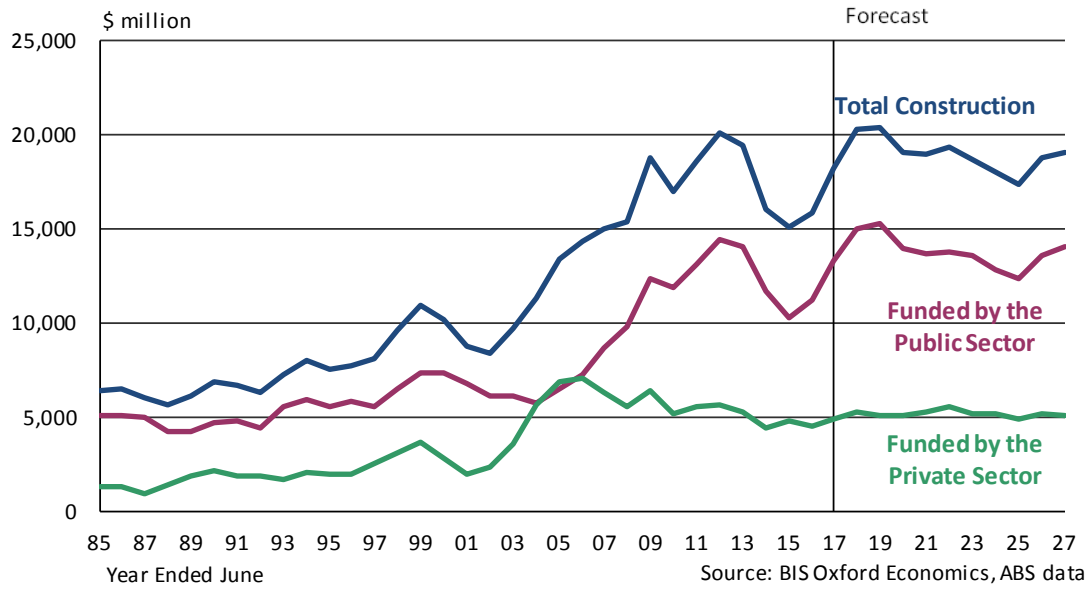
Road and road bridge activity in Australia is expected to continue rising over the next couple of years across both maintenance and construction. This follows a decline in activity between 2012/13 and 2014/15, which saw the level of road and road bridge activity fall back to 2007/08 levels. Over the remainder of the outlook period, activity is expected to remain reasonably flat and, importantly, stay below the peak experienced in 2011/12. This means that the demand for labour in this sector is not expected to exceed historic highs over the next decade – although it will be sustained at a high level in historical terms.

The trough in road and road bridge construction activity experienced in 2014/15 was entirely the result of reduced expenditure from the public sector, falling back from nearly $15 billion in 2011/12 to just over $10 billion in 2014/15. Over the outlook period, public sector funding is expected to recover, sitting between $12 billion and $15 billion per annum, while private sector funding is expected to remain flat around $5 billion per annum.

Road construction activity rose 15 per cent in 2016/17 and is expected to continue rising through 2017/18. The national market is about to see an unprecedented level of work on major projects, led by the WestConnex, NorthConnex, Pacific Highway Upgrade and Western Sydney Infrastructure Plan projects in New South Wales, works on the Bruce Highway, Warrego Highway and Gateway Motorway projects in Queensland, the North-South corridor in South Australia, the Western Distributor in Victoria, and the NorthLink WA project in Western Australia. The combination of these projects is expected to push roads activity to record highs around $20 billion in 2017/18 and 2018/19 before activity eases slightly but remains historically strong.

The bridges sub-sector in aggregate accounts for the smallest portion of national investment activity in Australia. As such, one-off or a hand-full of projects generally skew the forecasts. We note that the ABS only includes projects in this category which are predominantly bridge work - as opposed to road projects with bridge components. Bridge construction activity had been in decline since 2009/10 but has a pick up beginning from 2015/16 due to the greater emphasis on road and rail construction during the outlook period.

Figure 4.5: Road construction and maintenance work done, Australia ($M 2015/16 prices)



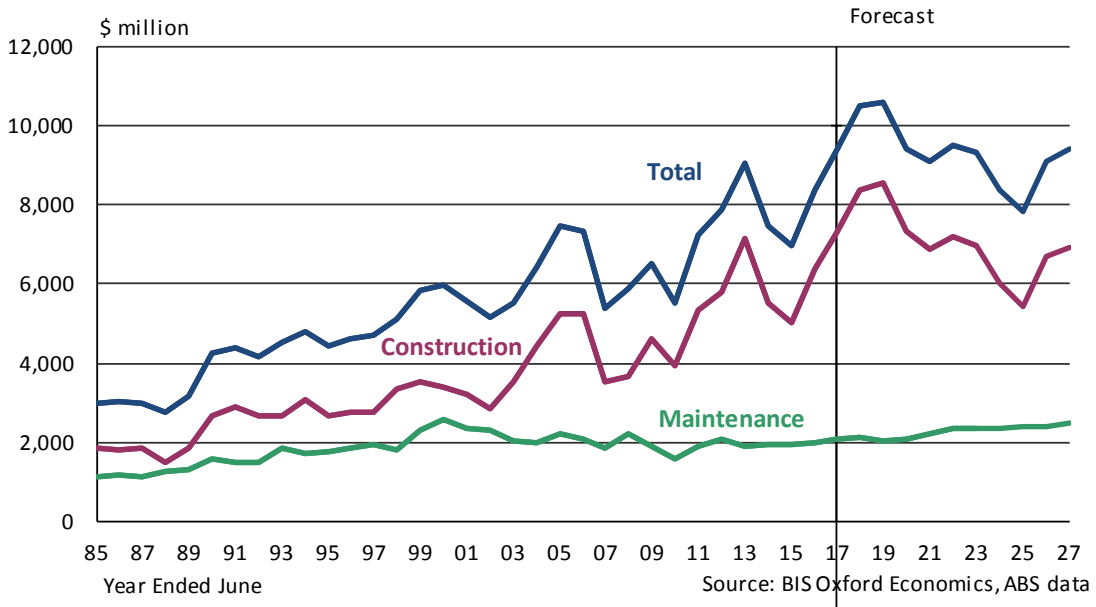
New South Wales Road and Bridge Activity Outlook

Road and road bridge construction in New South Wales reached a cyclical trough in 2014/15 at $5.0 billion. Since then, road and road bridge construction jumped 27 per cent in 2015/16 and a further 14 per cent in 2016/17 to reach $7.3 billion, driven predominantly by highways and arterials and toll road construction. The largest contributors in the short term will be the first two stages of WestConnex, the NorthConnex toll road project, higher levels of activity on the Pacific Highway upgrade and the construction of roads that will support the planned Western Sydney Airport.

Taken together, these projects are forecast to see work done reach a new peak of $8.5 billion by 2018/19. Activity is expected to fall back, but remain at historically high levels over the following three years, with the third stage of WestConnex commencing, to sustain work done above $6.7 billion.

Overall, road and road bridge construction is forecast to average $7.6 billion per annum over the next five years. This is nearly $1.5 billion higher than the previous five-year period, and we do not believe that these levels of activity will be seen again within the ten-year forecast period.

Figure 4.6: Road construction and maintenance work done, NSW ($M 2015/16 prices)



Victoria Road and Bridge Activity Outlook

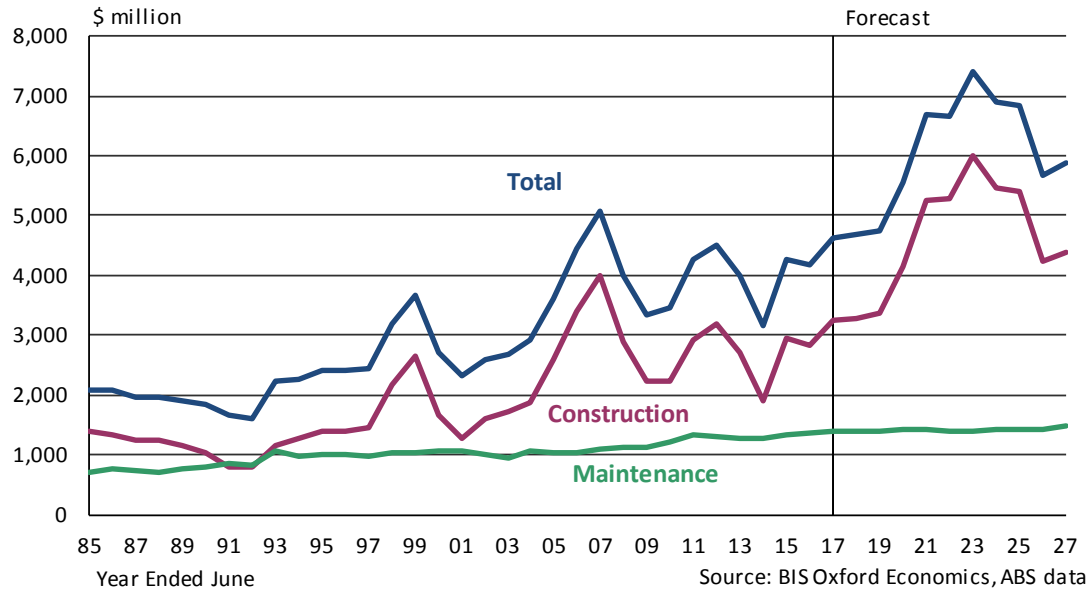
Road and road bridge construction in Victoria tends to be highly cyclical, driven by both major projects and subdivision activity. In 2014/15, growth in road construction of 54 per cent was driven by a strong housing market (leading to a surge in privately-funded subdivisions activity). Activity remained at relatively similar levels over 2015/16 as subdivisions activity remained strong, before jumping a further 15 per cent in 2016/17 to reach $3.2 billion.

Over the next ten years, we expect road and road bridge construction to rise strongly, reaching a record $6 billion in 2022/23. Growth is expected to be underpinned by the $6 billion Western Distributor project, and an increase in highways and arterials construction. There are two major components to the Western Distributor project; the $1 billion Monash Freeway upgrade and the $5 billion Western Distributor toll road project. The Monash Freeway upgrade recently started construction. This phase of the project was initially a $400 million project, but has recently increased in scope after the reallocation of Federal Government funds from the cancelled East West Link. There is some uncertainty around the next phase of the project, as funding may be an issue, with the Federal Government yet to make a financial commitment. The Victorian opposition leader has also flagged renegotiating the scope of the project if the Liberal/National coalition win the Victorian state election in 2018. We have assumed that the $5 billion toll road project will start in 2018/19.

Also benefiting from a reallocation of funds from the cancelled East West Link is the $1 billion M80 Western Ring Road. The $300 million Sunshine Avenue to Calder Freeway component is currently under construction. The next phase of the project is expected to commence in 2018/19.

Victoria's second largest road project is the $1.3 billion CityLink Tulla Widening, which started construction in 2015. The publicly funded stage of the project (Section 1: Melbourne Airport to Bulla Road) has a project value of $497 million. The privately funded stage (Section 2: Bulla Road to Power Street) commenced in 2015/16 and has a project value of $850 million. Both projects are due for completion in calendar year 2018.

Figure 4.7: Road construction and maintenance work done, VIC ($M 2015/16 prices)

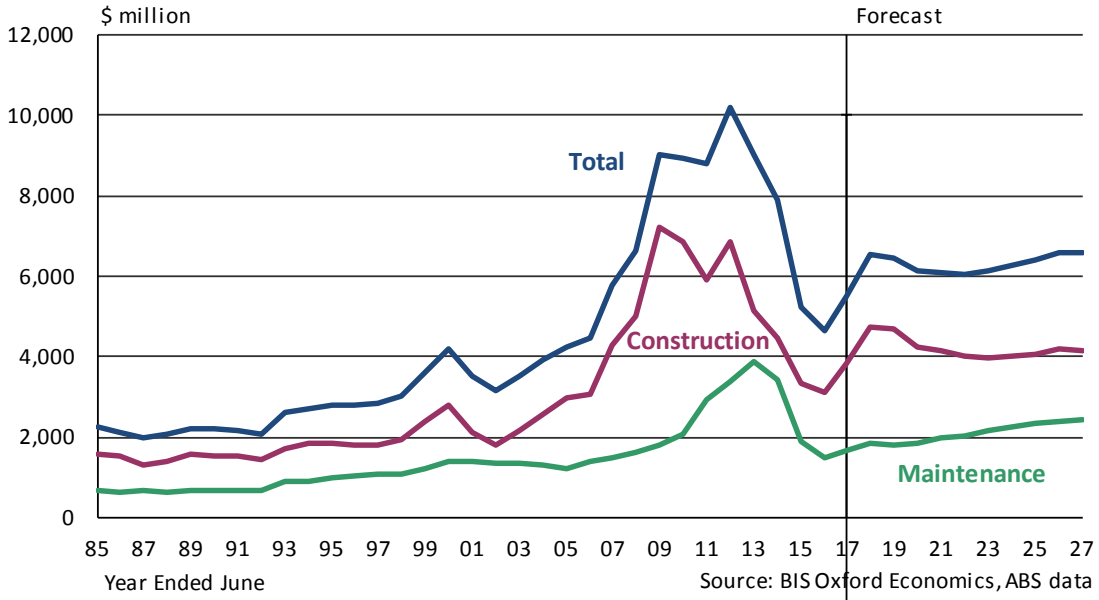


Queensland Road and Bridge Activity Outlook

Queensland road and road bridge construction activity is predicted to enter a stronger phase of growth, climbing to $4.7 billion by 2017/18. The upswing is being boosted by publicly funded highway and arterials with a number of major projects in tender or already contracted out. Work done is then anticipated to fall back to $4 billion over the following five years (to 2022/23) as public funding for these projects dries up.

Over the remainder of the outlook period, road and road bridge construction activity is expected to increase slightly to $4.2 billion, with steadily rising levels of maintenance driving an uptick in total road and road bridge activity in the state.

Figure 4.8: Road construction and maintenance work done, QLD ($M 2015/16 prices)



South Australia Road and Bridge Activity Outlook

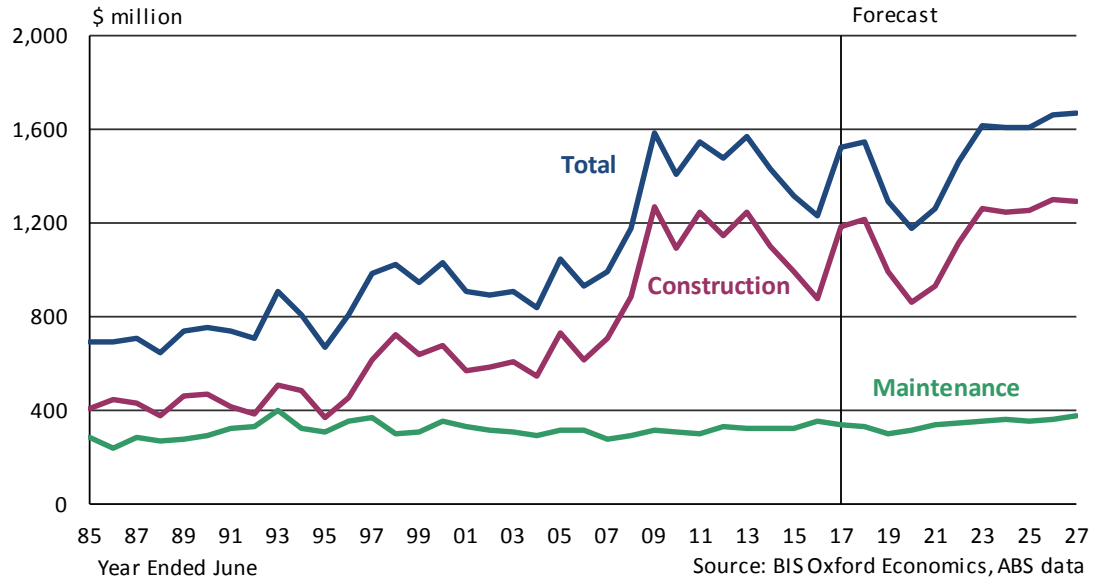
South Australian road and road bridge construction fell to $875 million in 2015/16, a level that has not been witnessed since the GFC. The fall in 2015/16 of 11.5 per cent was solely due to declines in private sector construction which far outweighed modest gains in publicly funded work. There was strong recovery witnessed in 2016/17, with road and road bridge construction work done bouncing back to $1.2 billion.

Over the next four years, another round of weakness is expected due to a lack of highways and arterials construction activity. This is entirely due to a fall in public sector funding which is the main source of funding for road and road bridge construction activity.

Over the remainder of the outlook period, BIS Oxford Economics anticipates road and road bridge construction activity to see some strength (for the six years to 2026/27), driven entirely by highways and arterials. Work on the North South Corridor is fundamental to this outlook, with key phases of this project taking place over the coming decade.

Overall, road and road bridge construction is forecast to average $1 billion per annum over the next five years, and $1.3 billion per annum over the subsequent five years to 2026/27.

Figure 4.9: Road construction and maintenance work done, SA ($M 2015/16 prices)



Western Australia and Bridge Activity Outlook

Road and road bridge construction in Western Australia peaked in 2008/09 at $2.9 billion, underpinned by a strong level of highways and arterials activity as well as a significant rise in mining access roads (in line with mining investment activity). Since then, mining access road construction has declined in line with falling mining investment. By 2016/17, total road construction had fallen to $1.9 billion.

The outlook for road and road bridge construction in Western Australia over the short to medium term will be influenced by how the new Labor Government is able to see out its plans.

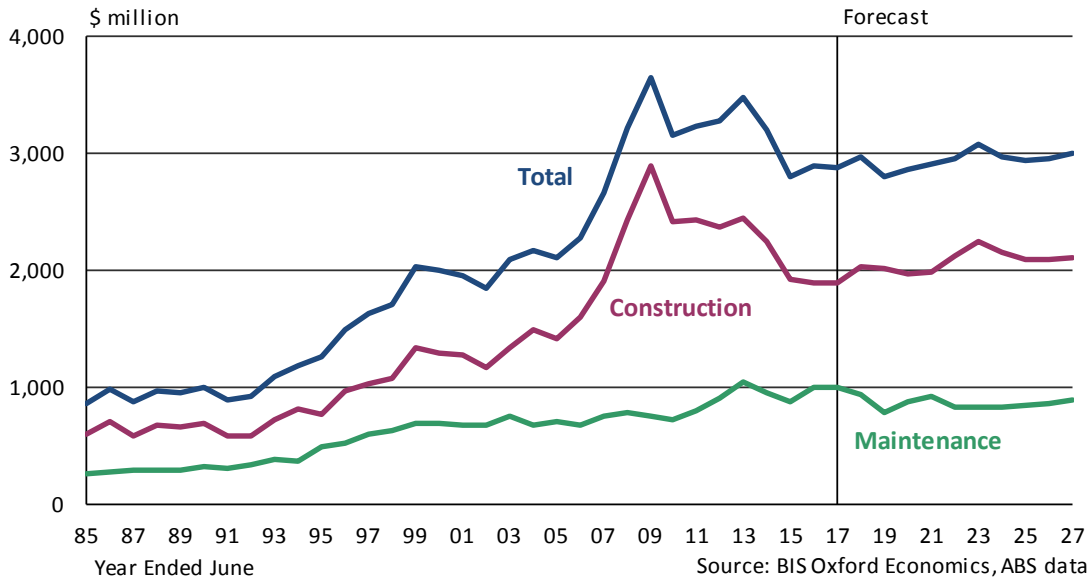
The Government has already cancelled the $1.7 billion Perth Freight Link, with the intention of replacing it with other smaller projects. It has announced two new projects in its place; a $166 million bridge linking Armadale and North Lake roads over the Kwinana Freeway and $95 million for two overpasses on Wanneroo Road over Ocean Reef Road and Joondalup Drive. It has also announced that it would bring forward the $145 million duplication of Armadale Road (Anstey Road to Tapper Road), although this project is already funded in the state budget. Note, however, that the Commonwealth Government has specifically pledged to provide funding for the Perth Freight Link project. The cancellation of this project may mean that the full funds would not be available for other projects.

Funding is the main constraint for roads activity in Western Australia. The current round of major projects has significant backing from the Federal Government. However, the Western Australian Government is facing significant budget difficulties, running budget deficits and expecting an increase in net debt over the three years to 2019/20.

Highways and arterials construction is expected to be relatively weak over the next five years. Without Federal Government assistance, highways and arterials expenditure in the state would likely be very feeble. Our base case is for a weaker profile for public work done in the medium term than if the freight link were to go ahead. However, this investment profile will be propped up later as work on replacement projects will take time to commence.

BIS Oxford Economics forecasts road and road bridge construction activity to average $2.1 billion per annum over the next decade to 2026/27. This is down 9.2 per cent on the average of the previous 10 year period and significantly below the peak in 2008/09 of $2.9 billion.

Figure 4.10:Road construction and maintenance work done, WA ($M 2015/16 prices)



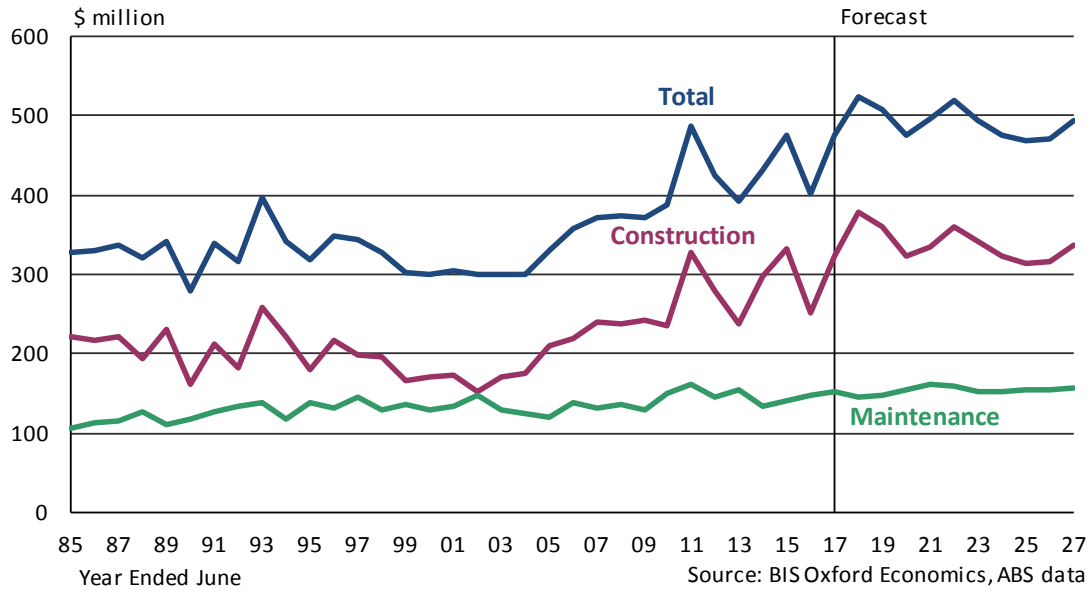
Tasmania Road and Bridge Activity Outlook

Road and road bridge construction reached $323 million in 2016/17, driven by an almost doubling in highways and arterials work. This is almost entirely due to work on the Midland Highway upgrade, with work ramping up to $87 million, along with an extra $9 million as part of the Midland Highway Road Safety Package. Also contributing to this strong activity is the work on the Summerleas Road Junction, which should see $17 million of work.

Over the two years to 2018/19, construction on the Midland Highway upgrade is expected to fall back to around $40 million per annum. We have also assumed that the $250 million second stage of works on the Midland Highway will commence from 2019/20 (after the first stage ends). Road construction is expected to fall over the two years to 2019/20, partly due to the decline in expenditure on the Midland Highway upgrade. Overall, road construction activity is expected to average $351 million per annum year over the five years to 2021/22.

In the longer term, Tasmania will continue to benefit from construction work on the Midland Highway upgrades. This development is likely to be supplemented by upgrades to the ageing road networks and opportunities for developments of major highways and local roads. Over the five years to 2026/27, road and road bridge construction is forecast to fall back slightly to average $326 million per annum.

Figure 4.11:Road construction and maintenance work done, TAS ($M 2015/16 prices)



Northern Territory Road and Bridge Activity Outlook

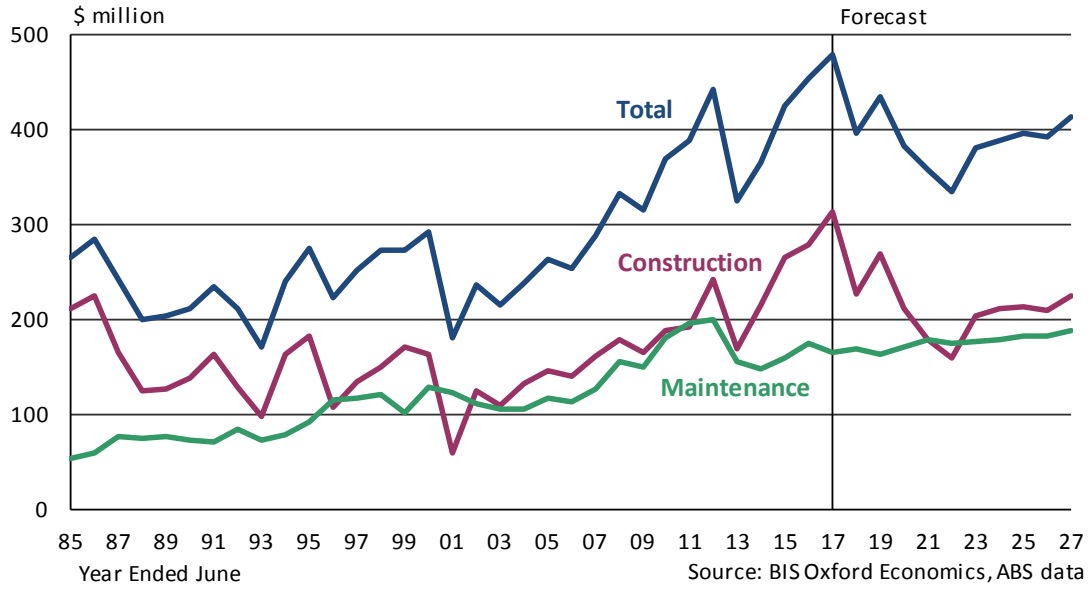
In the last three years, the Northern Territory has seen record levels of road and road bridge construction work done. 2014/15, 2015/16 and 2016/17 saw $265 million, $279 million and a record $313 million in construction activity respectively on the back of a surge in private road construction as well as more public investment in road infrastructure. This was driven by increased housing construction and population growth. Major road projects over this time include:

- The Tiger Brennan Drive Project
- Construction as part of the Northern Territory Roads Package
- Construction as part of the Regional Roads Productivity Package.

Over the medium term, we expect road construction to fall to $160 million in 2021/22. The completion of various works in the Northern Territory Road Package such as flood immunity improvements and upgrades to outback roads will realise this fall for the public sector.

In the three years to 2021/22, road construction is expected to decline, following the completion of major road projects, and a downturn in the local housing market. Funding for projects such as the Victoria Highway upgrades and upgrades to the road to Port Melville will be brought forward by the Darwin Port asset sale. Beyond this, funding such as the Northern Australia Infrastructure Facility will allow for increased investment in infrastructure, leading to an upturn in road and road bridge construction for the Northern Territory. The five-year average to 2026/27 is expected to be around $212 million per annum.

Figure 4.12:Road construction and maintenance work done, NT ($M 2015/16 prices)



Australian Capital Territory Road and Bridge Activity Outlook

The five years to 2014/15 saw very strong road and road bridge construction activity in the ACT, with an average of $264 million of work done over the period. This is significantly more than the previous five years to 2009/10, which saw only $78 million of work done. Major projects have underpinned this investment such as:

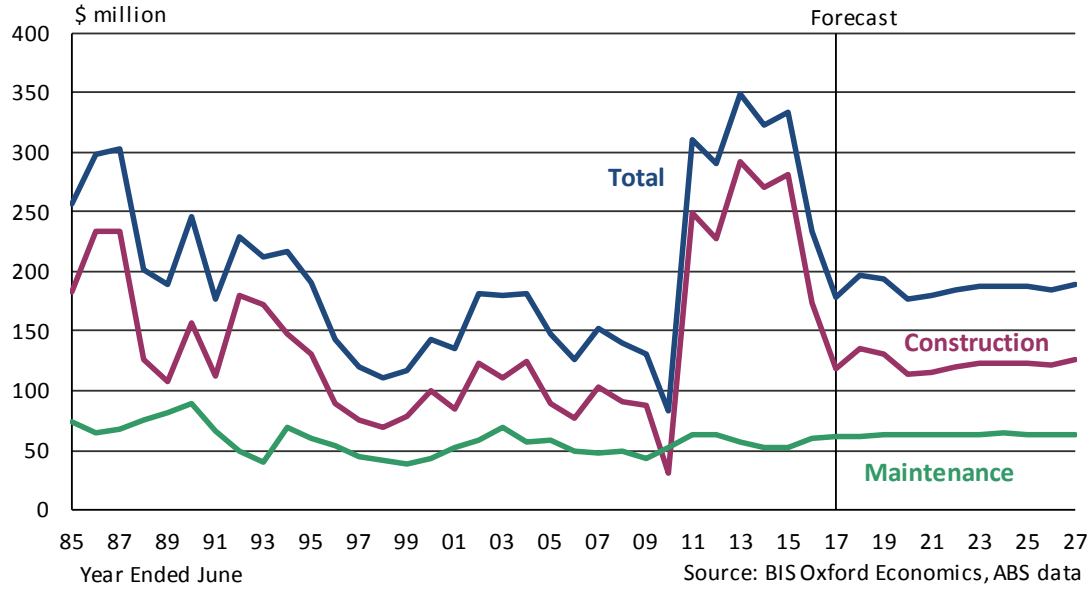
- The Majura Parkway
- The John Gorton Drive upgrades
- The Gungahlin Drive extension.

However, 2015/16, saw the completion of the Majura Parkway and John Gorton Drive projects which led to a 58 per cent fall in construction activity over the two years to 2016/17. A contraction in housing construction also saw a reduction in subdivision roads.

The next decade to 2026/27 will see road and road bridge construction activity normalise, thereby leading activity back to the historical norms seen prior to 2010/11. The absence of any large projects will dampen activity going forward.

The next decade to 2026/27 will see the average value of work done settle at $123 million per annum, assuming no large projects are announced.

Figure 4.13:Road construction and maintenance work done, ACT ($M 2015/16 prices)



5. Quantitative Modelling Results

5.1 Introduction and Methodology

This section provides estimates of the public sector roads workforce by skills cluster required to meet demand from roads activities over the ten year period to 2026-27 for Australia, New Zealand and for the Australian states and territories. The modelling also considers at the expected 'workforce gap' for each skills cluster annually over the forecast horizon taking into consideration demand, workforce attrition and productivity growth

At a national level it also considers the likely 'capability gap' – the difference between demand and supply – over the forecast horizon for the different clusters. This supply analysis suggests that competition for civil engineers over the forecast horizon will be less tight than over the previous decade at the national level in both Australia and New Zealand. However there is a key limitation to this analysis, which is the assumption that a new graduate can provide the necessary experience required to meet demand. There will be continued strong demand for highly experienced civil engineers across other construction sectors over the forecast horizon and these sectors will also experience attrition of their existing highly experienced workers. Further research is required to investigate the likely skills gap at different experience levels for the design skills cluster in the road sector over the forecast horizon and also the potential for net migration to fill any potential shortfall.

This modelling reports on occupations from the Informer, Technological and Artisan clusters, as well as a broader range of occupations in the Design cluster. A full breakdown of the occupations used in this study, cross-referenced by cluster, is included in Appendix A.

5.1.1 Demand, Supply and the Workforce Gap

The methodology used in this quantitative analysis involves, firstly, the estimation of a skilled (road) labour 'usage coefficient'. This is the amount of labour that is currently required to perform a certain volume of road-related activity. Then, projections of end use sector activity over the decade to 2027 have been translated, using these coefficients, into forecasts of future skilled labour demand.

Given the timeframe of the study, attrition of the existing workforce through ageing (e.g. via retirement and death) also becomes an important issue. The existence of workforce attrition means that the total additional skilled labour workforce requirement will end up higher than the total labour demand estimated by changed end use sector activity alone. This is because skilled labour also must be found to replace existing skills lost because of the ageing workforce.

The second step therefore involves the comparison of the expected demand for skilled labour with our projected levels of the existing workforce. The difference between the total labour demand and the size of the existing workforce is referred to as the 'workforce gap'. This gap, when positive, will need to be met by additional supply if projected levels of end use sector activity are to be achieved.

The final part of our methodology relates to estimating the potential new workforce supply. The estimated workforce gap less the supply of additional skilled labour via new graduates is defined in this report as the 'net capability position'.

5.1.2 Defining the Roads Sector

As outlined in Section 2.2 of this Report, the task of identifying a skilled roads workforce is complicated by the fact that there is no precise ABS definition of a 'roads' industry sector. While ABS Census data does have 'road and bridge construction' as an industry category, the reality is that using only Census data from this industry sector would, in our view, severely underestimate the size of the skilled roads workforce.

Consequently, BIS Oxford Economics considers that the roads sector not only includes the 'Road and Bridge Construction' sector but also a proportion of people employed in State and Local Government, Total Non-Building Construction and Professional Services. The size of the road industry labour force has been estimated based on the 2016 Census for Australia and 2013 Census for New Zealand. To bring the New Zealand Census data and our road industry estimates up to date, we have estimated data for New Zealand guided by known changes in industry sector activity since 2013.

5.1.3 Estimated Roads Workforce

The estimates of employment by skills cluster for Australia and New Zealand for 2016/17 are presented in Table 5.1. This represents the starting point for the analysis. A more detailed breakdown of estimated roads sector employment by skills cluster – as well as modelled projections of demands, attrition and the workforce gap – is provided in Appendix B.

We estimate that approximately 60 per cent of the total roads workforce are employed by public sector authorities, such as the state road authorities and local councils, with the remainder employed by the private sector. The bulk of the roads workforce is concentrated in the design skills and artisan skills clusters. Civil engineers make up the largest component of the design cluster along with project managers. While project managers in the roads industry could come from broad range of backgrounds, it is likely that a significant proportion have qualifications in civil engineering or other professional qualifications directly relevant to civil construction activity.

Labourers make up just under half of the artisan cluster workforce, with the remainder spilt between tradespersons and mobile plant operators. Unlike the design skills cluster that is made up of professionals, the artisan skills cluster includes a broad range of skill levels.

Table 5.1: Estimated Employment by Skills Cluster (2016/17)

Jurisdictions	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
NSW					
Total Roads Workforce	10,540	3,081	3,945	7,518	25,083
Public Roads Workforce	6,928	1,734	469	6,226	15,357
VIC					
Total Roads Workforce	5,536	2,025	1,921	3,995	13,478
Public Roads Workforce	3,269	1,387	258	2,189	7,103
QLD					
Total Roads Workforce	6,272	1,366	1,082	5,276	13,997
Public Roads Workforce	4,363	1,006	283	4,063	9,715
SA					
Total Roads Workforce	1,536	469	388	1,200	3,593
Public Roads Workforce	1,081	353	78	1,009	2,520
WA					
Total Roads Workforce	2,287	638	309	1,703	4,937
Public Roads Workforce	1,627	540	111	1,218	3,497
TAS					
Total Roads Workforce	540	125	88	647	1,399
Public Roads Workforce	386	93	21	520	1,019
NT					
Total Roads Workforce	188	20	14	217	440
Public Roads Workforce	135	16	5	148	304
ACT					
Total Roads Workforce	192	119	131	158	600
Public Roads Workforce	28	18	2	48	96
AUS					
Total Roads Workforce	27,090	7,844	7,877	20,715	63,527
Public Roads Workforce	17,817	5,147	1,227	15,421	39,611
NZ					
Total Roads Workforce	5,369	1,832	1,736	3,906	12,844
Public Roads Workforce	3,545	1,153	270	2,906	7,874

Source: BIS Oxford Economics, ABS Data, Stats NZ Data

5.1.4 Forecasting future skilled labour demand

The approach taken by BIS Oxford Economics to forecast future skilled labour demand is similar to other demand forecasting exercises we have undertaken for clients operating in the building and construction sector. That is, we firstly relate our estimates of 'base year' demand to an appropriate 'base year' activity indicator to derive a 'usage coefficient' per unit of end use sector activity. We then apply this usage coefficient to our forecasts of the activity indicator to derive forecasts of future demand.

In this case:

- Base year demand is estimated skilled employment in the roads sector in 2016/17.
- "End use" activity indicators chosen for the roads sector are:
  - Road and road bridge construction activity
  - Road and road bridge maintenance activity, and
  - Road net capital stock (as a proxy for the growth of the road network)

That is, the model assumes that future changes in demand for skilled labour in the roads sector are driven by changes in road and road bridge construction activity, road and road bridge maintenance activity and the net capital stock of roads. The net capital stock of roads is included in order to capture the demand for skilled labour that is not directly related to construction and maintenance work, but rather depends on the overall size of the road network (e.g. traffic engineers, urban planning and safety).

Activity indicator data sources

End use activity indicator data is drawn from both ABS and National Transport Commission (NTC) road and bridge data, as well as BIS Oxford Economics estimates. Forecasts of these data series are produced regularly by BIS Oxford Economics.

Road construction data is sourced from the ABS category of engineering construction — roads, highways and subdivisions from the ABS publication, Engineering Construction Activity, Australia (Cat. No. 8762.0). This data breaks down road construction by who funds and/or undertakes the work (the private or public sector). Road bridge construction is based on total bridge construction in the same ABS release, with BIS Oxford Economics estimates of rail and other non-road bridges excluded.

Forecasts of road and road bridge construction activity to 2027 are sourced from BIS Oxford Economics' regular multi-client report, Road Construction in Australia 2018 to 2032. This report uses both bottom up (e.g. project lists, Federal and State Budget papers, capital programs of state road authorities etc.) and top down approaches to reconcile the forecasts. The top-down modelling ensures the forecasts are consistent with historical levels of investment and with our assumptions of the economic environment, public sector capital expenditure cycle and private investment cycle.

Road and road bridge maintenance data is sourced from the regular NTC data collection from state and territory road authorities, for highways and arterial roads and road bridge maintenance, and ABS Local Government Finance Statistics (for local roads). BIS Oxford Economics also makes use of research from the Bureau of Transport and Regional Economics (BTRE), State and Federal Budget Papers, Australian Local Government Association (ALGA) reports as well as BIS Oxford Economics survey data.

Forecasts of road and road bridge maintenance activity to 2027 are sourced from BIS Oxford Economics' regular multi-client report, Road Maintenance in Australia 2017 to 2031. As with Road Construction in Australia, this report uses both bottom-up and top-down approaches to reconcile and forecast road maintenance activity.

Note that BIS Oxford Economics defines road and road bridge construction as including road rehabilitation that improves upon the original design standard of the road as well as substantial "one-off" repairs that add considerable value and life to the road asset. Asset renewal and maintenance activity which does not improve on the original design standard is considered maintenance.

Historical road net capital stock figures have been sourced from ABS Australian National Accounts Capital Stock data (Catalogue Number 5221.0) which is now discontinued. An extension to this data series — and forecasts to 2027 — have been estimated by BIS Oxford Economics for each Australian state and territory using ABS road construction data and subtracting an estimate of depreciation of the road capital stock.

5.1.5 Usage Coefficients

Usage coefficients were derived, firstly, by apportioning the estimated base year roads workforce, by occupation, across the three activity indicators. That is, the model assumes that demand for a set proportion of each occupation of the roads workforce is driven by changes in either road construction activity, or road maintenance activity or changes in the net capital stock of roads (where the sum of all these proportions equals 100 per cent).

The proportions chosen by BIS Oxford Economics, for all occupations across the private and public roads sector of each state, are shown in the Figure below. These proportions were determined through a detailed examination of the relative level of private and publicly funded road maintenance and construction activity in each state, consideration of the quality, age and trafficking of the road network in each state, and through consultation with key roads organisations.

Table 5.2: Estimated Skilled Roads Workforce Proportions, Percent

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST	NZ
Private Sector										
Road Maintenance	15%	15%	15%	15%	40%	33%	33%	40%	17%	40%
Road Construction	85%	85%	85%	85%	60%	67%	67%	60%	83%	60%
Other Roads Activity	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Public Sector										
Road Maintenance	15%	15%	25%	31%	25%	50%	50%	50%	20%	33%
Road Construction	50%	55%	60%	50%	60%	30%	30%	20%	53%	38%
Other Roads Activity	35%	30%	15%	19%	15%	20%	20%	30%	26%	29%

Source: BIS Oxford Economics

It is important to note that changes in the choice of these proportions can affect the size of the perceived capability deficit or surplus quantified by the model. This is because the choice of proportions changes the degree to which workforce demand is altered by, say, road construction activity (which is relatively volatile from year to year) as opposed to road maintenance work (which generally exhibits a trend increase over time). A strong and increasing outlook for road construction activity, for example, coupled with a high proportion of workforce demand allocated to road construction activity will drive a stronger overall demand for labour than if the proportion allocated to road construction were lower.

Once determined, the proportions were then used to calculate the estimated number of persons in each occupation for each end use activity. For each occupation in each state and territory, a usage coefficient was calculated for each end use activity by dividing the estimated roads workforce affected by that end use activity segment (via the proportions) by the level of end use segment activity in that year (2016/17). Forecasts of future skilled labour demand are then generated by applying these “fixed” coefficients to BIS Oxford Economics’ projections of future activity in each end use activity segment.

5.1.6 Modelling Workforce Attrition

The total skilled roads workforce requirement to meet future roads activity will inevitably be increased by the attrition of the existing workforce through ageing effects; particularly through retirement and death. In order to augment the model to allow for workforce attrition, we include assumptions regarding the approximate age profile of the workforce (based on unpublished road authority workforce data as well as broader ABS data), and the likelihood of retirement or death of persons in each age group (based on various ABS civilian population data series).

The figure below provides estimates of the current road workforce age composition for the artisan, design and other (being the informer and technological) clusters and shows that the artisan workforce has a lower share of its workforce that will be entering retirement over the forecast horizon. The designer cluster has the greatest share of workforce aged over 54 years (26.8 per cent), followed by other (informer and technological, 19.4 per cent) and then artisans (14.8 per cent). Given this, the designer cluster tends to have a greater rate of attrition than the other clusters considered in this analysis.

Table 5.3: Estimated Age Profile of the Roads Workforce Proportions by Cluster

Age Bracket	Total Artisan Workforce (Australia)	Total Design Workforce (Australia)	Total Other Workforce (Australia)
15-24	16.7%	2.1%	1.2%
25-34	23.9%	22.4%	17.9%
35-44	24.0%	23.3%	33.2%
45-54	20.6%	25.4%	28.2%
55-59	7.4%	14.0%	10.8%
60-65	5.0%	9.2%	7.2%
65-69	1.8%	2.9%	1.1%
70+	0.6%	0.7%	0.3%
Total	**100%**	**100%**	**100%**

Source: BIS Oxford Economics, ABS Data

5.1.7 Modelling New Graduate Supply

The combination of changing demand for roads skills driven by changes in road construction and maintenance activity, and the need to replace personnel lost through workforce attrition, results in an additional labour requirement or "workforce gap". This workforce gap, when positive, will need to be met by additional labour supply if forecast levels of end use sector activity are to be achieved. Possible sources of labour supply include:

- New graduates
- Net migration from overseas, and/or
- Net movement of skills between industries
- Other labour supply boosting initiatives (e.g. re-training, productivity improving measures, slower rates of attrition etc)

All of these supply sources are important in meeting future road workforce requirements. For this analysis we have only considered new engineering graduates – those completing bachelor degrees and associate degree or advanced diplomas – in the fields of civil engineering, engineering and related technologies, mechanical and industrial engineering and geomatic engineering. The design cluster includes project and procurement managers as well as administration staff. The supply of these skills has not been explicitly modelled. It is unlikely that graduates would enter into a management role, whereas the supply of administration staff is too broad to isolate a net capability position specifically for the roads sector. It has also proved difficult to estimate a net capability position for artisan skills in the roads sector based on projected completions of relevant vocational courses at TAFE. The capability position would depend to a large degree on the specific skills and the level of experience required.

5.1.8 The Capability Deficit or Surplus

The estimated total labour requirement or 'workforce gap' less the supply of additional skilled labour via new graduates is defined in this report as the 'net capability position'. If positive, it translates into a 'capability deficit'. Similarly, a negative implies a situation of 'capability surplus'. The presence of a capability deficit implies that the roads industry needs to attract additional labour above that expected to be sourced from new graduates — such as through immigration, from other industries, or via other labour supply boosting initiatives (e.g. by increasing productivity or reducing the rate of workforce attrition) — if it is to achieve forecast levels of future roads activity.

It is important to note that the capability deficit (or surplus) is a theoretical construct. In practice there will be no observable capability deficit. In practice, either labour demand (and roads activity) will fall back to meet the constrained level of labour supply — implying that some future roads activity will need to be cut back or foregone — or measures will be put in place that will boost labour supply to meet projected roads activity.

5.1.9 Scenario Analysis

The baseline scenario used here is described as “The Business as (Almost) Usual” scenario. This provides a baseline from which the impacts of other scenarios can be modelled. Under this scenario there is only very gradual development in new technologies which take much longer to disrupt the roads transport industry. Agencies will still need to plan for technological change, but these changes do not create significant impacts over the next two decades. With little actual change in transport technologies ‘on the road’ within the next two decades, there are expected to be only minor changes to roads funding through existing regimes and therefore it is assumed that the current agency roles to delivery, asset management and regulation are largely maintained. As a consequence, ‘baseline’ road construction and maintenance forecasts are used by BIS Oxford Economics to model future demand for skills in the Design and Artisan clusters, and the shares of roads agency workforces between Designer, Artisan and ‘Other’ skills clusters are steady.

The baseline projections are calculated based on BIS Oxford Economics’ baseline road construction and road maintenance forecasts (outlined in Section 4) and assumes a 1.5 per cent annual improvement in labour productivity across all skills.

We have also considered two alternative scenarios for roading activity over the forecast horizon:

- Technology and Response, and
- The Constrained World.

The **Technology and Response** scenario envisages that technological disruption has a greater impact on the road transport sector during the next one to two decades – and that this is met by a full policy response by governments and roads agencies. Following recent industry soundings, it is still expected that technological disruption will take time, but the full range of known impacts regarding CAV, C-ITS and MaaS are deployed during the next two decades. A long period of transition towards driverless vehicles eventuates as it inevitably takes time for the existing fleet of vehicles to turn over. Road users are relatively fast adopters of the technologies, however, leading to more economical mobility services being launched by private sector fleet operators. Roads agencies become more integrated with broader transport agencies to provide holistic solutions to transport planning. The revenue challenges to roads agencies are met through adjusting funding models towards road user charging as well as new fees paid by fleet operators to run on road networks. Many existing functions of roads agencies are contracted to the private sector in partnership arrangements where they are demonstrated to offer competitive or innovative advantages without impinging safety and other agency objectives. The risk of unsustainable increases in road use wrought by the new technologies sees agencies adopt innovative behavioural approaches to collectivise road use. Together with the efficiencies offered by connected, cooperative and autonomous driving, this eventually reduces needs for new investment in the road network, but not within the next five years. It is assumed that this scenario would result in road construction and maintenance being lower over the second half of the forecast horizon, higher productivity and a shift from designers and artisan to informers and technological skills.

The **Constrained World** offers the same degree of technological development as in the Technology and Response scenario, but agencies and governments only offer a constrained response to meet these challenges. Political challenges mean that governments are not able to introduce broad based road user charging as a replacement for revenues from fuel taxes and licencing, although a form of road user charging is applied for heavy vehicles. Losses in revenue intensify needs to prove new investment in the roads network is productive, with most funds received from road user charging being targeted at maintenance. Meanwhile, there is a shift towards outsourcing delivery of road works as a means of doing more with less. Agencies are resistant to change, however, and retain a prescriptive approach to regulation and procurement with the private sector, keeping many remaining functions in house. Congestion rises significantly due to an inability to offer sharing solutions to new technologies, driving large increases in road use from the mid 2020s. In urban areas this drives a need for new investment in roads networks which, due to funding constraints, are increasingly delivered and financed by the private sector. Under this scenario, the uptake of technology is presumed to be slower than under the base case and workforce demand is characterised by lower productivity, higher construction and maintenance activity and a modest increase in the share of the artisan and design skills clusters.

5.1.10 Limitations of the Model

A key limitation of the model is that the measurement of requirements in terms of labour or 'personnel', not necessarily skills and experience. Obviously the role of a retiring skilled professional with many years of experience cannot be matched by a new graduate. This is particularly true when supply is focused on new graduates, but the impact may be lessened by the hiring of personnel from other industries, or via immigration, where existing skills and experience may be higher. Other important limitations include the fact that the model does not consider underemployment of labour or existing skills deficits but instead assumes that demand and supply are perfectly matched in the base year.

5.2 Modelling Results under Baseline Scenario

This section provides the workforce breakdowns estimates based on the Census 2016 data for Australian states and territories and the equivalent estimates for New Zealand based on forward projections of the Census 2013 figures. Also provided are the graphical representations of projected labour demand for the design and artisan skills clusters and other skills (technological and informer) over the 10 years to 2027. It is assumed that demand and supply are in balance across all skills sectors and industry activities (maintenance, construction and network) as at 2017. The workforce gap illustrated in the charts for each jurisdiction is based on the difference between labour demand and the starting workforce as at 2017, accounting for attrition through retirements and death. **All data for the labour demand, attrition and workforce gap charts presented in this section, broken down by occupation and cluster, are provided in Appendix B to this Report.**

5.2.1 Australian workforce projections

The overall workforce breakdown for Australia based on the Census 2016 data is provided in the figure below along with the total employment for the occupations which make up the skills clusters across the industry sectors which are assumed to include workers engaged in roading activity – total construction (including road and bridge construction), public administration and safety, professional services and other sectors.

It is important to reiterate that only the bottom two lines of the table (and the subsequent tables shown for each state and New Zealand) are directly relevant here, with the other rows being raw Census data (or in the case of New Zealand, population estimates from BIS Oxford Economics based on the most recent Census). While Census data does have "road and bridge construction" as an industry category, the reality is that not all persons working in the roads sector will record this as their industry sector when completing the Census. Indeed using only Census data from this industry sector would, in our view, severely underestimate the size of the roads workforce.

Table 5.4: Australia Total Roads Employment (Census 2016)

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**28,865**	**923**	**671**	**90,835**	**121,294**
Building Construction	15,432	556	207	24,244	40,439
Total Non-Building Construction	5,116	119	151	6,507	11,893
Road & Bridge Construction	*2,148*	*44*	*18*	*3,152*	*5,362*
General Trade Construction	8,317	248	313	60,084	68,962
Public Administration & Safety	**14,082**	**7,025**	**3,308**	**5,350**	**29,765**
Federal Government	1,648	1,077	649	24	3,398
State Government	4,099	2,640	1,230	286	8,255
Local Government	4,830	2,006	388	2,931	10,155
Other	3,505	1,302	1,041	2,109	7,957
Professional Services	**22,860**	**10,476**	**27,224**	**2,821**	**63,381**
Other Sectors	**46,952**	**26,193**	**32,593**	**66,885**	**172,623**
Total All Sectors	**112,732**	**44,607**	**63,857**	**165,865**	**387,061**
Total Roads Workforce	**10,540**	**3,081**	**3,945**	**7,518**	**25,083**
Public Roads Workforce	**6,928**	**1,734**	**469**	**6,226**	**15,357**

Source: BIS Oxford Economics, ABS Data

Modelling of future roads workforce demand for this quantitative analysis is focused on the Designer, Artisans and Other (Information and Technology) skills clusters. Responses from earlier industry surveys and interviews suggested that measuring changes in demand for the latter (non-traditional) skills sets will be extremely difficult. We have approached the problem in the base case by assuming that the coefficients for the base year of 2017 apply over the forecast horizon.

While we are confident that the level of Artisan and Design cluster demand is directly related to construction and maintenance activities, we are not so sure that the Informer and Technological skills clusters have such a close relationship – and this was borne out in industry interviews. In the hypothetical base case presented here however (which is more akin to previous workforce capability analyses undertaken for Austroads) there is assumed to be little technological change (and construction and maintenance activities do not vary dramatically) and so we feel that this simplifying assumption does not unduly affect the forecasts of demand for Informer and Technology cluster demand. However, it is possible to indicate whether demand for these types of skills will be higher or lower under different technological/funding scenarios, and this modelling is presented in Section 3 at the national level. From industry feedback, it will be important that roads agencies (or the broader industry it can contract from) have at least some of these skills across all scenarios, but more or less may be in demand based on the world that eventuates. Ultimately, a mix of skills will be required.

The Australian data is calculated as the sum of the results for the respective states and territories. The data shows that design skills is the largest employment cluster in the roads industry. This reflects the traditional role of the road sector with respect to maintenance and construction activity. However, it is expected that these skills ratios will change with the increasing adoption of smart technologies and the potential penetration of driverless vehicles that are expected to underpin an increase in share of planners, analysts and information technology experts in the road workforce mix and a decrease in the share of artisans and construction-related professionals. There is however considerable uncertainty over the timeframe for the uptake of these technologies and therefore the baseline scenarios assumes that there is no change in the ratios of employment between clusters over the forecast horizon.

This section provides the workforce breakdowns estimates based on the Census 2016 data for Australian states and territories and the equivalent estimates for New Zealand based on forward projections of the Census 2013 figures. Also provided are the graphical representations of projected labour demand for the design and artisan skills clusters and other skills (technological and informer) over the 10 years to 2027. It is assumed that demand and supply are in balance across all skills sectors and industry activities (maintenance, construction and network) as at 2017. The workforce gap illustrated in the charts for each jurisdiction is based on the difference between labour demand and the starting workforce as at 2017, accounting for attrition through retirements and death.

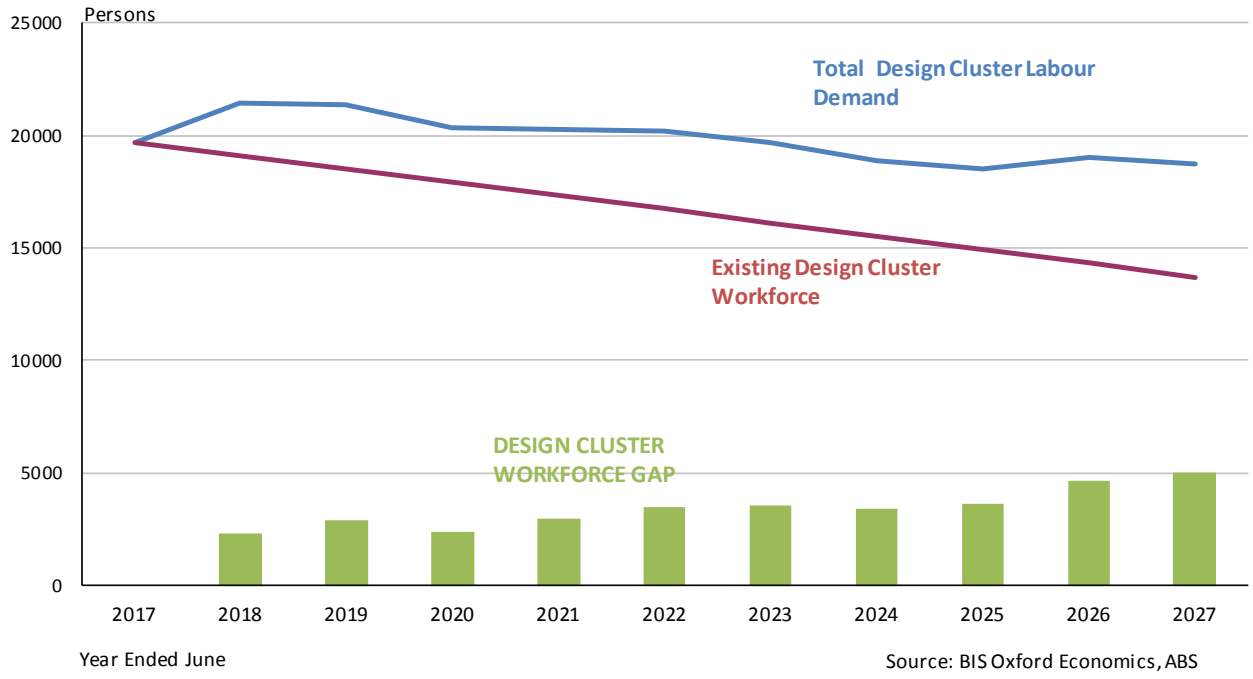
***Note**: in the charts for this section, forecasts are provided separately for Designer, Artisan and Other (Informer and Technologist) skills clusters. All data for the labour demand, attrition and workforce gap charts presented in this section, broken down by occupation and cluster, are provided in Appendix B to this Report.*

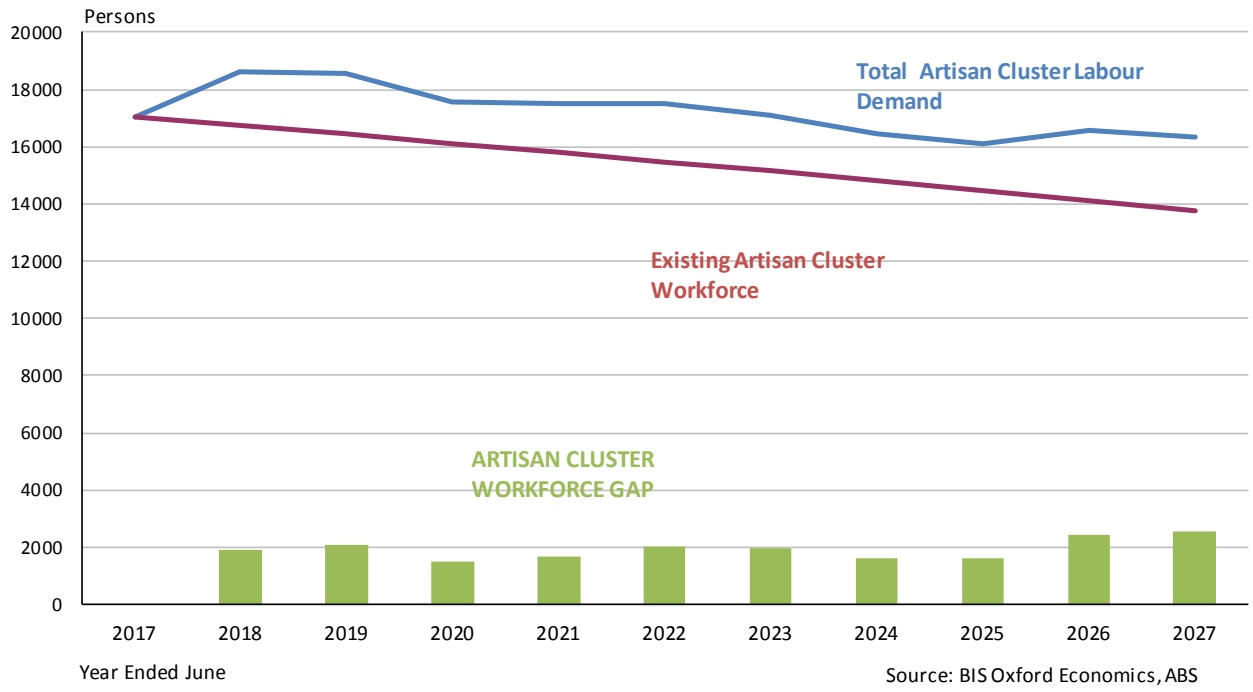
Australian workforce gaps

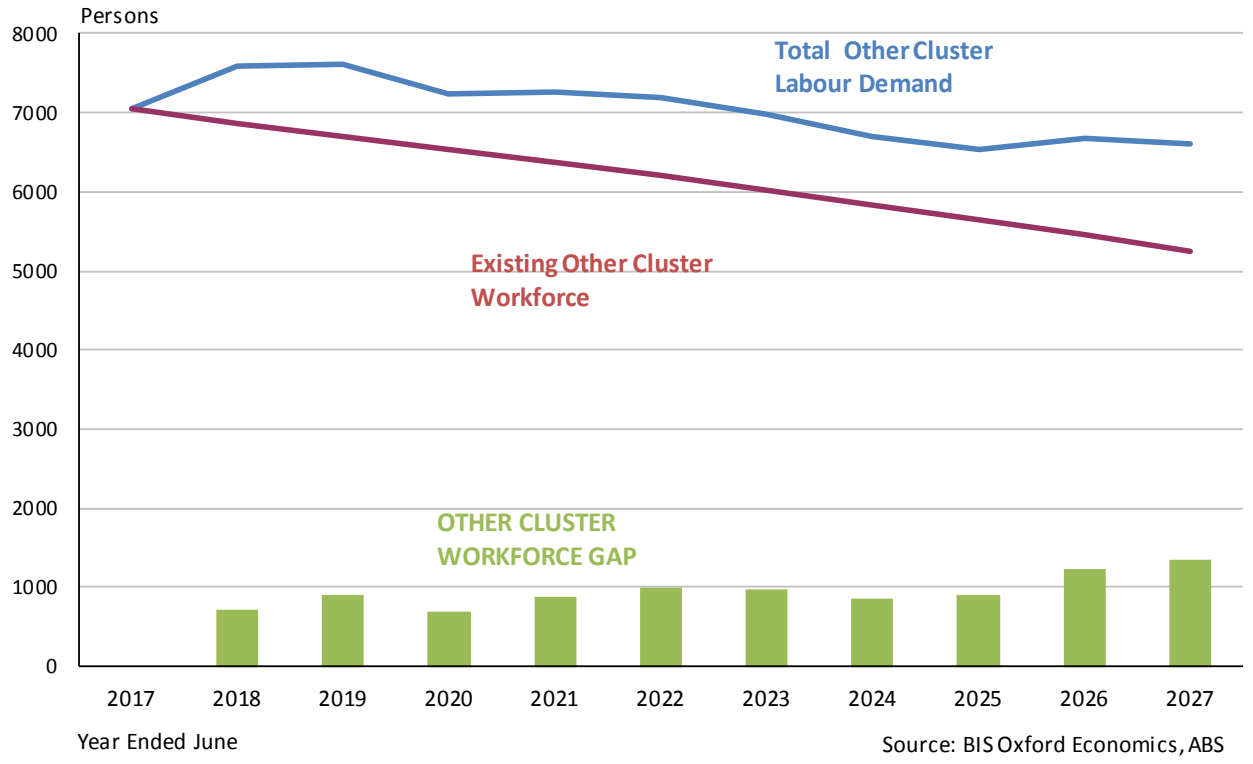
Given the estimated age profiles of the roads workforce by cluster — and the assumed likelihood of retirement and death in each age group — we estimate that the existing Australian workforces across the clusters will shrink as shown in the charts below. The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

The assumption of constant usage coefficients per volume of work done and the same assumed splits across maintenance and construction activities results in similar demand profile patterns for the national artisan and design cluster road workforces. However, the older designer workforce results in the emergence of a wider workforce gap through attrition (than either the artisan or other clusters) that will need to be meet through additional supply.

Figure 5.1: Australian Public Roads Workforce Gaps




Persons
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
8000
7000
6000
5000
4000
3000
2000
1000
0
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS

New South Wales workforce gaps

Table 5.5: New South Wales Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**28,865**	**923**	**671**	**90,835**	**121,294**
Building Construction	15,432	556	207	24,244	40,439
Total Non-Building Construction	5,116	119	151	6,507	11,893
Road & Bridge Construction	*2,148*	*44*	*18*	*3,152*	*5,362*
General Trade Construction	8,317	248	313	60,084	68,962
Public Administration & Safety	**14,082**	**7,025**	**3,308**	**5,350**	**29,765**
Federal Government	1,648	1,077	649	24	3,398
State Government	4,099	2,640	1,230	286	8,255
Local Government	4,830	2,006	388	2,931	10,155
Other	3,505	1,302	1,041	2,109	7,957
Professional Services	**22,860**	**10,476**	**27,224**	**2,821**	**63,381**
Other Sectors	**46,952**	**26,193**	**32,593**	**66,885**	**172,623**
Total All Sectors	**112,732**	**44,607**	**63,857**	**165,865**	**387,061**
Total Roads Workforce	**10,540**	**3,081**	**3,945**	**7,518**	**25,083**
Public Roads Workforce	**6,928**	**1,734**	**469**	**6,226**	**15,357**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in New South Wales translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 7,340 designer cluster employees in 2016/07, labour demand is expected to rise sharply to 8,242 employees by 2018/19 as rapidly increasing roads activity more than offsets labour productivity (1.5 per cent per annum) under the baseline scenario. However, by 2019/20 demand is expected to fall back in line with weakening roads activity. Further upward shifts in labour demand are anticipated in 2021/22 and 2025/26 in line with further cycles in roads activity, but then retreat again. Overall, demand is anticipated to remain higher than 2016/17 through to 2023/24, reflecting a long period of high roads activity.

For artisan cluster employees, modelled labour demand is expected to rise from 6,596 to 7,407 over the next two years, before cycling back again in subsequent years. New bursts of roads activity through the forecast period keep artisan labour demand relatively strong through much of the next decade, though not exceeding the 2018/19 peak. More detailed forecasts by occupation within these clusters is included in Appendix B.

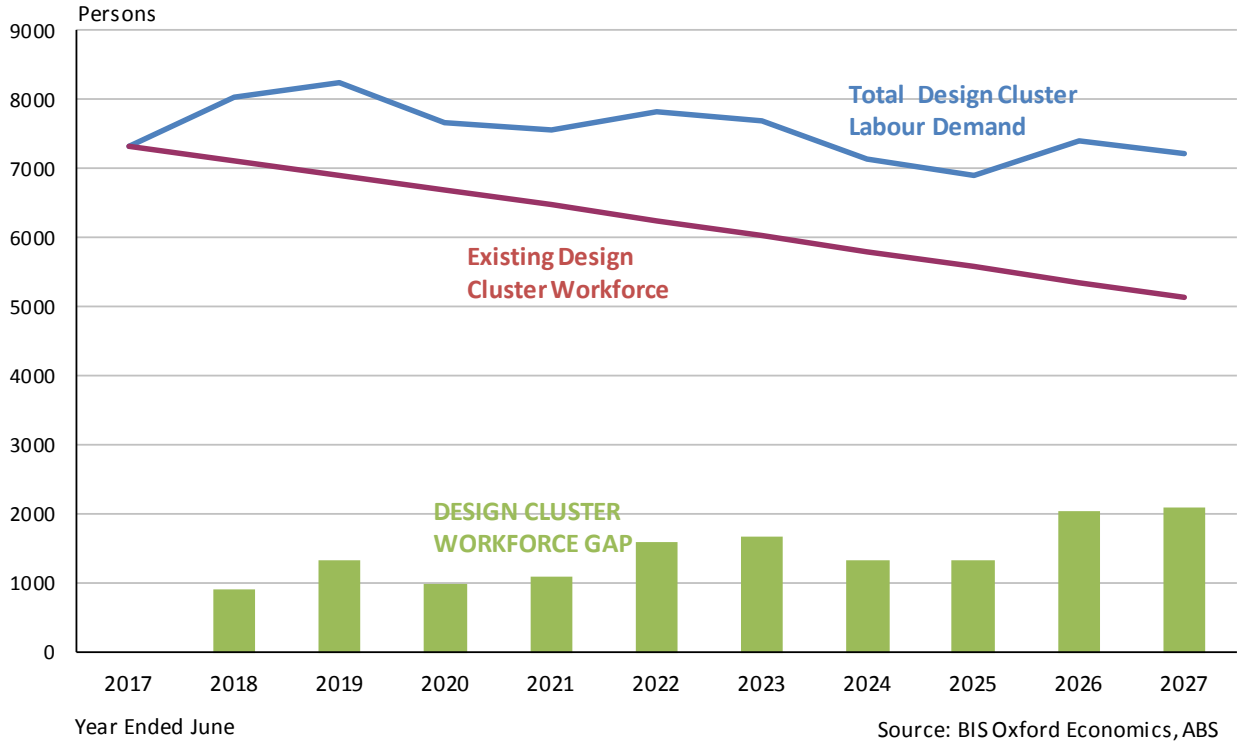
For the other skills cluster (informer and technological), demand is expected to rise from 2,335 to 2,621 over the next two years before easing in subsequent years (typically between 2,400 to 2,500 persons to 2022/23.

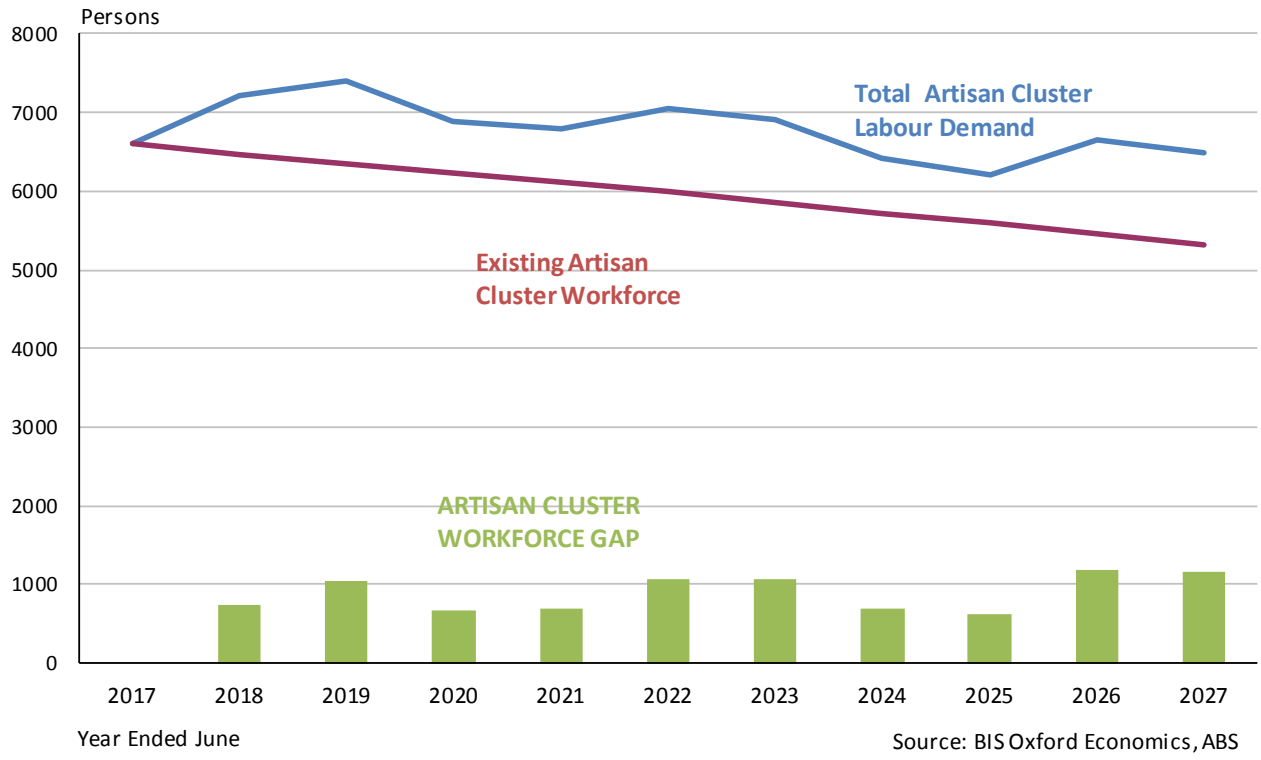
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

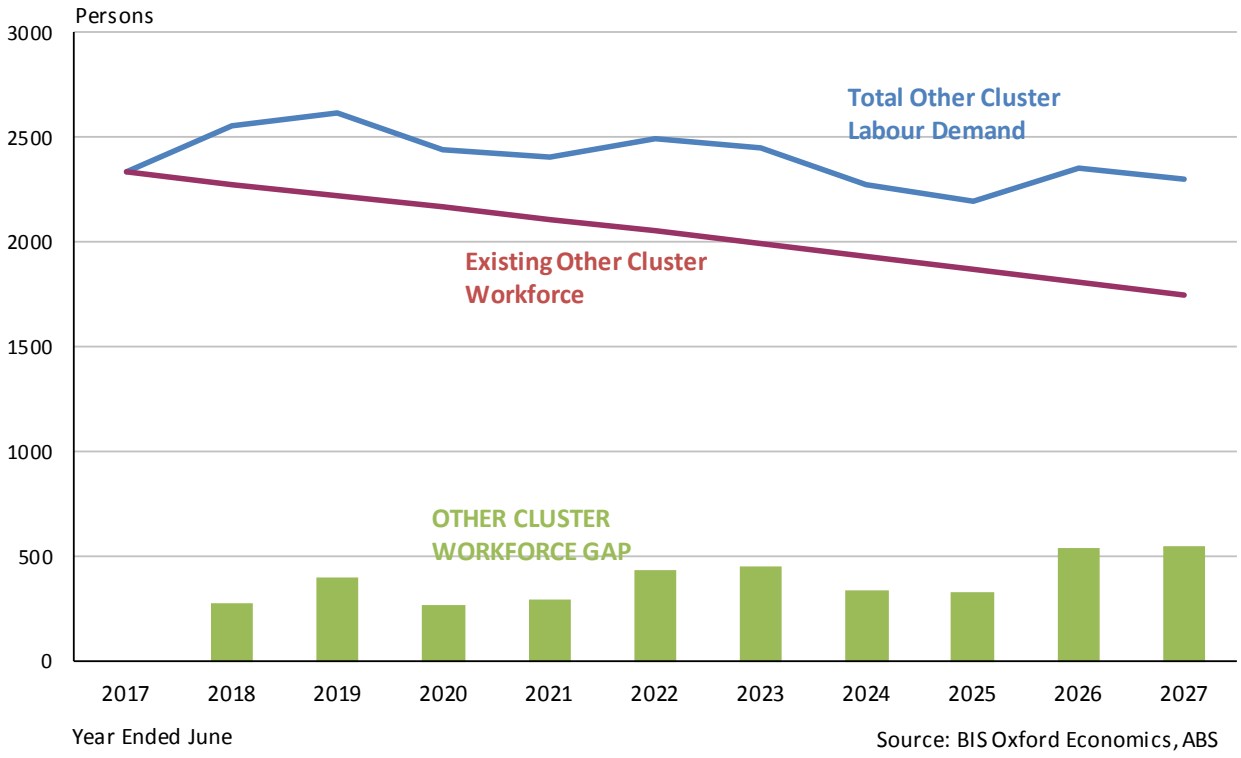
Given the estimated age profile of the New South Wales roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster (30 per cent attrition). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Overall, for all clusters in the New South Wales roads sector, modelling indicates a large workforce gap over time as attrition of the existing workforce accompanies steady or growing levels of labour demand. For the Designer cluster, the workforce gap is expected to rise to a peak of 2,089 employees by 2026/27. A similar pattern of growth in the workforce gap is anticipated for the artisan and other workforces during the coming decade, with the gap widening to 1,168 employees by 2026/27 in the artisans cluster and 554 employees in the other cluster. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.2: NSW Public Roads Workforce Gaps




Persons
8000
7000
6000
5000
4000
3000
2000
1000
0
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
3000
2500
2000
1500
1000
500
0
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS

Victoria workforce gaps

Table 5.6: Victoria Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**20,622**	**778**	**438**	**77,194**	**99,032**
Building Construction	11,793	491	132	21,053	33,469
Total Non-Building Construction	3,231	45	98	4,993	8,367
Road & Bridge Construction	*1,054*	*14*	*13*	*1,906*	*2,987*
General Trade Construction	5,598	242	208	51,148	57,196
Public Administration & Safety	**8,798**	**5,959**	**2,064**	**2,029**	**18,850**
Federal Government	1,179	995	394	7	2,575
State Government	2,148	1,999	594	72	4,813
Local Government	3,217	1,949	328	794	6,288
Other	2,254	1,016	748	1,156	5,174
Professional Services	**18,100**	**9,144**	**23,988**	**1,995**	**53,227**
Other Sectors	**39,083**	**22,005**	**26,554**	**48,671**	**136,313**
Total All Sectors	**86,633**	**37,890**	**53,087**	**129,977**	**307,587**
Total Roads Workforce	**5,536**	**2,025**	**1,921**	**3,995**	**13,478**
Public Roads Workforce	**3,269**	**1,387**	**258**	**2,189**	**7,103**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in Victoria translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 3,663 designer cluster employees in 2016/07, labour demand is expected to rise to 3,967 employees by 2020/21. Weakening roads activity in aggregate thereafter, combined with ongoing increases in labour productivity is expected to see demand for designer cluster employees fall to 2,957 employees by 2026/27, below current levels of under the baseline scenario.

For artisan cluster employees, modelled labour demand is expected to rise from 2,452 to 2,656 employees over the next four years, before cycling back again in subsequent years. For 'other' cluster employees, demand is expected to rise from 1,843 to 1,996 by 2020/21 before declining in subsequent years.

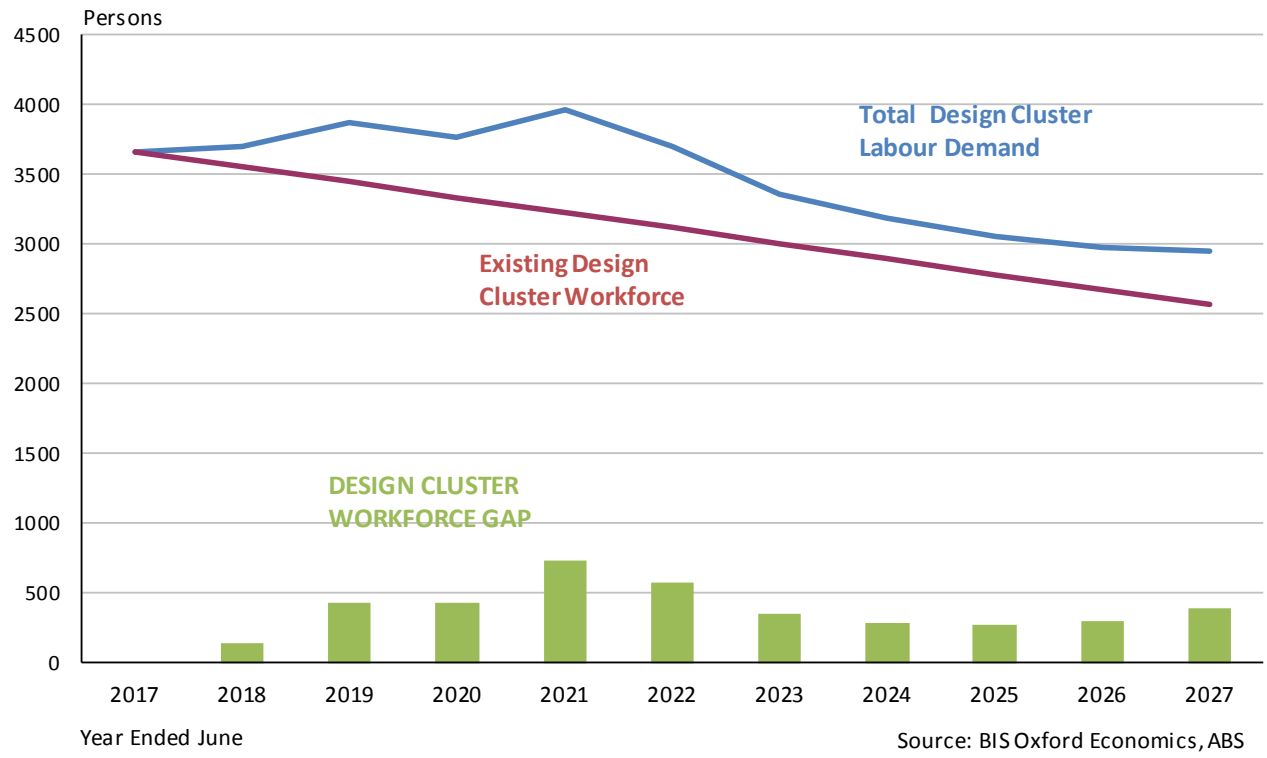
More detailed forecasts by occupation within these clusters is included in Appendix B.

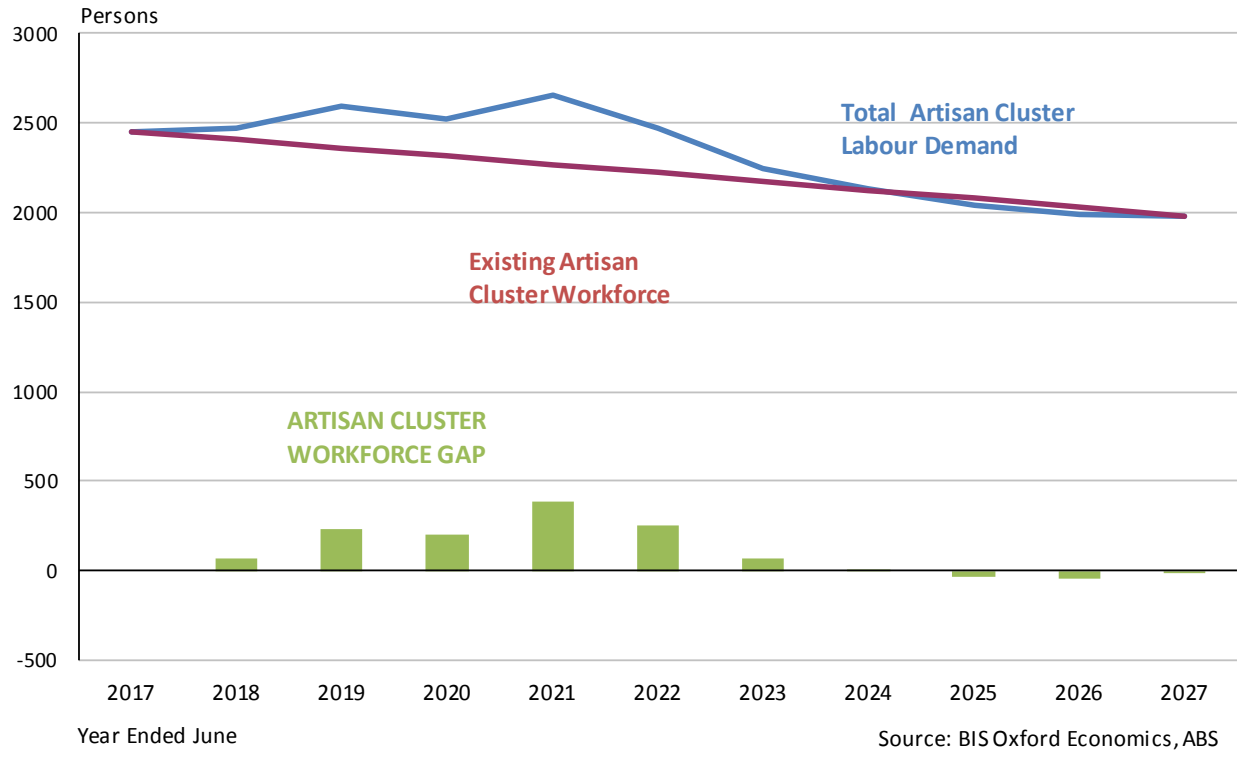
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

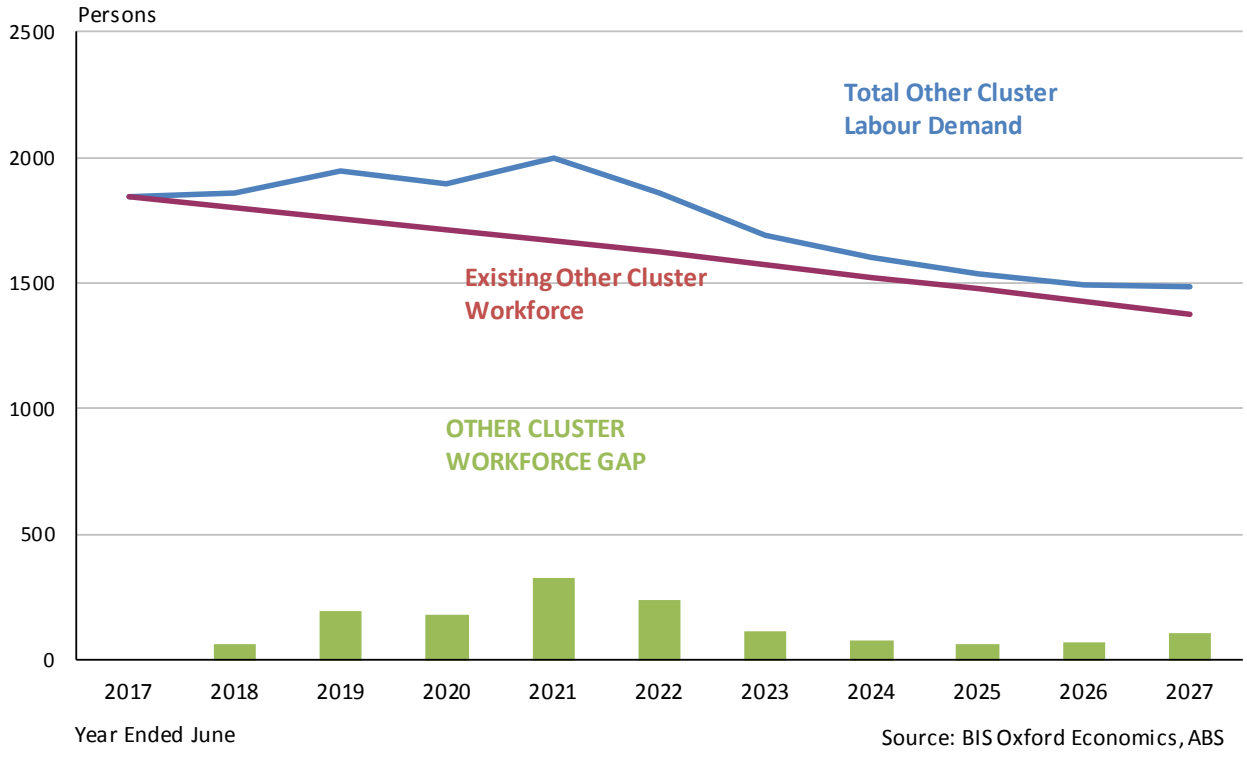
Given the estimated age profile of the Victorian roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster. The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieve.

Overall, for all clusters in the Victorian roads sector, modelling indicates a sharply rising workforce gap over the next four years to 2020/21 as attrition of the existing workforce accompanies strong growth in labour demand. For the Designer cluster, the workforce gap is expected to rise to a peak of 737 employees by 2020/21, before the gap eases in subsequent years. Further attrition sees the gap begin to widen again by the end of the decade. A similar pattern of growth in the workforce gap is anticipated for the artisan and other (informer and technologist) workforce clusters during the coming decade, with the gap widening to 385 and 328 employees respectively by 2020/21. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.3: VIC Public Roads Workforce Gaps




Persons
3000
2500
2000
1500
1000
500
0
-500
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
2500
2000
1500
1000
500
0
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS

Queensland workforce gaps

Table 5.7: Queensland Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**18,257**	**561**	**245**	**62,332**	**81,395**
Building Construction	8,899	314	47	16,164	25,424
Total Non-Building Construction	3,787	65	77	5,811	9,740
Road & Bridge Construction	*1,687*	*42*	*9*	*2,551*	*4,289*
General Trade Construction	5,571	182	121	40,357	46,231
Public Administration & Safety	**11,134**	**4,877**	**2,443**	**4,206**	**22,660**
Federal Government	1,005	520	559	10	2,094
State Government	4,470	2,414	1,052	152	8,088
Local Government	3,981	1,328	354	2,551	8,214
Other	1,678	615	478	1,493	4,264
Professional Services	**15,912**	**4,376**	**9,996**	**2,856**	**33,140**
Other Sectors	**31,749**	**10,951**	**10,231**	**60,388**	**113,319**
Total All Sectors	**77,146**	**20,776**	**22,901**	**129,822**	**250,645**
Total Roads Workforce	**6,272**	**1,366**	**1,082**	**5,276**	**13,997**
Public Roads Workforce	**4,363**	**1,006**	**283**	**4,063**	**9,715**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in Queensland translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 5,177 designer cluster employees in 2016/17, labour demand is expected to rise sharply to 5,960 employees through 2017/18 and remain at a high level in 2018/19. Weakening roads activity in aggregate thereafter, combined with ongoing labour productivity is expected to see demand for designer cluster employees fall to 5,361 employees by 2022/23 – still higher than 2016/17 levels – before rising again on the back of increasing roads activity.

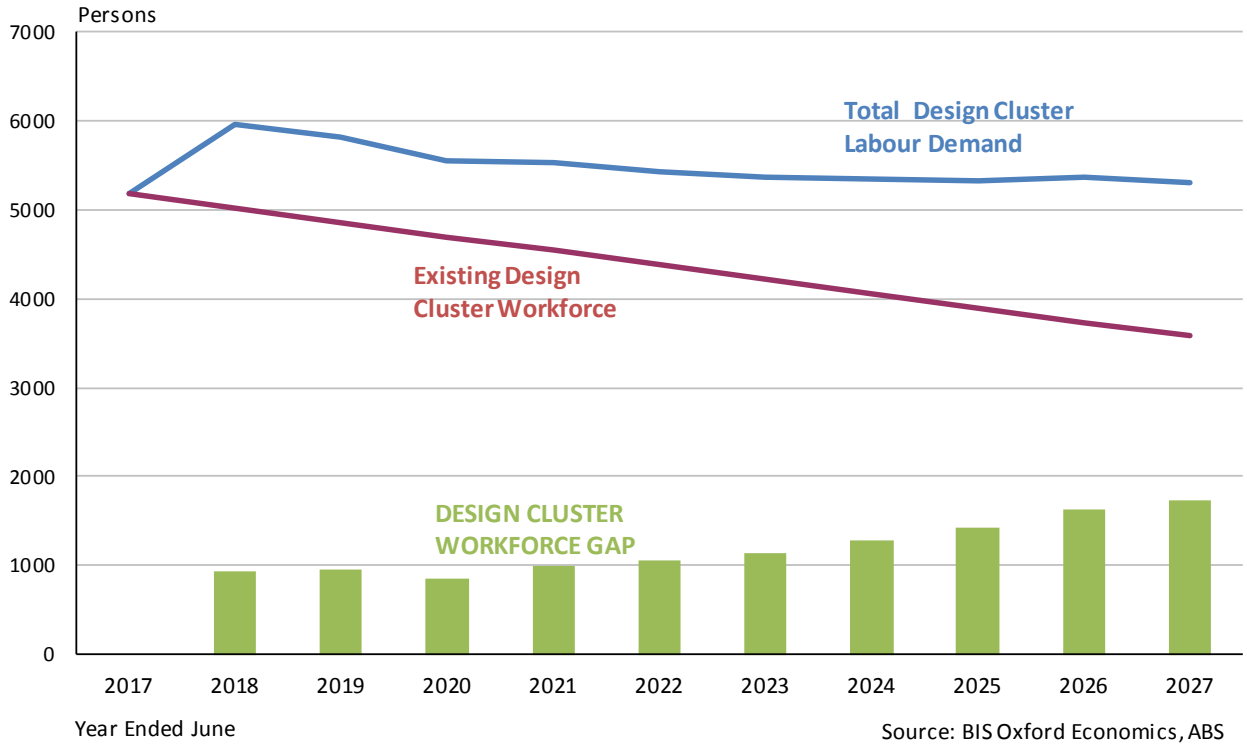
For artisan cluster employees, modelled labour demand is expected to rise from 4,822 to 5,551 employees over 2017/18 before easing back slightly in 2018/19. Declines are expected in subsequent years – approaching 2016/17 levels of demand once again – before rising late in the forecast period.

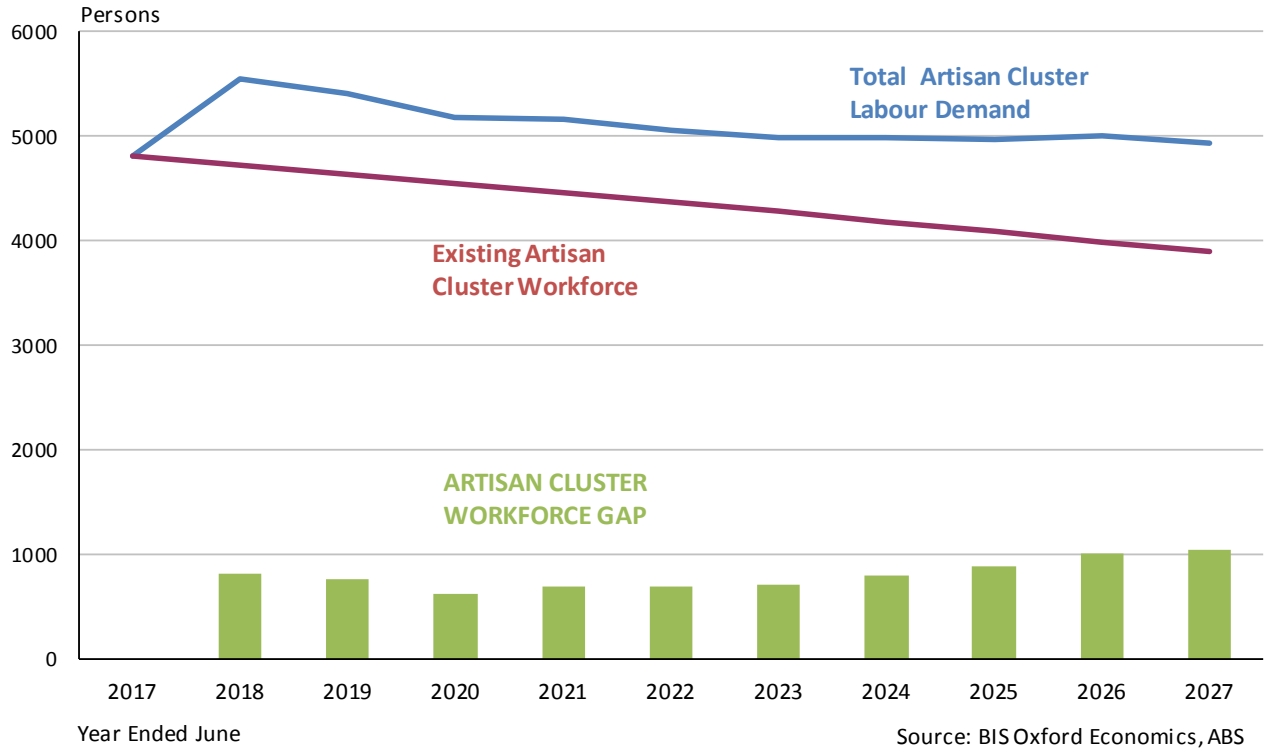
Informer and Technologist cluster labour demand is expected to rise from 1,529 to 1,761 before settling in a range from 1,560 and 1,650 per annum, generally higher than in 2016/17. More detailed forecasts by occupation within these clusters is included in Appendix B.

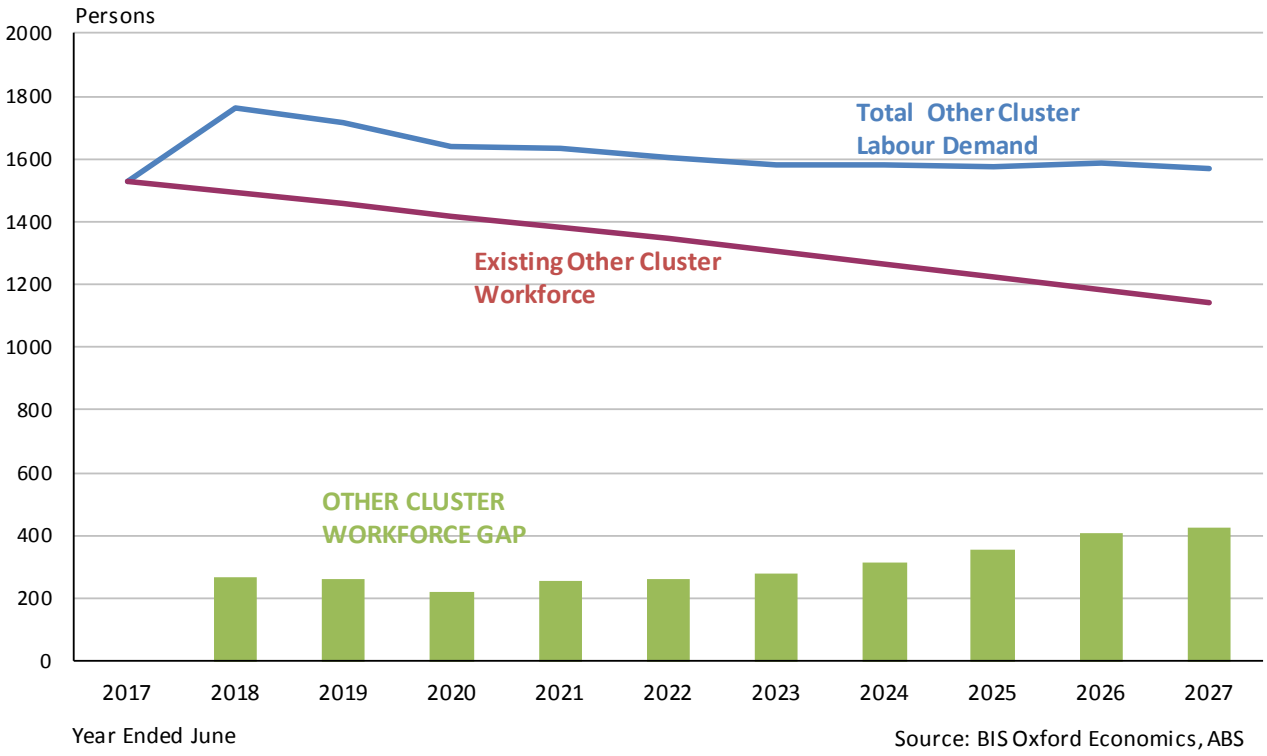
Given the estimated age profile of the Queensland roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster. The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Overall, for all clusters in the Queensland roads sector, modelling indicates a sharply rising workforce gap over 2017/18 based on sharply rising roads activity and labour demand. However, unlike Victoria and New South Wales, this gap is anticipated to grow relatively steadily through the forecast period as sustained levels of demand combine with further attrition of the existing workforce For the Designer cluster, the workforce gap is expected to rise to 1,723 employees by 2026/27. For the Artisan workforce, the gap is expected to widen to 1,045 employees by the decade. For the other cluster (informer and technologist), the workforce gaps is expected to rise to 427 persons. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.4: QLD Public Roads Workforce Gaps




Persons
6000
5000
4000
3000
2000
1000
0
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS

South Australia workforce gaps

Table 5.8: South Australia Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**4,720**	**122**	**66**	**17,652**	**22,560**
Building Construction	2,379	54	12	4,157	6,602
Total Non-Building Construction	800	16	17	1,308	2,141
Road & Bridge Construction	*330*	*7*	-	*559*	*896*
General Trade Construction	1,541	52	37	12,187	13,817
Public Administration & Safety	**3,936**	**1,829**	**1,232**	**995**	**7,992**
Federal Government	628	276	333	3	1,240
State Government	1,537	793	384	89	2,803
Local Government	872	438	79	492	1,881
Other	899	322	436	411	2,068
Professional Services	**4,162**	**1,250**	**3,378**	**733**	**9,523**
Other Sectors	**10,516**	**3,363**	**3,887**	**16,683**	**34,449**
Total All Sectors	**23,319**	**6,584**	**8,600**	**36,072**	**74,575**
Total Roads Workforce	**1,536**	**469**	**388**	**1,200**	**3,593**
Public Roads Workforce	**1,081**	**353**	**78**	**1,009**	**2,520**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in Queensland translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 1,263 designer cluster employees in 2016/17, labour demand is expected to rise to 1,311 employees through 2017/18 before easing back in subsequent years. Rising roads activity later on is offset by ongoing productivity gains, keeping overall demand trapped in a range of 1,100 ro 1,200 through much of the forecast period.

For artisan cluster employees, modelled labour demand is expected to rise from 1,180 to 1,225 employees over 2017/18 before similarly easing later on. Even though demand is anticipated to weaken below 2016/17 levels, it is still expected to be significant – and rising again by the end of the forecast period.

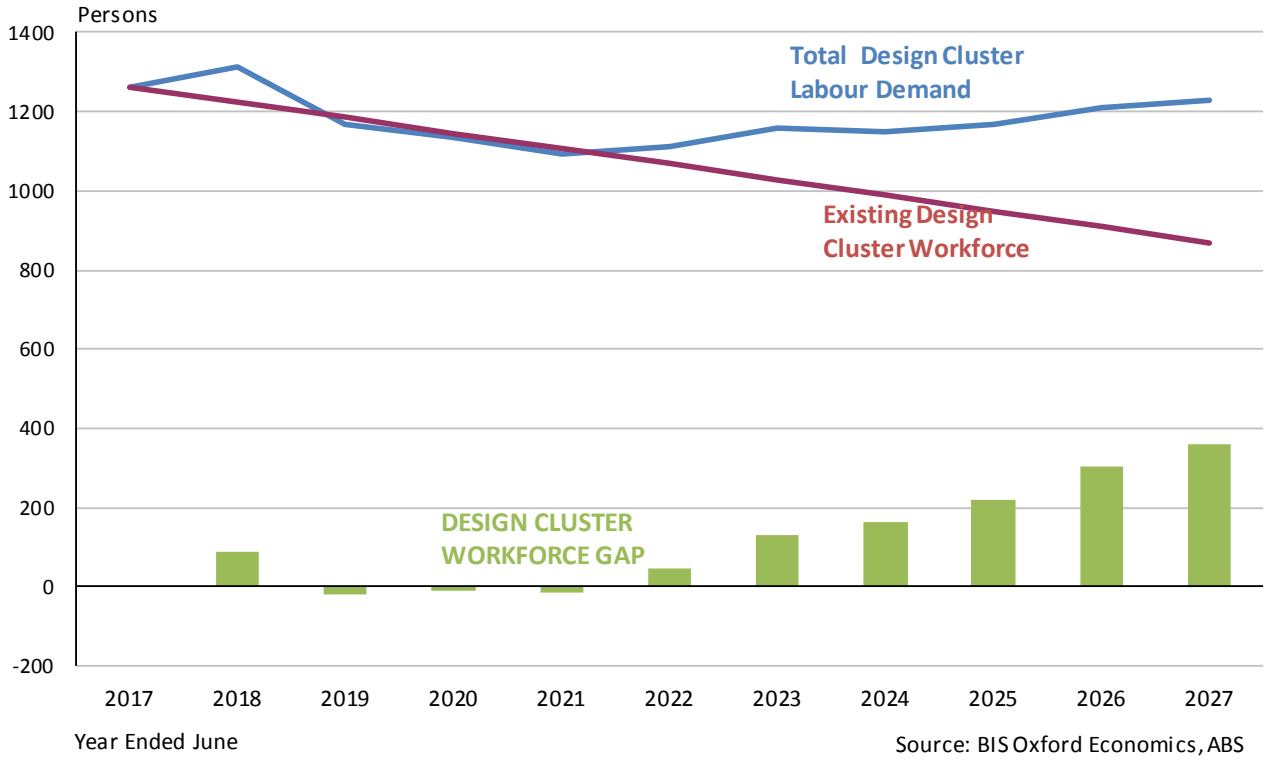
Informer and Technologist cluster employment demand is expected to rise from 1,180 to 1,225 persons in the current year before easing in later years. More detailed forecasts by occupation within these clusters is included in Appendix B.

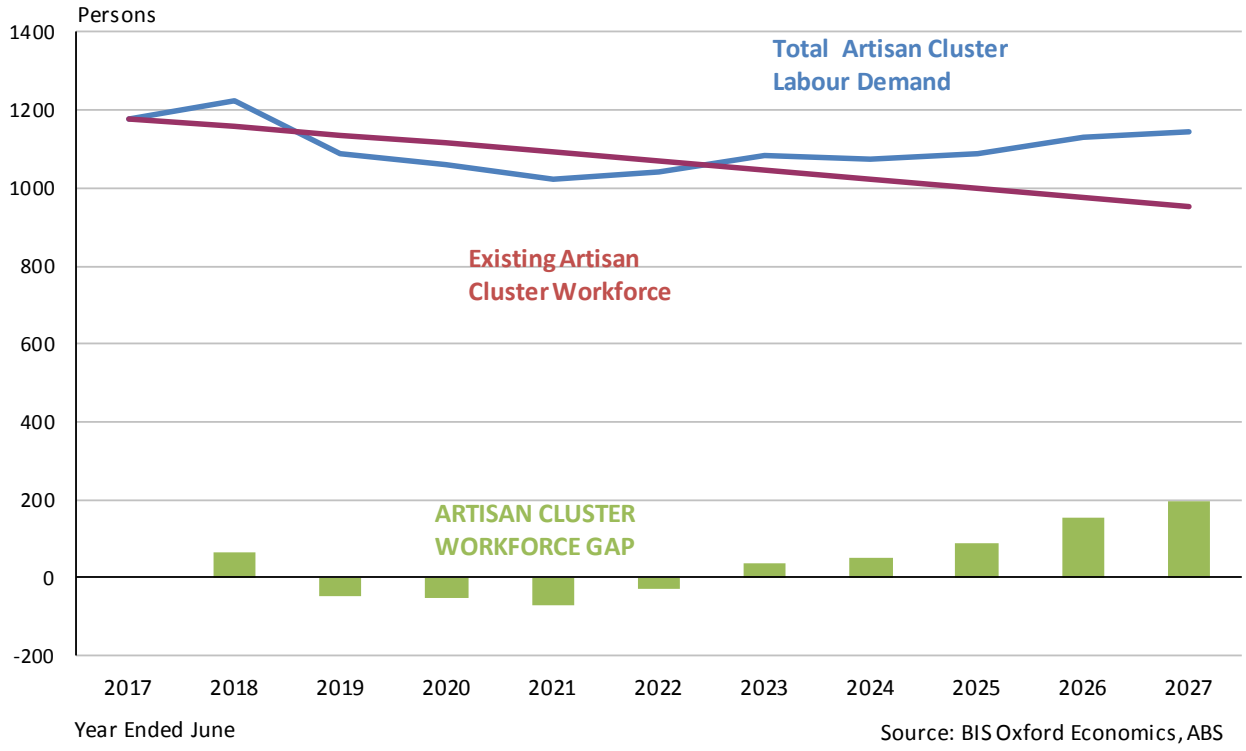
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

Given the estimated age profile of the South Australian roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster (31 per cent – higher than most other states and territories). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

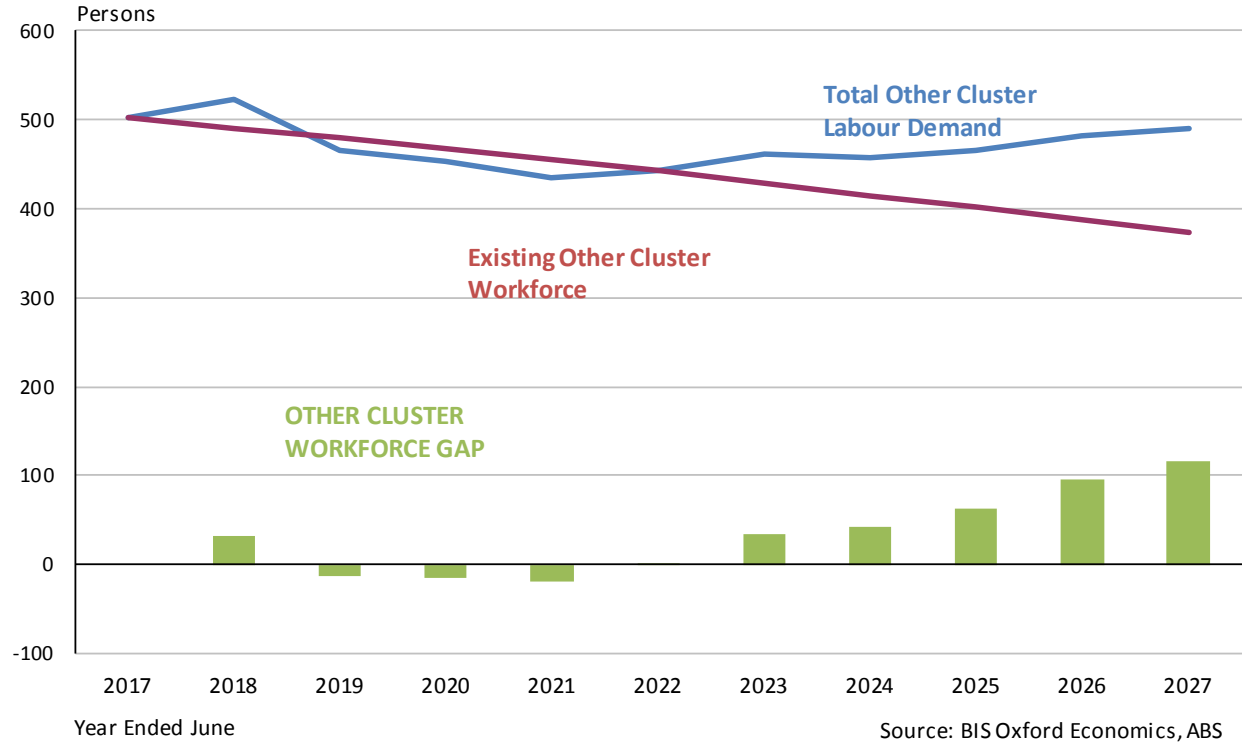
Overall, for all clusters in the South Australian roads sector, modelling indicates a rising workforce gap over 2017/18 based on rising roads activity and labour demand. However, unlike eastern states of Australia, this gap is anticipated to move negative (labour surplus) as falling levels of demand more than offset further attrition of the existing workforce. A return of a positive workforce gap is expected by 2021/22, expanding significantly in subsequent years, particularly in the Designer and Other clusters. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.5: SA Public Roads Workforce Gaps





Source: BIS Oxford Economics, ABS



Source: BIS Oxford Economics, ABS

Western Australia workforce gaps

Table 5.9: Western Australia Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**11,744**	**394**	**246**	**36,651**	**49,035**
Building Construction	5,425	142	71	7,819	13,457
Total Non-Building Construction	2,620	32	54	4,889	7,595
Road & Bridge Construction	*571*	*10*	-	*960*	*1,541*
General Trade Construction	3,699	220	121	23,943	27,983
Public Administration & Safety	**4,963**	**2,681**	**933**	**1,558**	**10,135**
Federal Government	516	293	122	-	931
State Government	1,906	1,353	465	86	3,810
Local Government	1,541	663	122	622	2,948
Other	1,000	372	224	850	2,446
Professional Services	**10,900**	**2,422**	**5,089**	**1,942**	**20,353**
Other Sectors	**26,131**	**6,397**	**5,551**	**41,737**	**79,816**
Total All Sectors	**53,798**	**11,902**	**11,845**	**81,960**	**159,505**
Total Roads Workforce	**2,287**	**638**	**309**	**1,703**	**4,937**
Public Roads Workforce	**1,627**	**540**	**111**	**1,218**	**3,497**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in Western Australia translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 1,677 designer cluster employees in 2016/17, labour demand is expected to rise to 1,827 employees through 2017/18 before generally trending down through the rest of the decade as relatively steady growth in roads activity is slightly more than offset by increasing productivity.

For artisan cluster employees, modelled labour demand is expected to rise from 1,255 to 1,367 employees over 2017/18 before similarly easing later on. Even though demand is anticipated to weaken below 2016/17 levels, it is still expected to be significant – and stabilising again by the end of the forecast period.

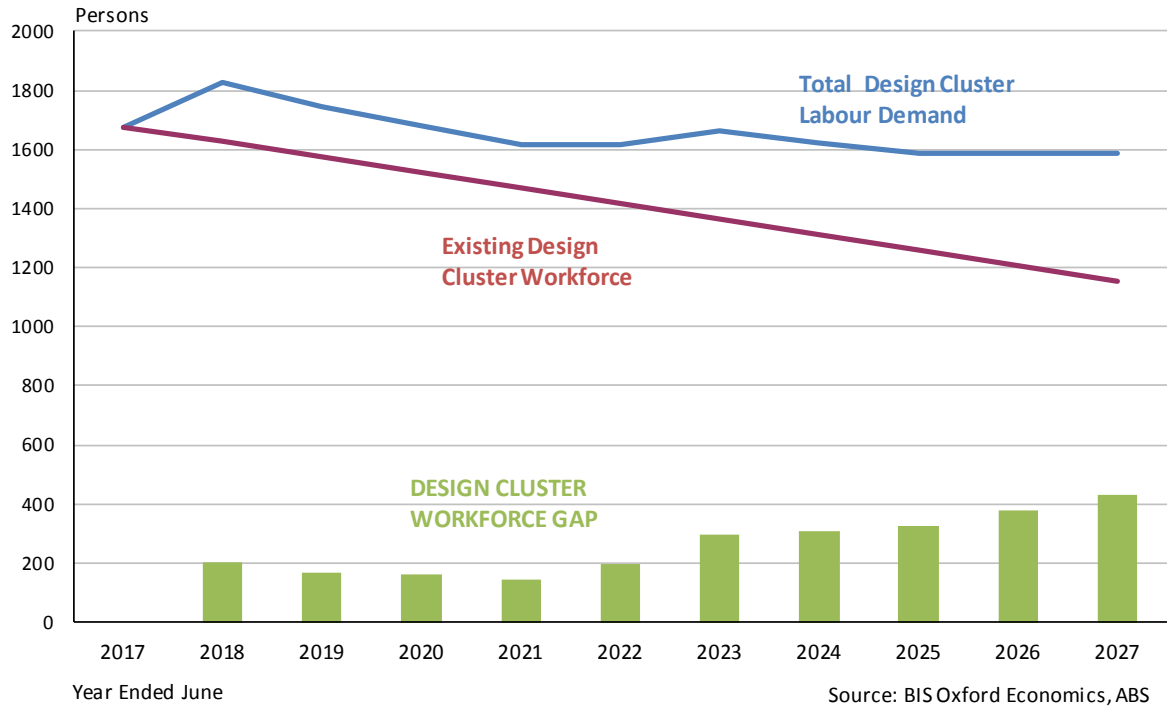
Informer and Technologist cluster employment is expected to rise from 671 to 731 persons in the current year before easing back in later years, but remaining above current levels of demand until the early 2020s.

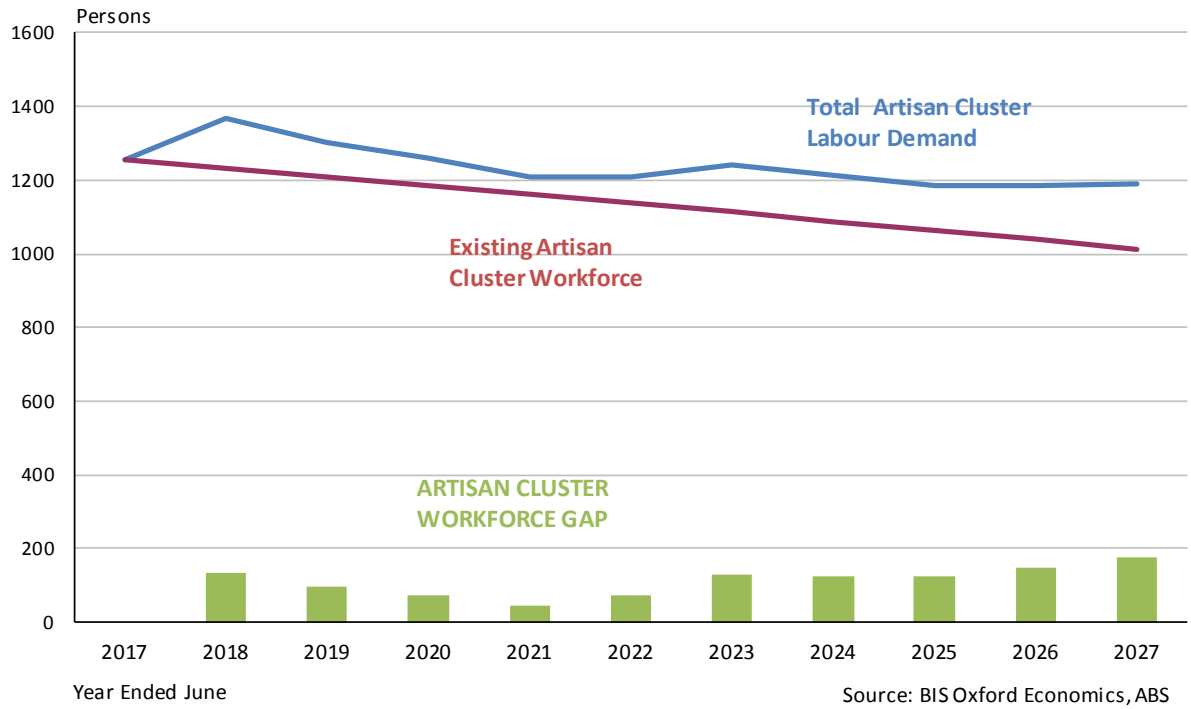
More detailed forecasts by occupation within these clusters is included in Appendix B.

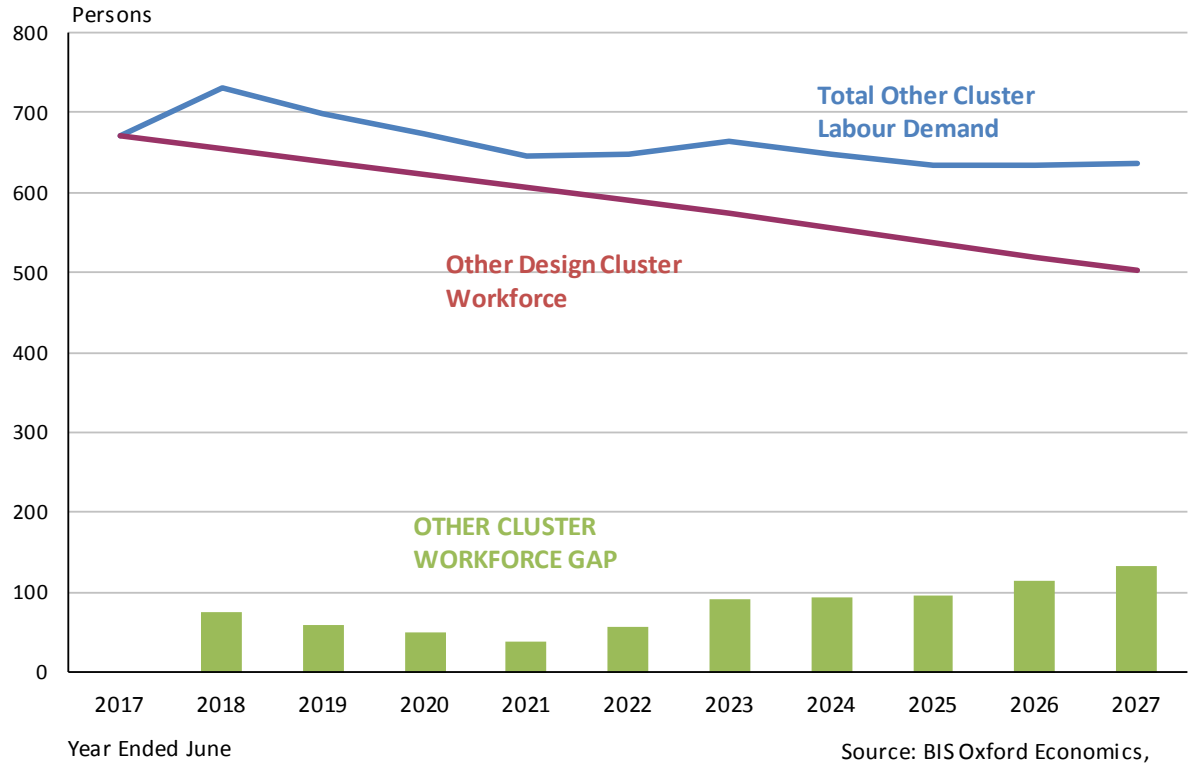
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

Given the estimated age profile of the Western Australian roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 26 per cent over the next ten years, with the highest concentration in the design cluster (31 per cent – higher than most other states and territories). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Figure 5.6: WA Public Roads Workforce Gaps






Persons
800
700
600
500
400
300
200
100
0
Total Other Cluster Labour Demand
Other Design Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics,

Tasmania workforce gaps

Table 5.10: Tasmania Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**997**	**22**	**6**	**5,810**	**6,835**
Building Construction	418	11	-	1,485	1,914
Total Non-Building Construction	217	-	-	592	809
Road & Bridge Construction	*105*	-	-	*373*	*478*
General Trade Construction	362	11	6	3,733	4,112
Public Administration & Safety	**1,043**	**601**	**212**	**305**	**2,161**
Federal Government	179	74	40	-	293
State Government	387	344	122	14	867
Local Government	354	117	24	229	724
Other	123	66	26	62	277
Professional Services	**1,236**	**316**	**653**	**195**	**2,400**
Other Sectors	**2,415**	**914**	**708**	**5,564**	**9,601**
Total All Sectors	**5,719**	**1,873**	**1,603**	**11,876**	**21,071**
Total Roads Workforce	**540**	**125**	**88**	**647**	**1,399**
Public Roads Workforce	**386**	**93**	**21**	**520**	**1,019**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in Tasmania translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 422 designer cluster employees in 2016/17, labour demand is expected to rise to 446 employees through 2017/18 before falling in line with weakening roads activity. Design cluster demand will continue to decline, though at a more gradual pace, as stabilising roads activity is more than offset by further productivity improvements.

For artisan cluster employees, modelled labour demand is expected to rise from 568 to 601 employees over 2017/18 before similarly easing later on – and below 2016/17 levels of demand.

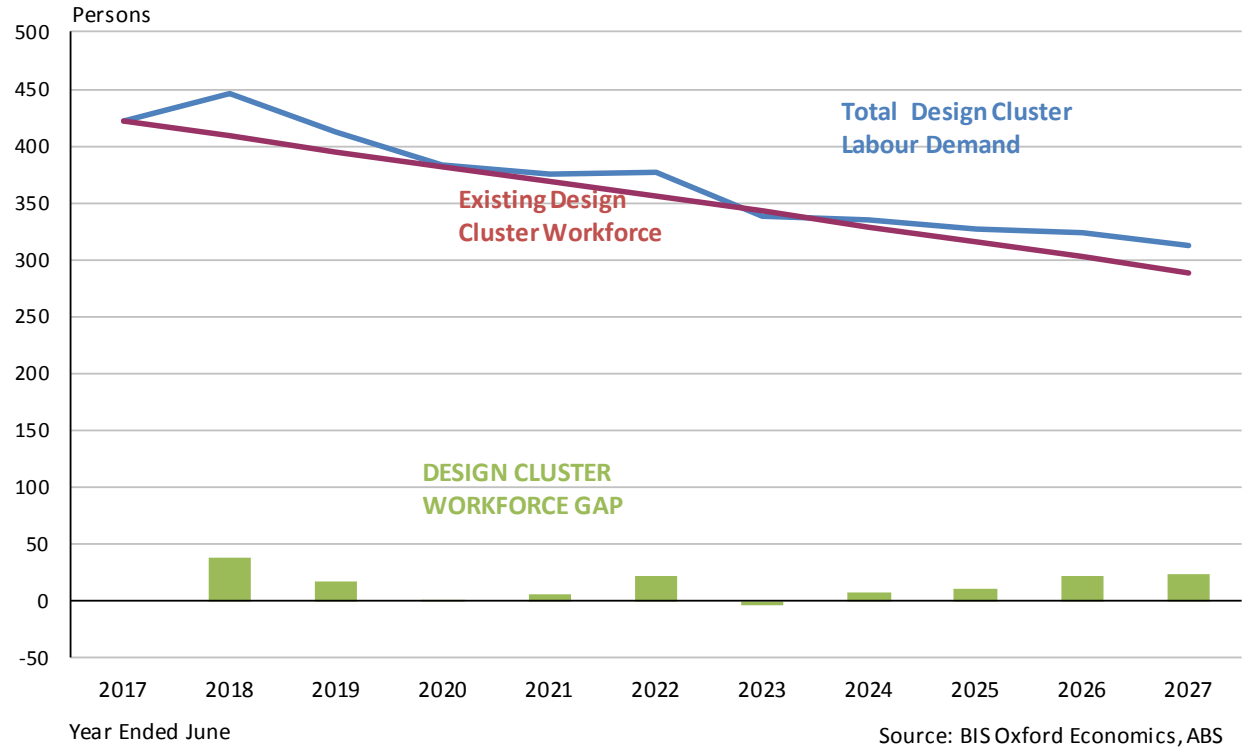
Informer and Technology cluster employment demand is expected to rise from 124 to 131 persons before easing in subsequent years. More detailed forecasts by occupation within these clusters is included in the Excel datafile accompanying this report.

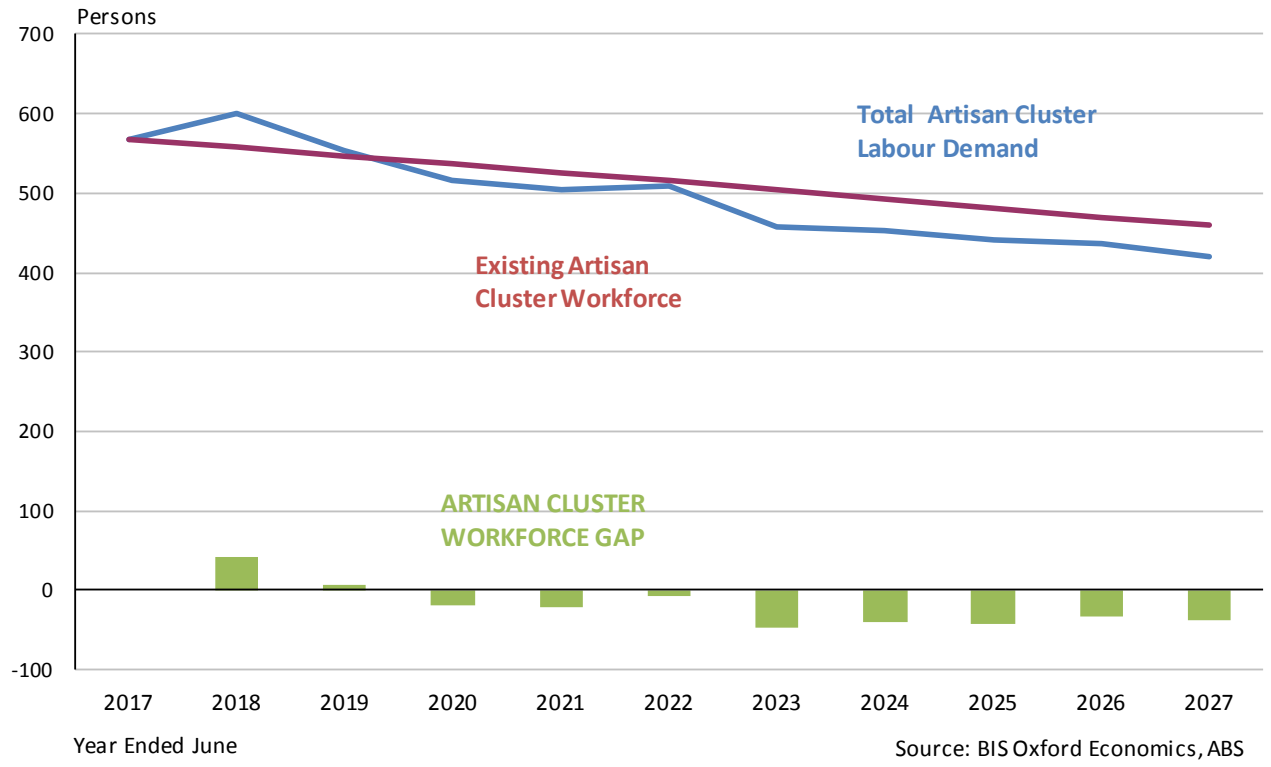
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

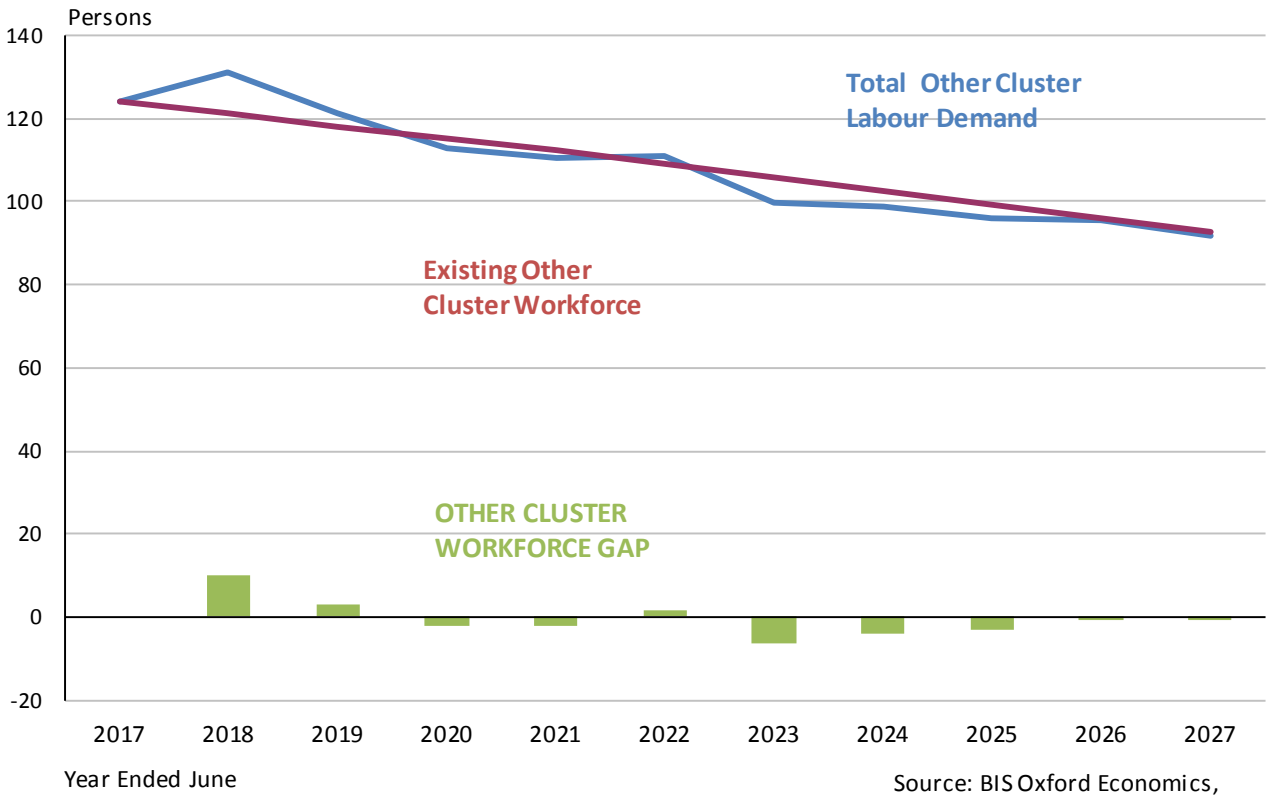
Given the estimated age profile of the Tasmanian roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster (32 per cent – the highest of all Australian states and territories). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Overall, for both the Designer and Artisan clusters in the Tasmanian roads sector, modelling indicates a significantly rising workforce gap over 2017/18 based on rising roads activity and labour demand. However, this gap is anticipated to narrow – and then fall negative (surplus) –given further attrition of the existing workforce which magnifies the impact of weakening labour demand. This situation will not last long for the Design cluster workforce gap which is expected to turn positive again by 2023/24, although a negative workforce gap (surplus) in the Artisan cluster is expected to be sustained. By contrast, following a workforce gap in the near term for the Informer and technologist cluster, this is expected to move back to balance, more or less, during the remainder of the forecast period. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.7: TAS Public Roads Workforce Gaps




Persons
700
600
500
400
300
200
100
0
-100
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
140
120
100
80
60
40
20
0
-20
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics,

Northern Territory workforce gaps

Table 5.11: Northern Territory Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**1,142**	**13**	**3**	**3,536**	**4,694**
Building Construction	422	3	-	745	1,170
Total Non-Building Construction	335	3	3	807	1,148
Road & Bridge Construction	*64*	-	-	*105*	*169*
General Trade Construction	385	7	-	1,984	2,376
Public Administration & Safety	**1,149**	**403**	**164**	**489**	**2,205**
Federal Government	119	36	-	-	155
State Government	659	256	118	13	1,046
Local Government	93	14	3	73	183
Other	278	97	43	403	821
Professional Services	**815**	**113**	**239**	**756**	**1,923**
Other Sectors	**1,592**	**345**	**235**	**2,659**	**4,831**
Total All Sectors	**4,741**	**888**	**636**	**7,495**	**13,760**
Total Roads Workforce	**188**	**20**	**14**	**217**	**440**
Public Roads Workforce	**135**	**16**	**5**	**148**	**304**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in the Northern Territory translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 138 designer cluster employees in 2016/17, labour demand is expected to rise to 152 employees through 2017/18 before falling in line with weakening roads activity compared to recent years. Design cluster demand will stabilise at around 115 persons from 2021/22.

For artisan cluster employees, modelled labour demand is expected to rise from 152 to 167 employees over 2017/18 before similarly easing later on.

Informer and Technologist labour demand is anticipated to rise from 22 to 24 persons in the current year, and generally stabilising at around 18-19 persons in the longer term.

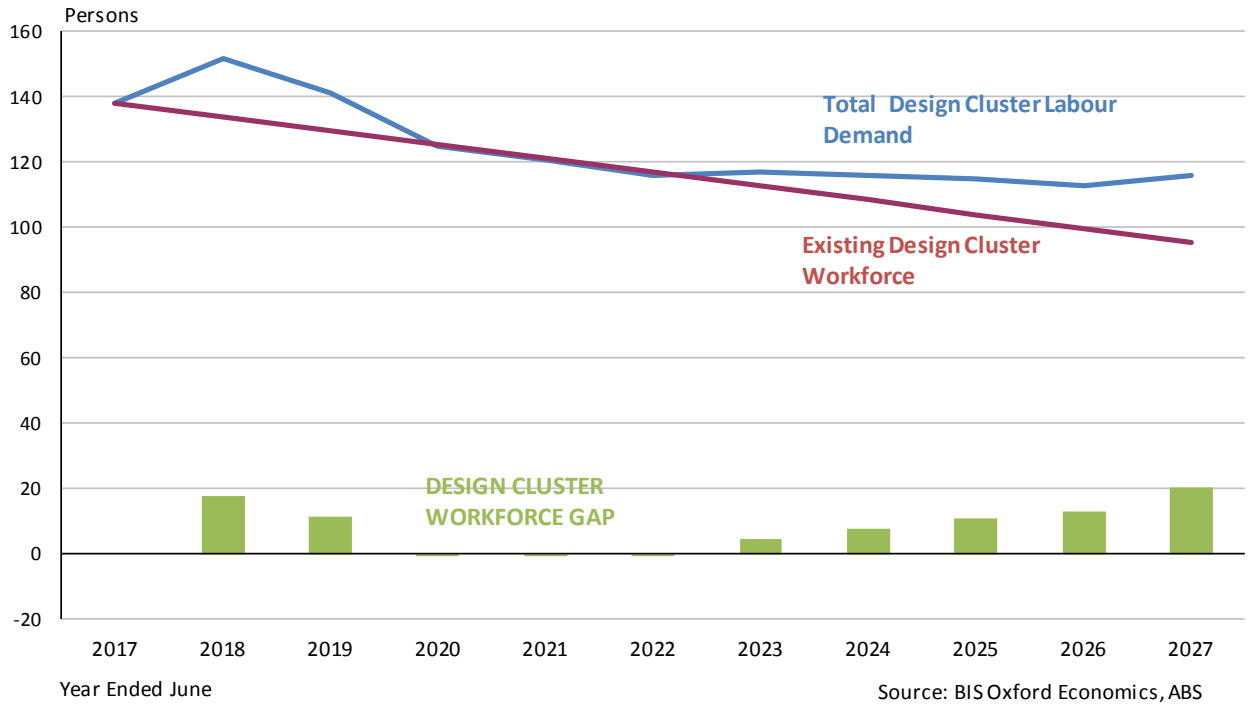
More detailed forecasts by occupation within these clusters is included in Appendix B.

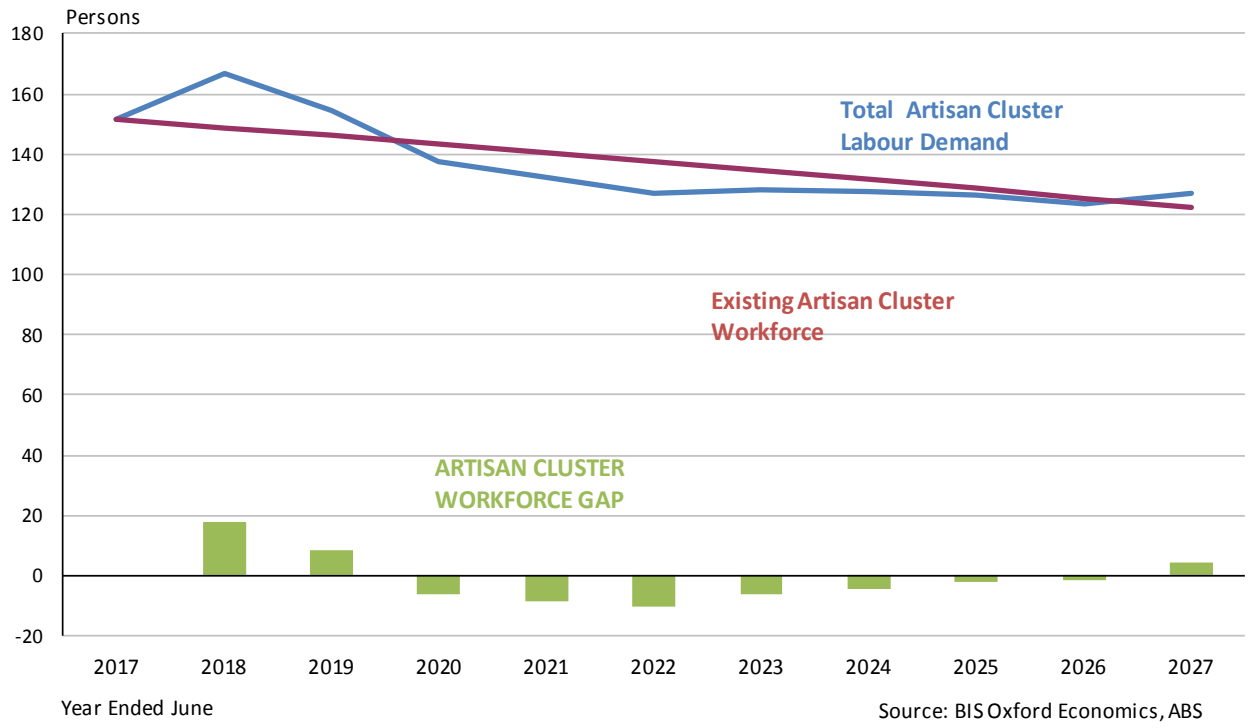
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

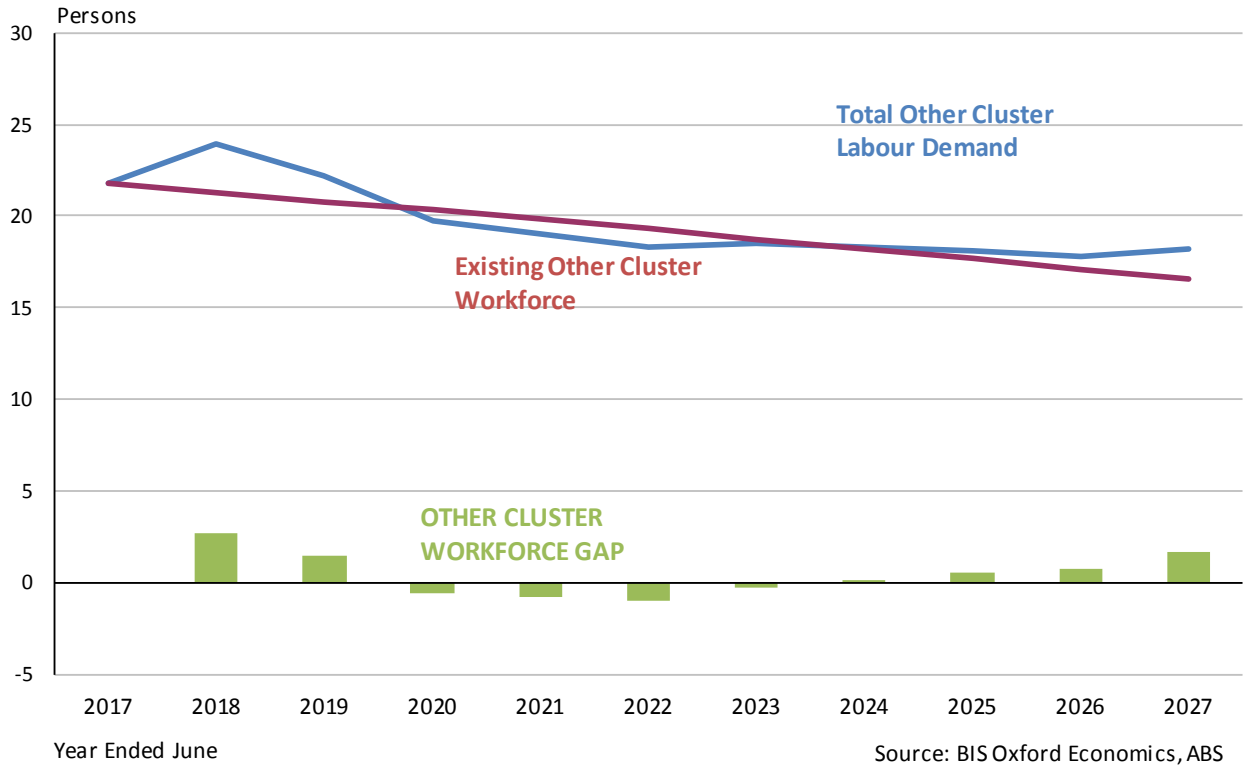
Given the estimated age profile of the Northern Territory roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the design cluster (over 31 per cent – almost the highest of all Australian states and territories). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Overall, for all clusters in the Northern Territory roads sector, modelling indicates a rising workforce gap over 2017/18 and 2018/19 based on rising roads activity and labour demand. However, this gap is anticipated to narrow – and then fall negative (surplus) - given further attrition of the existing workforce which magnifies the impact of weakening labour demand. Rising labour demand and accelerating workforce attrition over the second five year period is expected to see the workforce gap become positive once again, exceeding the 2017/18 peak by 2026/27, with most pressure evident in the Designer cluster given rapid attrition of the existing workforce. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.8: NT Public Roads Workforce Gaps




Persons
180
160
140
120
100
80
60
40
20
0
-20
Total Artisan Cluster Labour Demand
Existing Artisan Cluster Workforce
ARTISAN CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS


Persons
30
25
20
15
10
5
0
-5
Total Other Cluster Labour Demand
Existing Other Cluster Workforce
OTHER CLUSTER WORKFORCE GAP
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
Year Ended June
Source: BIS Oxford Economics, ABS

Australian Capital Territory workforce gaps

Table 5.12: Australian Capital Territory Employment by Skill Cluster as at August 2016

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**1,330**	**18**	**3**	**4,066**	**5,417**
Building Construction	821	13	3	1,081	1,918
Total Non-Building Construction	107	-	-	133	240
Road & Bridge Construction	*25*	-	-	*50*	*75*
General Trade Construction	402	5	-	2,852	3,259
Public Administration & Safety	**5,642**	**6,104**	**4,095**	**292**	**16,133**
Federal Government	3,600	4,583	3,093	52	11,328
State Government	619	506	169	24	1,318
Local Government	37	11	4	-	52
Other	1,386	1,004	829	216	3,435
Professional Services	**1,562**	**1,733**	**3,106**	**159**	**6,560**
Other Sectors	**2,171**	**1,430**	**1,781**	**1,510**	**6,892**
Total All Sectors	**10,731**	**9,290**	**9,010**	**6,022**	**35,053**
Total Roads Workforce	**192**	**119**	**131**	**158**	**600**
Public Roads Workforce	**28**	**18**	**2**	**48**	**96**

Source: BIS Oxford Economics, ABS Data

BIS Oxford Economics' outlook for road and road bridge activity in ACT translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 22 designer cluster employees in 2016/17, labour demand is expected to fall to 15 employees through to 2018/19 before rising very gradually in line with an increasing roads task.

For artisan cluster employees, modelled labour demand is expected to fall from 39 to 27 employees over the next two years before stabilising and then rising to 35 persons by 2023/24.

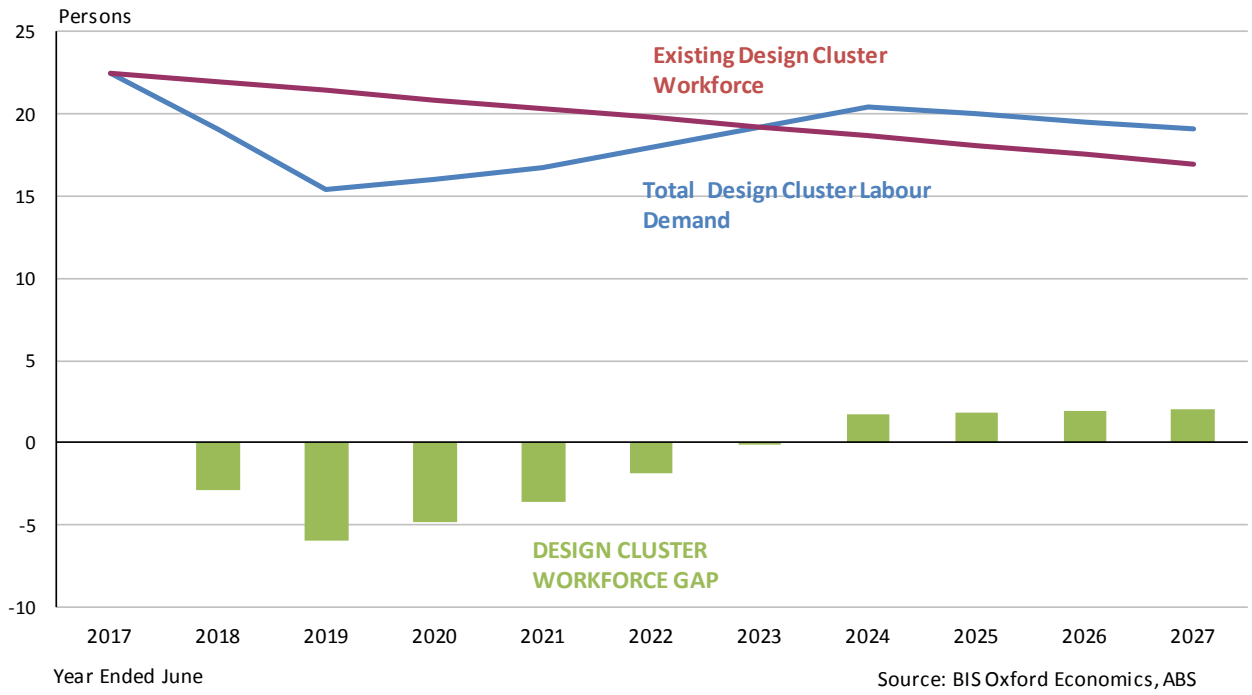
Informer and Technologist cluster labour demand is expected to fall from 16 to 11 employees over the next two years, before rising back to around 14 persons through the forecast period.

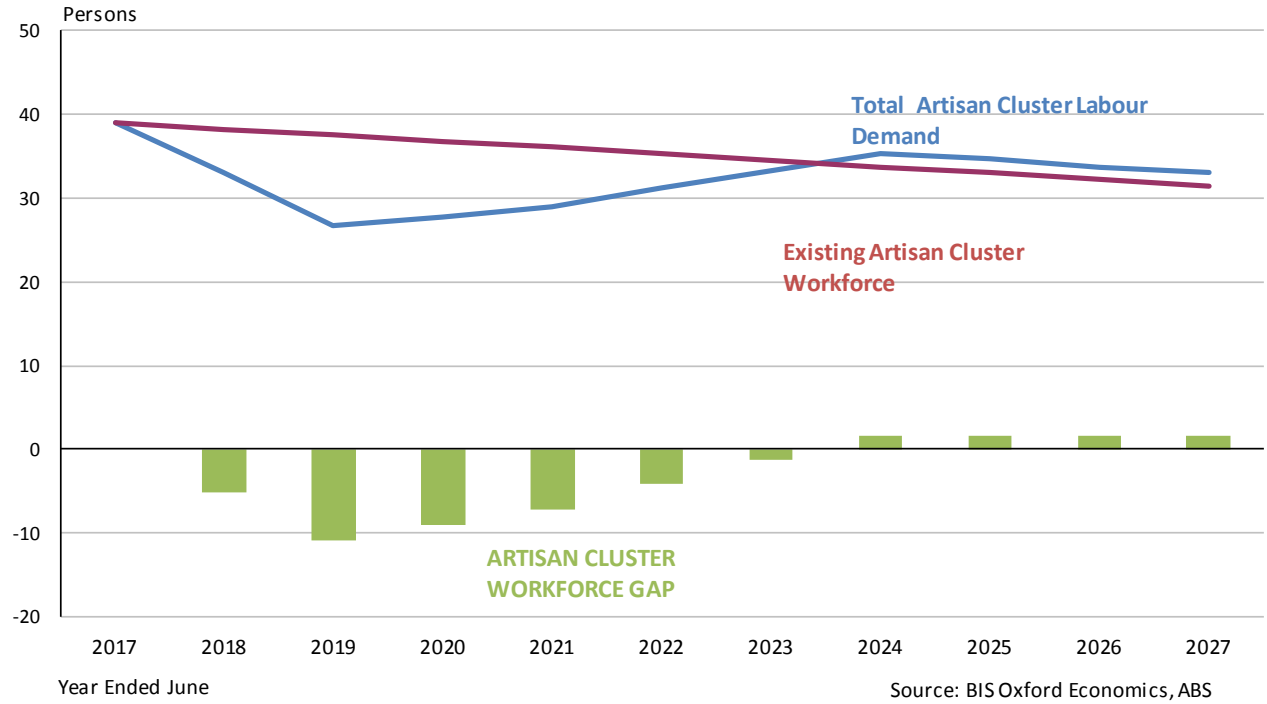
More detailed forecasts by occupation within these clusters is included in Appendix B.

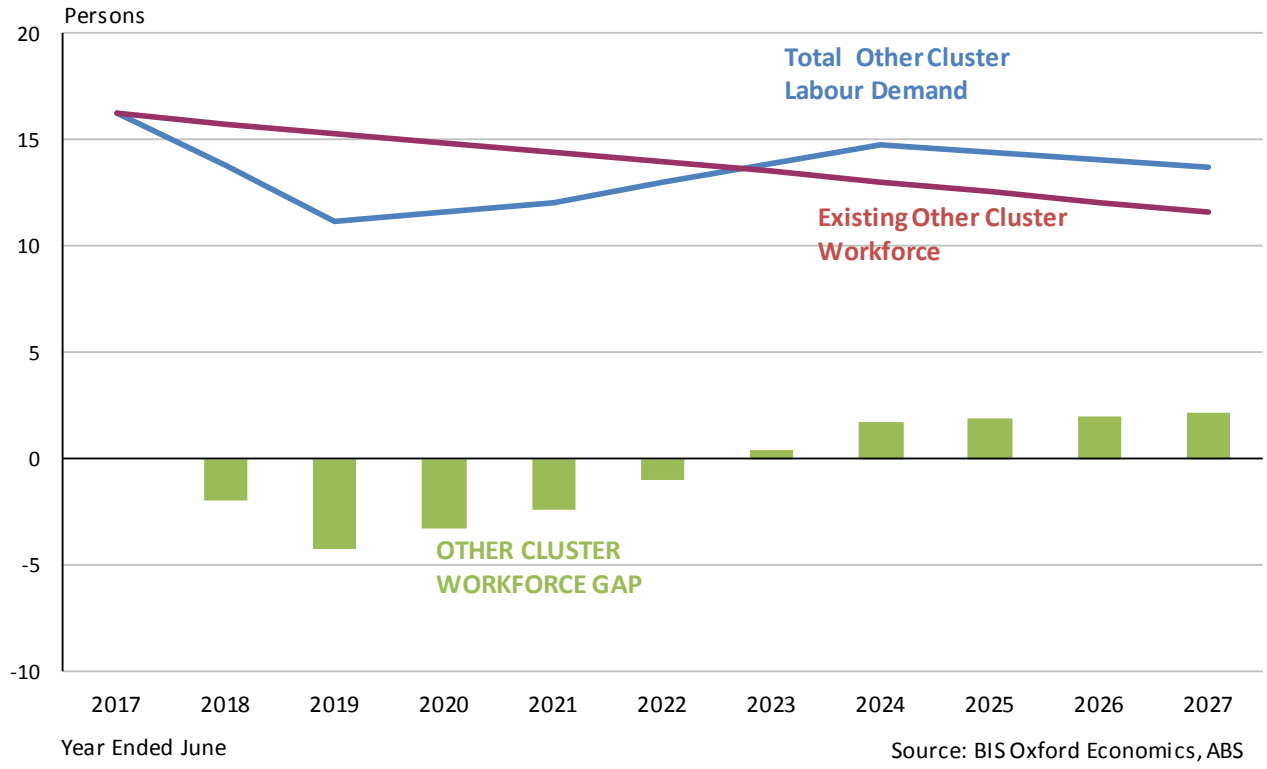
The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce 'base', primarily through retirement and death (but also through people leaving the workforce for other reasons).

Given the estimated age profile of the Australian Capital Territory roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 23 per cent over the next ten years, with the highest concentration in the other cluster (25 per cent – almost the highest of all Australian states and territories). Even so, the ACT has one of the smallest attrition rates for the existing workforce in Australia, reducing future demand requirements relative to other states. The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

Figure 5.9: ACT Public Roads Workforce Gaps







5.2.2 New Zealand workforce projections

Table 5.13: New Zealand Total Roads Employment (2016/17 estimate based on 2013 Census)

Sector	Design Skills	Informer Skills	Technological Skills	Artisan Skills	Total
Total Construction	**14,961**	**536**	**1,029**	**59,890**	**76,416**
Building Construction	4,712	85	141	15,705	20,642
Total Non-Building Construction & Construction Services	10,240	448	887	44,183	55,759
Road & Bridge Construction	*2,090*	*42*	*97*	*3,830*	*6,061*
Public Administration & Safety	**7,508**	**6,893**	**2,884**	**1,229**	**18,514**
Federal Government	1,516	3,492	1,308	43	6,360
Local Government	2,723	1,956	728	321	5,728
Other	2,018	1,445	848	865	5,175
Professional Services	**16,574**	**7,840**	**19,182**	**2,728**	**46,324**
Other Sectors	**31,472**	**15,548**	**19,927**	**43,846**	**110,793**
Total All Sectors	**70,515**	**30,817**	**43,022**	**107,693**	**252,047**
Total Roads Workforce	**5,369**	**1,832**	**1,736**	**3,906**	**12,844**
Public Roads Workforce	**3,545**	**1,153**	**270**	**2,906**	**7,874**

Source: BIS Oxford Economics, Stats NZ Data

The estimated base year New Zealand roading workforce – based on an extrapolation of the most recent Census data for New Zealand – is illustrated in the figure below. A more detailed breakdown of the base year workforce by occupation within each cluster is provided in Appendix B.

Modelling of future roads workforce demand for this quantitative analysis is focused on the Designer, Artisans and Other (Information and Technology) skills clusters. Responses from earlier industry surveys and interviews suggested that measuring changes in demand for the latter (non-traditional) skills sets will be extremely difficult. We have approached the problem in the base case by assuming that the coefficients for the base year of 2017 apply over the forecast horizon.

While we are confident that the level of Artisan and Design cluster demand is directly related to construction and maintenance activities, we are not so sure that the Informer and Technological skills clusters have such a close relationship – and this was borne out in industry interviews. In the hypothetical base case presented here however (which is more akin to previous workforce capability analyses undertaken for Austroads) there is assumed to be little technological change (and construction and maintenance activities do not vary dramatically) and so we feel that this simplifying assumption does not unduly affect the forecasts of demand for Informer and Technology cluster demand. However, it is possible to indicate whether demand for these types of skills will be higher or lower under different technological/funding scenarios, and this modelling is presented in Section 3 at the national level. From industry feedback, it will be important that roads agencies (or the broader industry it can contract from) have at least some of these skills across all scenarios, but more or less may be in demand based on the world that eventuates. Ultimately, a mix of skills will be required.

The baseline scenario used here is described as “The Business as (Almost) Usual” scenario. This provides a baseline from which the impacts of other scenarios can be modelled. Under this scenario there is only very gradual development in new technologies which take much longer to disrupt the roads transport industry. Agencies will still need to plan for technological change, but these changes do not create significant impacts over the next two decades. With little actual change in transport technologies ‘on the road’ within the next two decades, there are expected to be only minor changes to roads funding through existing regimes and therefore it is assumed that the current agency roles to delivery, asset management and regulation are largely maintained. As a consequence, ‘baseline’ road construction and maintenance forecasts are used by BIS Oxford Economics to model future demand for skills in the Design and Artisan clusters, and the shares of roads agency workforces between Designer, Artisan and ‘Other’ skills clusters are steady.

New Zealand workforce gaps

BIS Oxford Economics’ outlook for road and road bridge activity in New Zealand translates into demand for labour as shown as the following figures (blue lines).

From an estimate of 3,539 designer cluster employees in 2016/07, labour demand is expected to move higher as increasing labour productivity (1.5 per cent per annum) under the baseline scenario fails to keep pace with mild increases in roads activity. By 2026/2, however, designer cluster labour demand is expected to be similar to 2016/17.

For artisan cluster employees, modelled labour demand is expected to rise from 2,880 to just under 3,000 employees across the next few years, before easing slightly thereafter given growth in labour productivity.

Informer and Technologist employment demand is expected to be higher, particularly over the next five years, rising from 1,411 persons to 1,457 persons before easing in subsequent years.

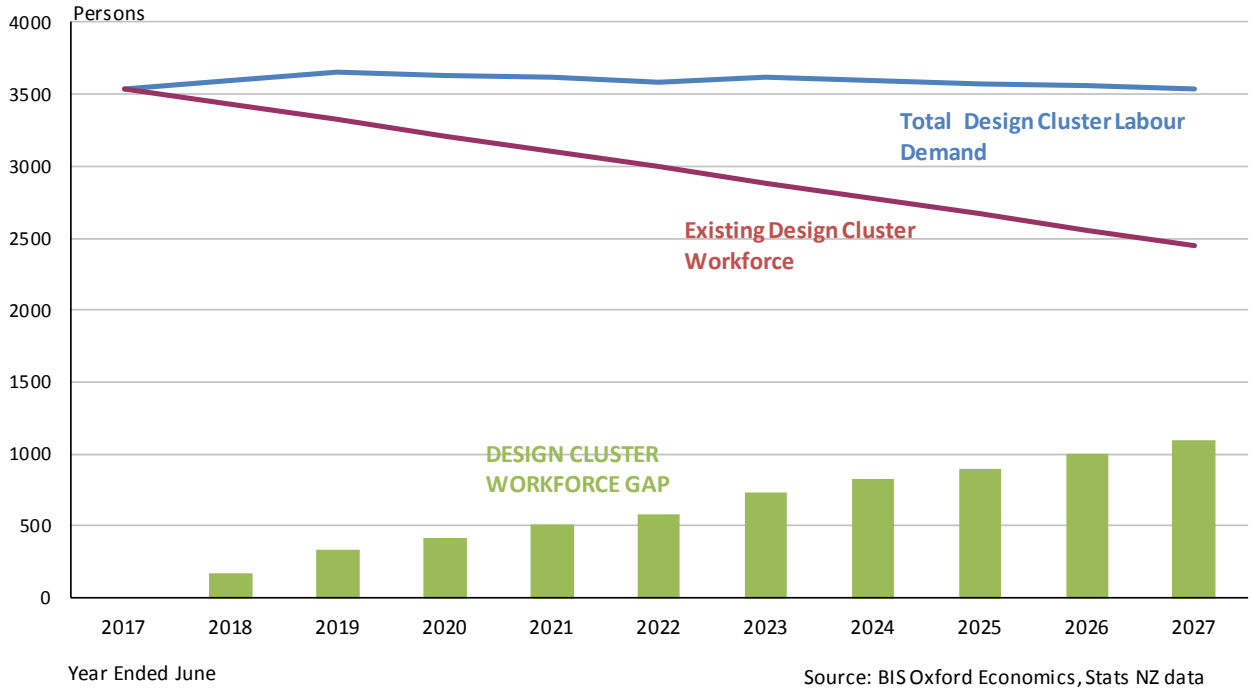
More detailed forecasts by occupation within these clusters is included in Appendix B.

The total skilled roads workforce requirement to meet future roads activity is inevitably higher than the labour demand generated by the model given attrition of the existing workforce ‘base’, primarily through retirement and death (and through people leaving the workforce for other reasons).

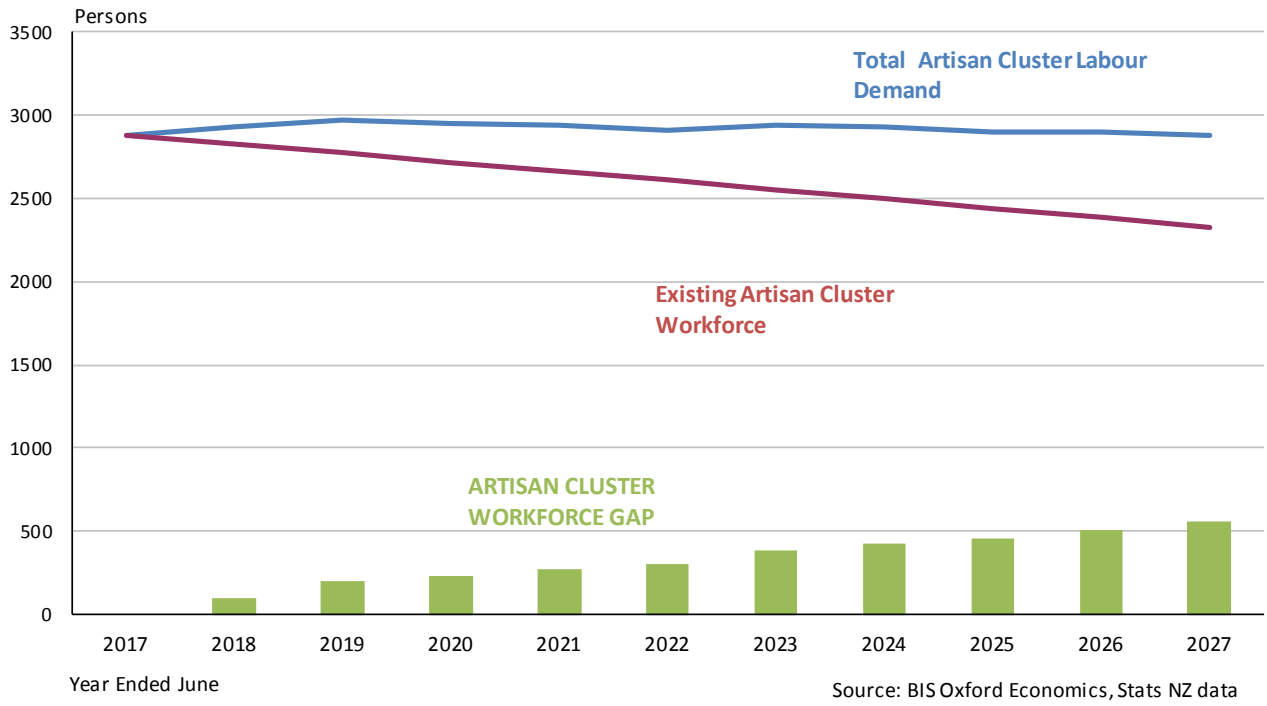
Given the estimated age profile of the New Zealand roads workforce — and the assumed likelihood of retirement and death in each age group — we estimate that the current workforce will shrink by around 25 per cent over the next ten years, with the highest concentration in the designer cluster (31 per cent). The difference between the (declining) existing workforce and total labour demand is the workforce gap. The workforce gap will need to be met by new supply (e.g. graduates, migration, or absorption from other industries) if forecast levels of end use road sector activity are to be achieved.

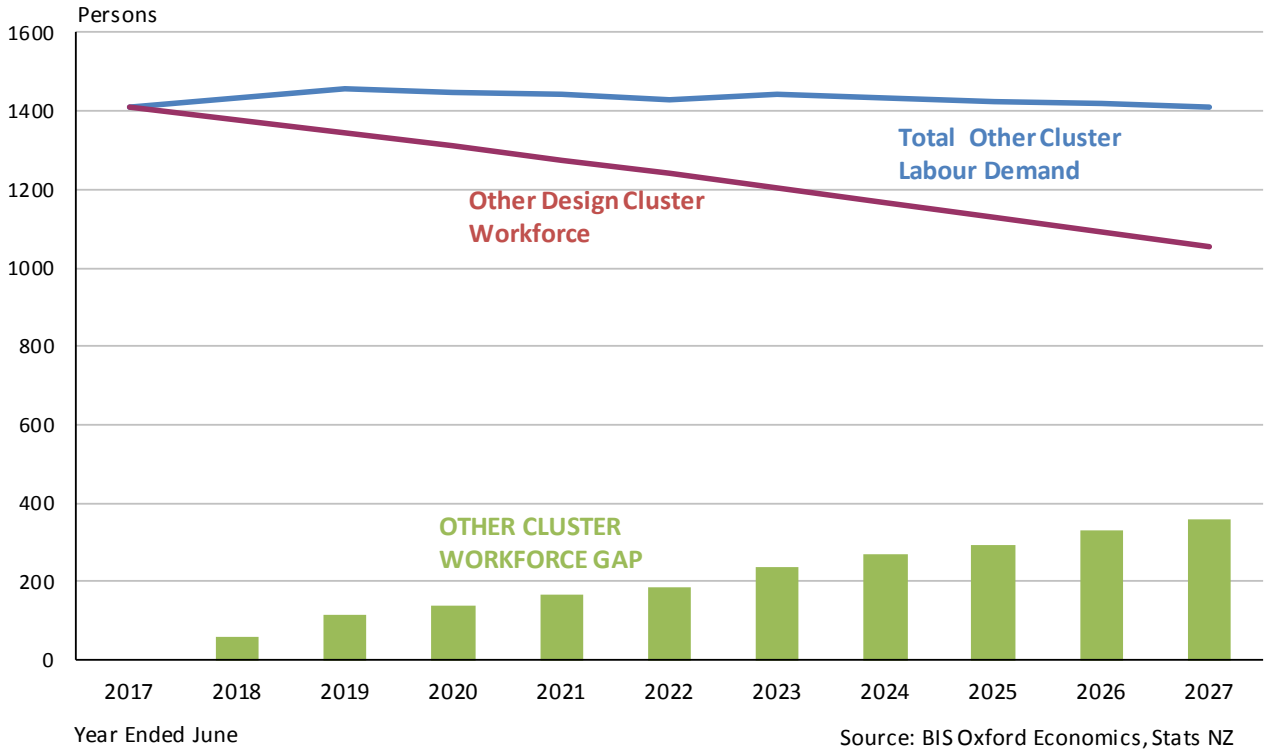
Overall, for all clusters in the New Zealand roads sector, modelling indicates a growing workforce gap over time as attrition of the existing workforce is greater than the (falling) labour demand over time. For the Designer cluster, the workforce gap is expected to rise to 410 employees by 2026/27, whilst for the Artisan cluster, the workforce gap is modelled to rise to 556 persons by 2026/27. A gap of 360 persons is anticipated in the Informer and Technologist cluster. A more detailed breakdown of attrition and the workforce gap by occupation within each cluster is provided in Appendix B.

Figure 5.10: New Zealand Public Roads Workforce Gaps



Source: BIS Oxford Economics, Stats NZ data





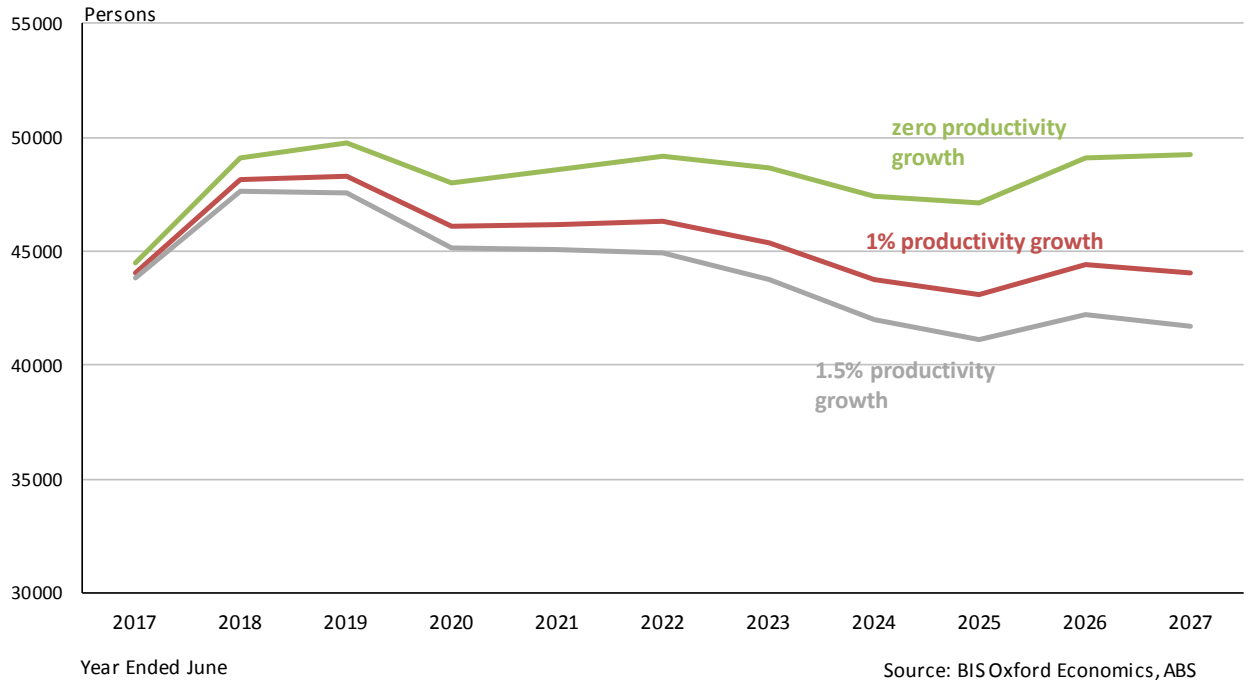
5.3 Modelling Results under Alternative Scenarios

The baseline scenario modelling in the previous Section assumes that the usage coefficients for each of the skills clusters are uniformly impacted by annual productivity growth of 1.5 per cent and that there is no change in the relative share of skills used across maintenance, construction and network activities over the forecast horizon.

The Australian construction sector exceeded labour productivity growth of 1.5 per cent between the peaks of the last two complete growth cycles (1998-99 and 2011-12), but productivity growth in New Zealand's construction sector has historically fallen short of 1 per cent. The rate of productivity growth achieved will play an important role in determining the size of the workforce required to meet a given volume of work and the extent of any workforce gap over the forecast horizon.

Chart 3.1 shows projected total demand for labour in the public sector across all clusters under the base case 1.5 per cent productivity growth assumption, under a 1 per cent productivity growth assumption and under a zero productivity growth assumption. If productivity growth averaged 1 per cent over the forecast horizon an additional 1,700 workers would be required annually in the each of the five years to 2026-27 compared to the baseline scenario.

Figure 5.11: Australian Public Sector Roads Labour Demand - Productivity Scenarios



In addition to the baseline scenario we have considered two alternative scenarios; one where productivity growth slows and a slower adoption of new technologies results in higher construction and maintenance activity and a corresponding shift in the workforce shares towards artisans and designers; and one which sees a higher productivity growth outcome underpinned by a faster than anticipated uptake of new technologies, resulting in a reduced requirement for new roads to be built and an accompanying reduction in maintenance activity demand. As a result, there is projected to be a shift in demand from artisans and designers involved in constructing roads to analysts, planners and information technology technicians involved in overseeing the efficient running of a more technology-intensive network.

These two scenarios are described in the Task 3 report and in the proceeding section as 'Constrained World' and 'Technology and Response' respectively.

Under the Constrained World scenario it is assumed that compared to the baseline scenario:

- Construction activity is 5 per cent higher over the five years to 2026-27
- Maintenance activity is 5 per cent higher over the five years to 2026-27
- Productivity growth declines year on year from 1.5 per cent in 2016-17 to 1 per cent in 2026-27
- The share of the design and skills clusters in the total workforce both increase by 1 per cent between 2016-17 and 2026-27 and the share of the other skills cluster falls by 5 per cent.

Under the Technology and Response scenario it is assumed that compared to the baseline scenario:

- Construction activity is 5 per cent lower over the five years to 2026-27
- Maintenance activity is 5 per cent lower over the five years to 2026-27
- Productivity growth increases year on year from 1.5 per cent in 2016-17 to 2.0 per cent in 2026-27
- The share of the design and skills clusters in the total workforce both fall by 2 per cent between 2016-17 and 2026-27 and the share of the other skills cluster increases by 10 per cent.

The charts below show the impact that these assumptions would have on demand for each skills cluster.

Figure 5.12: Australia Public Sector Design Cluster Employment - Scenarios

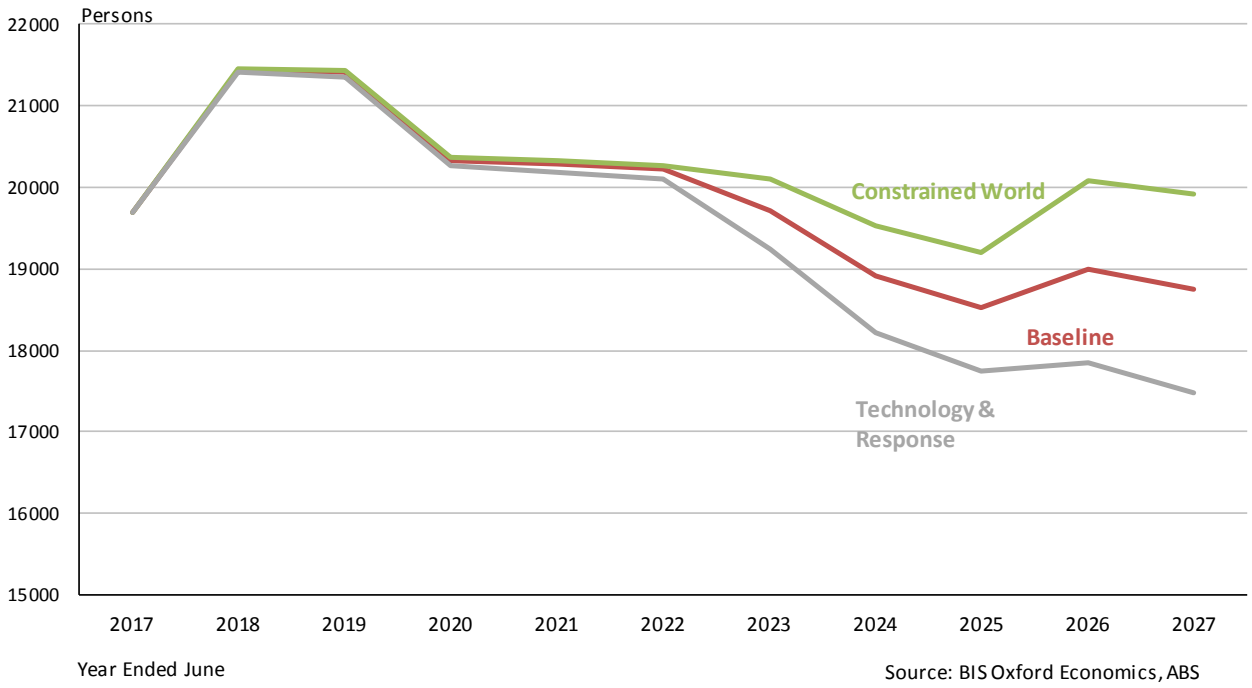


Figure 5.13: Australia Public Sector Artisan Cluster Employment - Scenarios

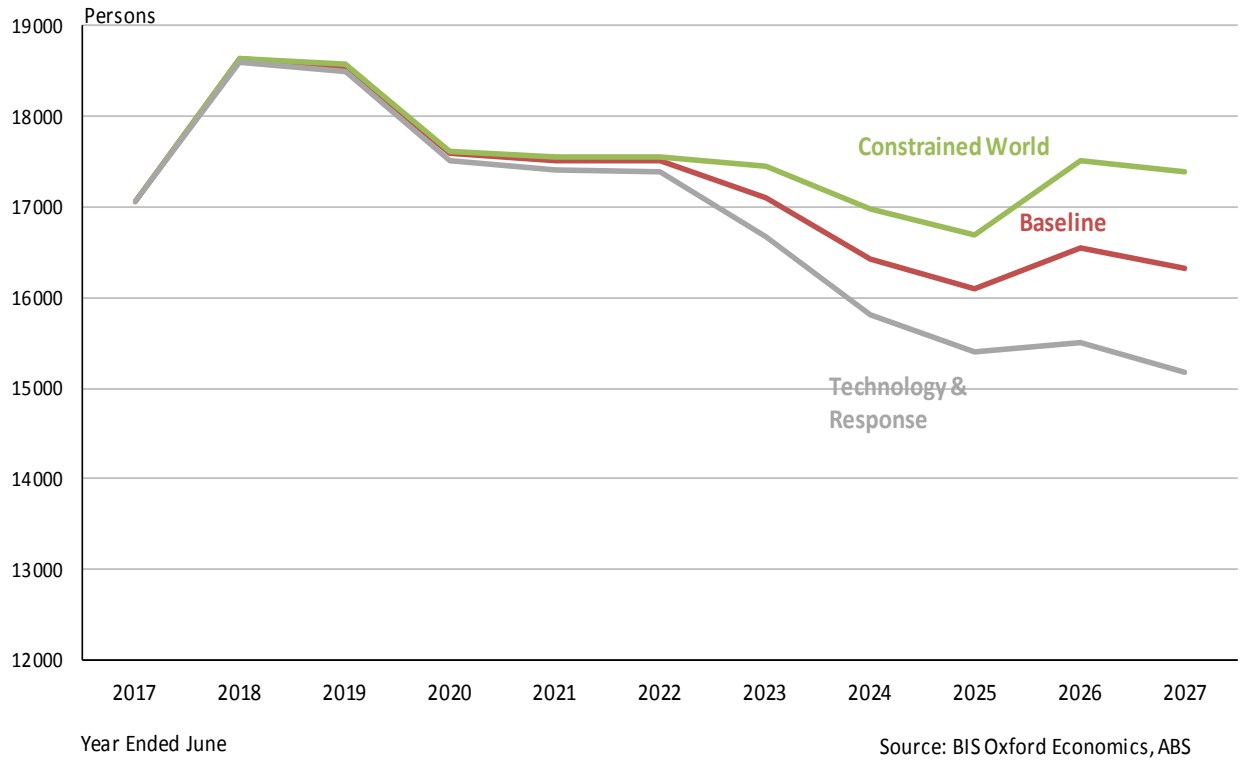
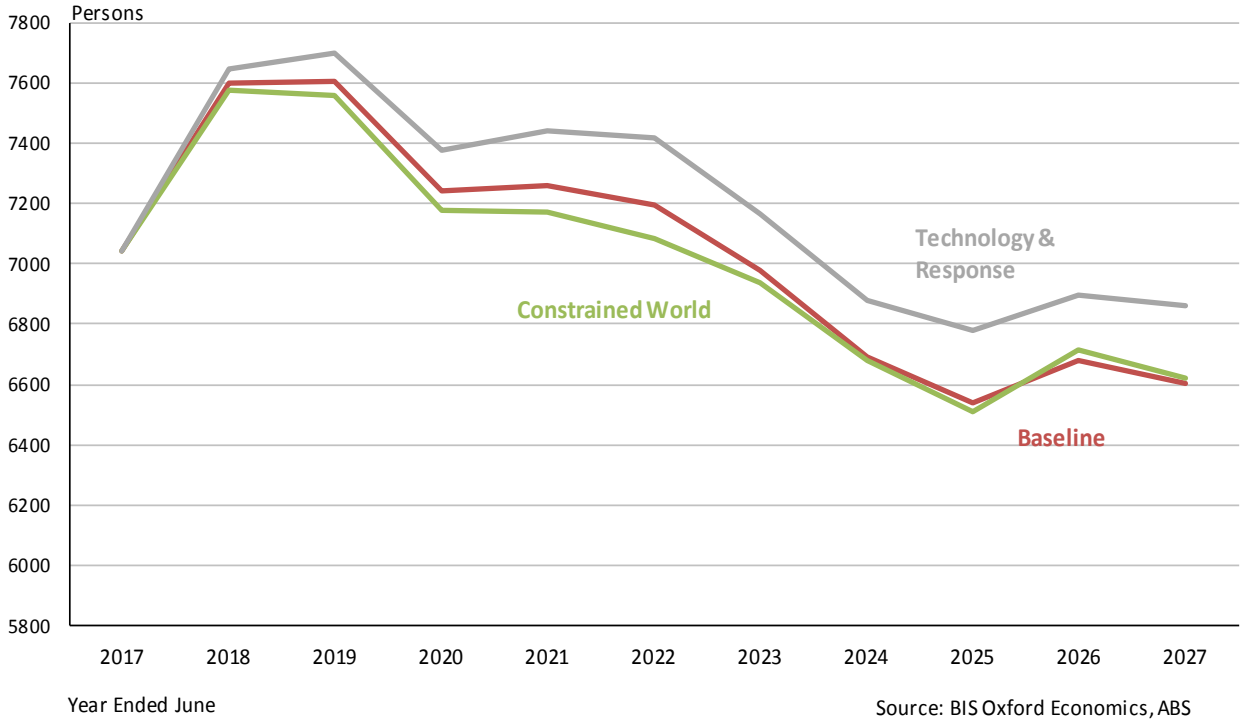


Figure 5.14: Australia Public Sector Other Cluster Employment - Scenarios



Under the Constrained World scenario we see an increased demand for designers and artisans required to undertake higher levels of construction and maintenance activity, which result from lower uptake rates for demand management technologies. Conversely, under the Technology and Response scenario it is assumed that there is a more rapid uptake of these technologies requiring more analysts, planners and information technology technicians, but a lower share of artisans and designers as the application of these technologies will defer the need for some additional large-scale investment.

While we have recently seen an acceleration in the development of disruptive technologies related to the road sector, the full potential of these technologies and the timeframe over which they are likely to be adopted remains unclear. For this report we are only projecting demand over a 10 year horizon; long lead times for major road projects and the role of budget cycles and government policy in determining the outlook for road activity, together with the need for new technologies to be rigorously tested before widespread adoption, limits the potential for a significant shift in the composition of work in the road and bridge sector – and therefore associated labour demand – over the forecast horizon.

However in the longer term we are likely to see major changes in the road and bridge activity. A significant shift towards public transport, on-demand car use and active transport could see a weaker profile for road activity; however, the adoption of driverless cars could conversely induce road usage demand. While it is not clear at this stage how consumer preferences, government policy and technology will interact, what is becoming increasingly clear is that smart technologies aimed at improving the efficiency of road transportation will play an increasingly important role in the design and operation of road and bridge infrastructure.

5.4 Workforce Capability Outlook

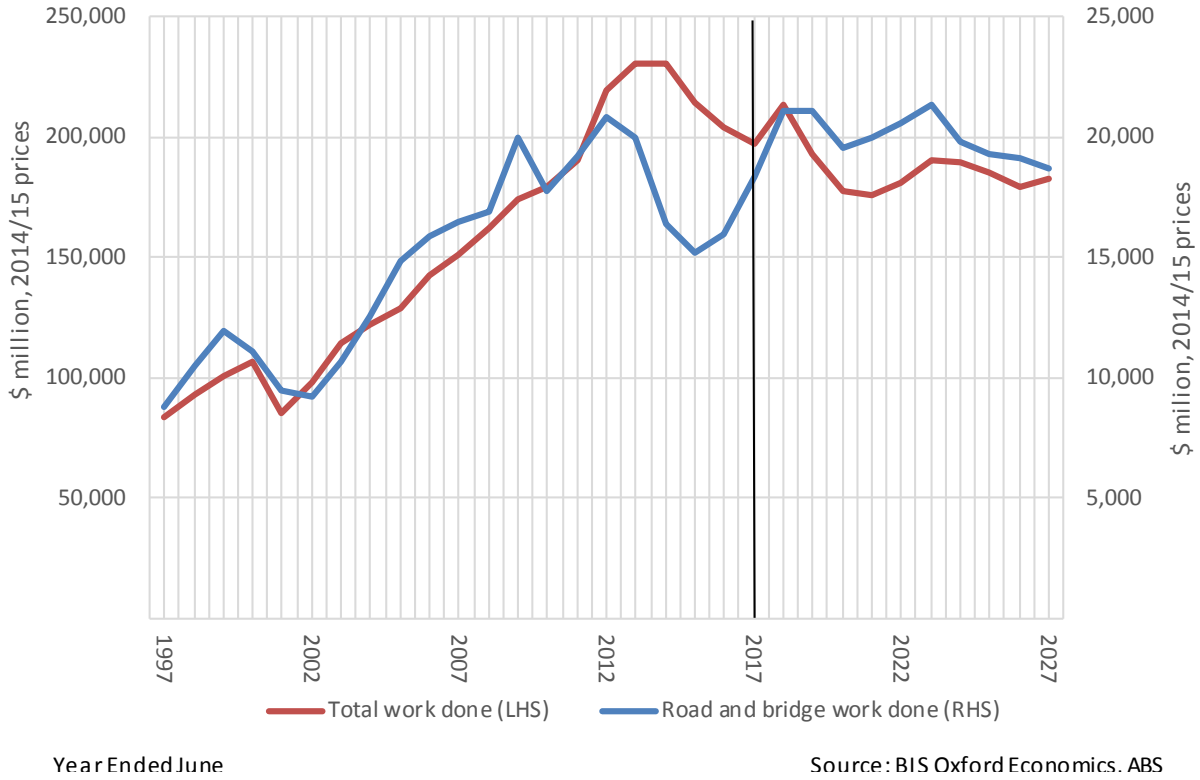
5.4.1 Workforce demand outlook to 2027

Positive workforce gaps can be met through new domestic entrants to the workforce, new overseas entrants to the workforce and through cross industry transfers. The ability to ramp up net migration of skilled workers to meet skills shortages and to attract cross industry transfers are both important factors in understanding the future capability gap for the roads sector. For cross industry transfers the overall strength of the economy, and particularly of sectors with competing demands for skills, will be an important factor in determining the ability to attract and retain workers. Sectors which are able to pay higher wages rates will have an advantage in attracting these workers.

The decade-long mining investment boom underpinned very strong competition for skilled workers for which supply was met both through migration and cross-industry transfers and – with a lag – through an increase in the domestic skilled workforce. The volume of work done in this sector has now fallen significantly from its 2013/14 peak levels. Activity is however bottoming out and we expect to see activity start to strengthen over the second half of the forecast horizon. There is obviously a significant overlap in the skill sets needed for civil construction works in the mining and heavy industry and road and bridge sectors – particularly for integrated mining projects which often include road, railways and port components. The mining sector is also highly profitable and able to attract workers from other sectors. The weaker growth profile for mining investment over the forecast horizon will therefore ease the competition the road and bridge sector faces for skilled construction workers from that sector.

The figure below shows that while we are not anticipating a major cycle in total construction activity in Australia over the forecast horizon, work levels are expected to remain historically high.

Figure 5.15:Total vs Road and Bridge Construction - Australia

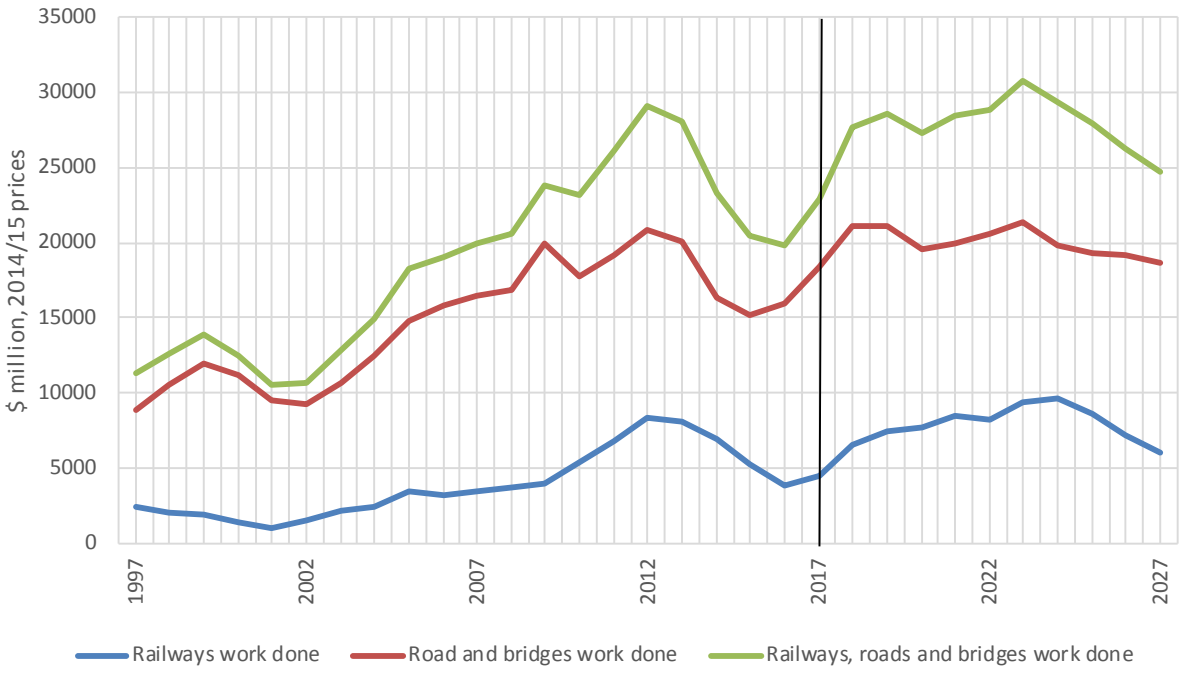


Year Ended June

Source: BIS Oxford Economics, ABS

While mining investment activity is expected to ease back further over the next five years, total railway construction activity is expected to see a strong growth phase underpinned by urban passenger service activity and the Inland Rail freight project in NSW, Victoria and Queensland.

Figure 5.16: Railways vs Road and Bridge Construction - Australia



Year Ended June

Source: BIS Oxford Economics, ABS

Road and rail projects have a greater requirement for design skills throughout their lifecycle than mining projects, where the input is predominantly required during the investment phase. Therefore while we're not expecting strong growth in demand nationally for skilled civil construction workers over the forecast horizon there will continue to be localised strong competition for skilled engineering professionals in certain states where there is a significant round of transport infrastructure set to get underway.

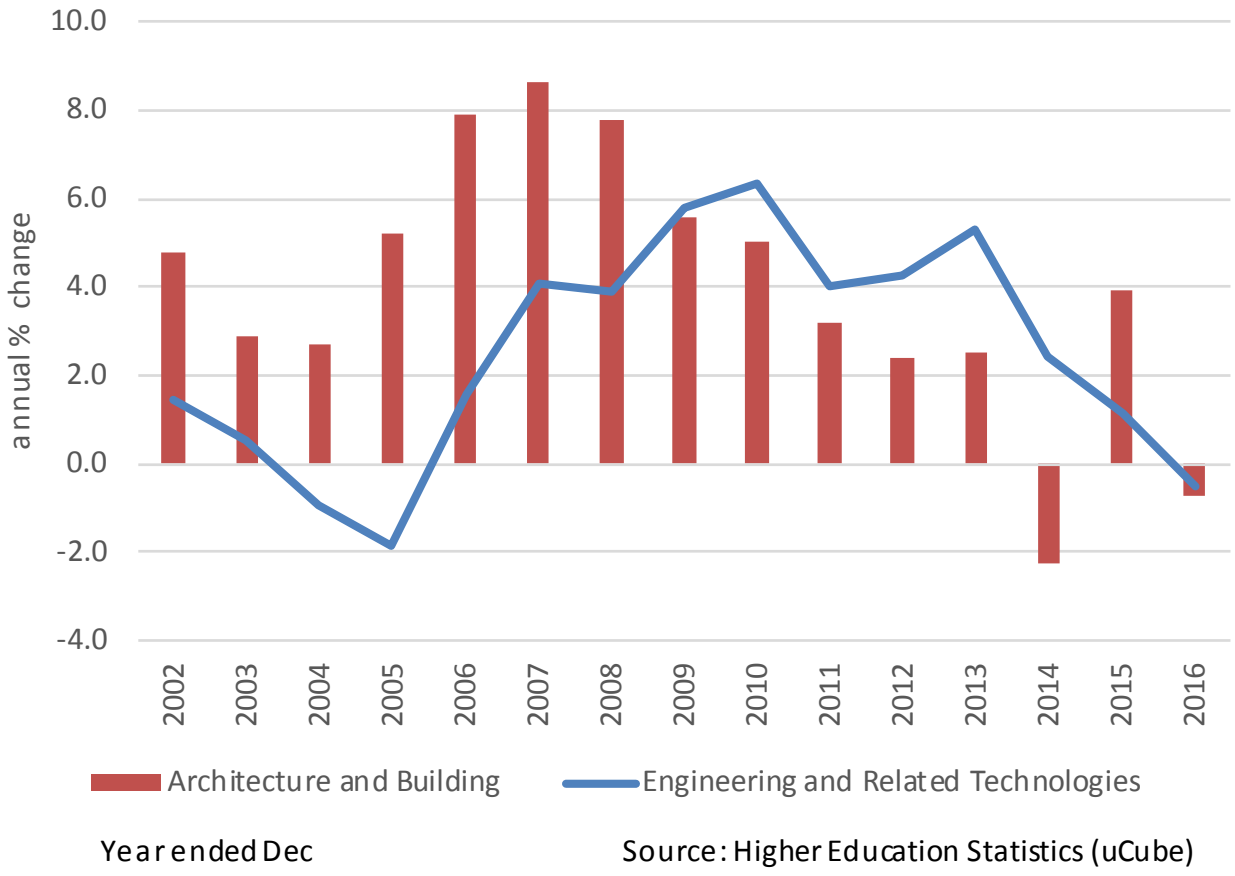
5.4.2 Workforce supply outlook to 2027

Designers

Australia's recent construction boom drove strong demand for skilled workers and strong growth in wages for many civil construction related occupations. This in turn led to an increase in the supply of graduates in these occupations. This occurred with a lag, as the pricing signals first translated into higher enrolments in the relevant qualifications and subsequently, following an average 3 to 4 year course, an increasing supply of graduates.

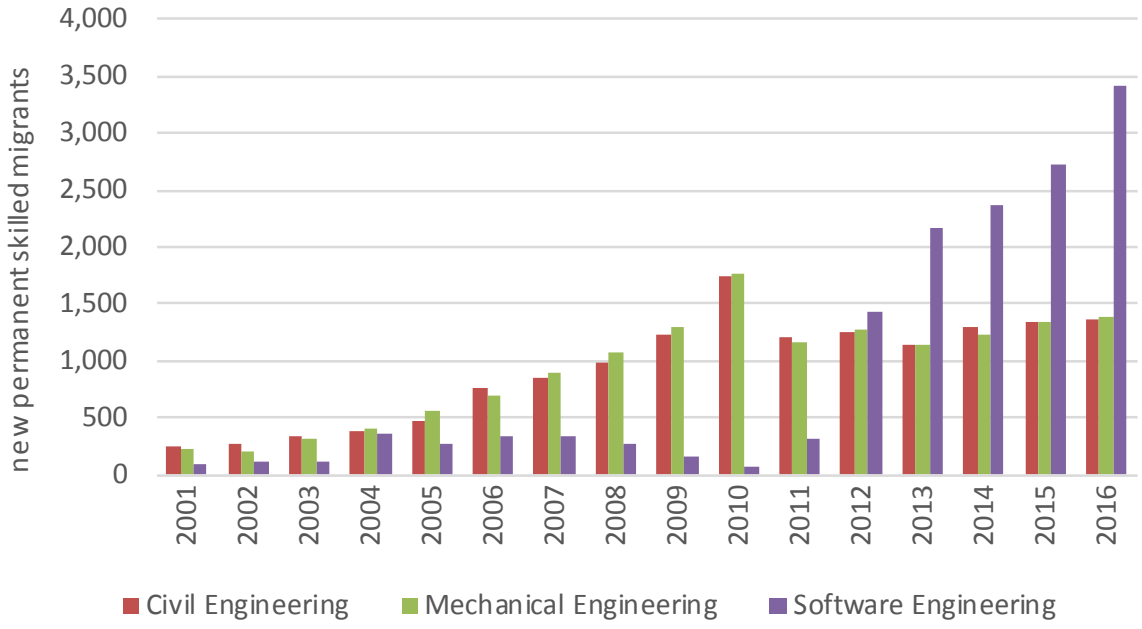
The figure below shows strong growth in enrolments for both architecture and building and engineering and related technologies degree courses through the middle of the last decade, bolstered by the strength of employment markets for these occupations. Growth in enrolments has slowed post-GFC in line with the weakening domestic and global investment outlook. Enrolments remain at high levels, however, and this will support the supply of graduates in these occupations in the near term. In three years to 2016 the number of students completing these courses averaged around 5,000 annually for architecture and building and over 11,000 for engineering and related technologies (of which approximately 1,800 were in civil engineering).

Figure 5.17:Growth in undergraduate and postgraduate enrolments - Australia



Despite the weakening in growth in investment activity, there is still a shortage of skilled engineers as demonstrated by the sustained high numbers of skilled migrant visas granted annually in these fields.

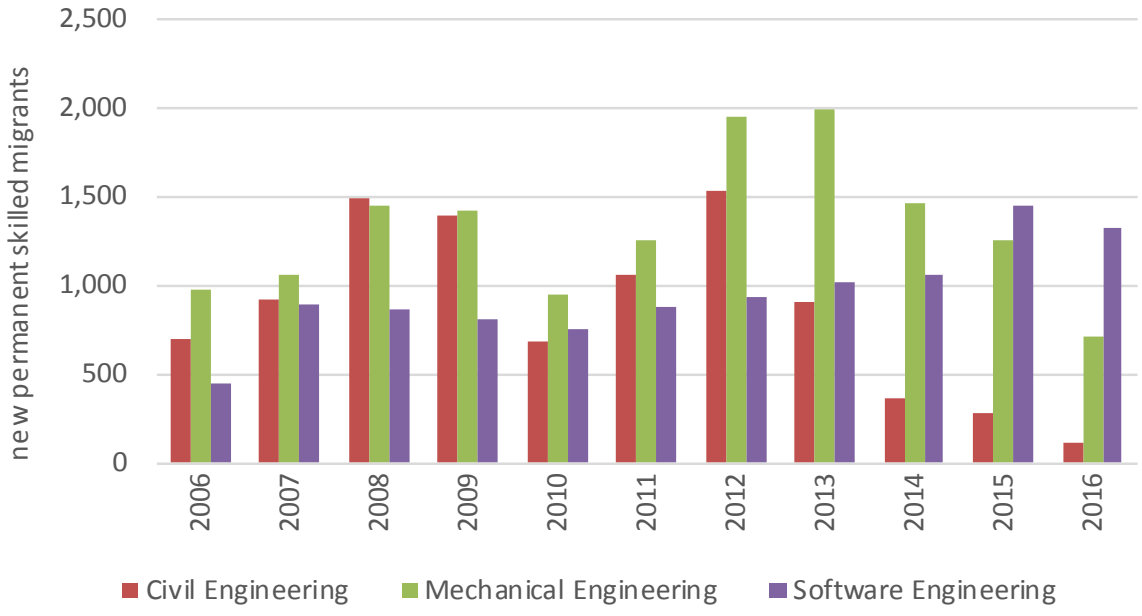
Figure 5.18:New permanent migration visas granted by selected occupation



Year ended June Source: Engineers Australia Statistical Overview 13th Edition

This figure shows that there was strong year-on-year growth in the number of civil and mechanical engineers granted new permanent migration visas over the second half of the last decade. The annual intake levelled out over the first half of this decade but remained historically high as at 2015/16. Chart 4.5 shows that the number of new temporary 457 visas granted for civil engineers over the three years to 2015/16 was substantially lower than the numbers granted in the 8 years to 2012/13, reflecting the weakening investment environment. The number of temporary visas granted for mechanical engineers also weakened over the three years to 2015/16, but to a much less extent than for civil engineers. Conversely, the number of visas issued to software engineers has grown strongly through the current decade, both for temporary and permanent migrants.

Figure 5.19:New 457 visas granted by selected occupation



Year ended June Source: Engineers Australia Statistical Overview 13th Edition

Over the decade to 2026/27, sustained high construction activity should prevent a significant downturn in the supply of new graduates. We should also see more cross-industry transfers and less attrition of older engineers, which is often seen during cyclical downturns in investment activity. On balance, competition for engineers nationally are expected to ease over the forecast horizon. However, as previously mentioned, road and rail activity in NSW, VIC and QLD will be strong, particularly over the first five years, and this will underpin continued strong demand for experienced civil engineers in these states.

As with engineering related courses, growth in enrolment counts for domestic students undertaking architecture and building degrees (which includes surveyors) strengthened through the middle of the last decade but have subsequently slowed in-line with investment activity. As with civil engineers we should see an easing in competition for surveyors and spatial scientists nationally over the forecast horizon, particularly over the last five years. Demand will remain solid, with an upswing in non-residential building markets taking up much of the slack from moderating residential markets and this should prevent a significant downturn in the supply of new graduates.

On balance, the outlook for the design skills cluster workforce capability gap in the road and bridge sector over the ten years to 2026/27 is more favourable than over the previous decade. This will be true even if we see a substantial weakening in domestic degree completion counts over the second half of the forecast horizon. This however is not expected given that the outlook for construction activity remains firm, as does the outlook for maintenance and network operations given the recent and planned growth in the capital stock of infrastructure assets, particularly road and rail.

Artisans

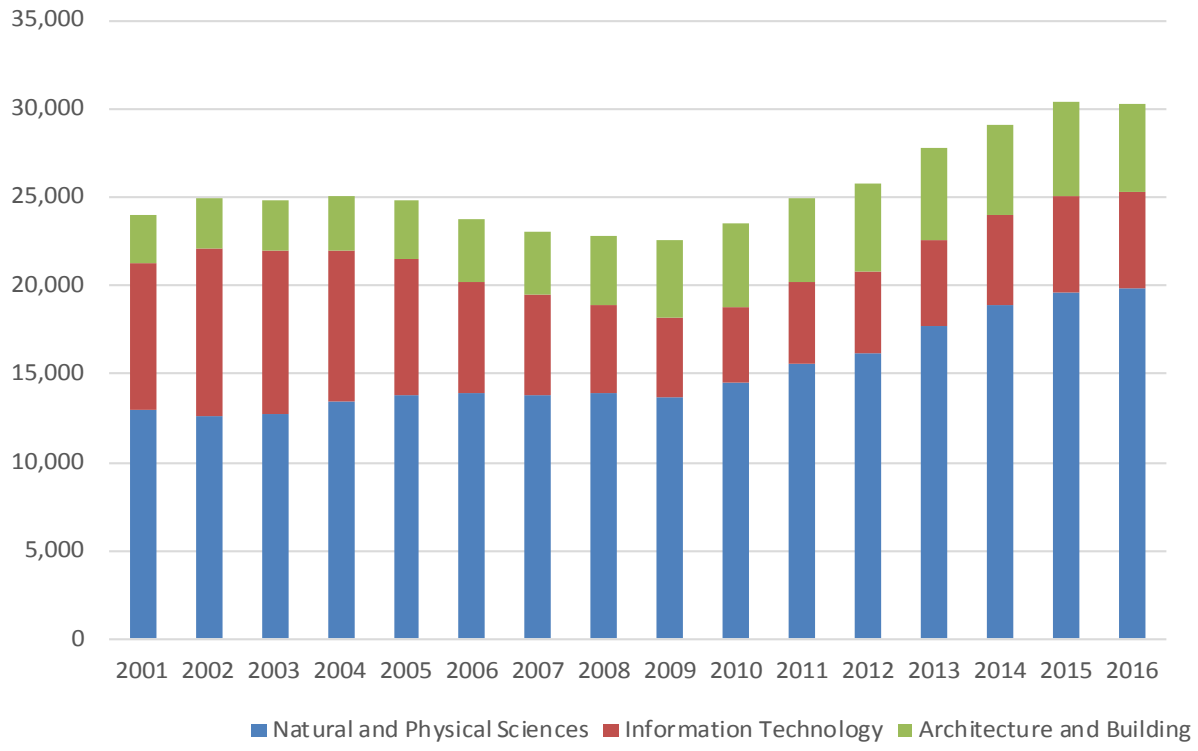
The artisan skills cluster includes a mix of skilled and unskilled workers. Competition for these workers was intense during the construction boom, particularly prior to the onset of the GFC. The downturn in mining investment activity since 2013/14 has seen competition for workers ease, but demand for workers nationally remains high and will remain so over the forecast horizon in-line with total construction activity. The potential supply of artisan workers is linked to the overall strength of the economy and particularly the unemployment rate of an individual jurisdiction. Nationally we anticipate the unemployment rate to firm over the five years to 2021/22 to around 5 per cent, but we're not expecting to see a return to the very tight labour market conditions seen in the run-up to the GFC. Again, the picture will vary and some areas will see stronger competition for workers as a result of synchronised activity in major infrastructure projects, e.g. road and rail projects in Sydney, Melbourne and Brisbane.

Other (Informers and Technologists)

The other skills cluster includes analysts, urban planners and ICT professionals. Under the base case it is assumed that the share of these professionals in the workforce does not change over the forecast horizon.

The figure below illustrates completion counts for undergraduate and graduate courses in information technology, natural and physical sciences, and architecture and building at Australian higher education institutions over the ten years to 2016.

Figure 5.20:Domestic degree completion counts by field of education



Year ended December

Source: Department of Eduation and Training

As previously discussed, participation in architecture and building degrees (architects, surveyors, planners) strengthened through the middle of the last decade in line with national construction activity. There have previously been significant skills shortages nationally for all three occupations, but research by the Department of Jobs and Small Business shows that there are now just localised shortages in the eastern seaboard states. These shortages are expected to continue to ease in line with weakening residential activity in these states.

Studies of university data have shown that growth in natural and physical sciences degree completion counts has been driven by behavioural and biological sciences and combined degrees rather than by growth in pure 'enabling' science degrees such as chemistry, mathematics and physics. This corresponds with the pattern seen nationally for HSC enrolments. There therefore remains a persistent undersupply of graduates from STEM disciplines. Notably, pure economics is another a subject which has seen a sharp decline in participation rates at the both the HSC and degree level over the past two decades.

Under the base case of no significant shift in the composition of the road and bridge workforce and no major shift in the sector's technological base, there is not projected to be a significant workforce capability gap for skilled workers from occupations within the natural and physical sciences field and other quantitative disciplines, e.g. economics. This however assumes that the sector is able to retain its current workforce. The undersupply of new graduates nationally, together with the increasing adoption of new technologies economy-wide, will increase competition for new and existing workers from these disciplines.

Statistics from the Department of Education and Training show that domestic enrolment counts for undergraduate and postgraduate information technology degrees at higher education institutions nearly halved between 2002 and 2009[4]. Enrolments have since stabilised but 2016 enrolment counts were still some 30 per cent lower than those seen in 2002. Enrolments in information technology courses provide by TAFE[5] and other vocational providers also halved between 2002 and 2009 and have continued to decline. In addition to the low enrolment numbers, information technology courses have low completion rates – upwards of 70 per cent of students signed up to courses do not complete them.

Given the rapid speed at which new technologies are being developed and adopted, the weakness in the number of domestic students graduating in IT and other STEM disciplines is a cause for concern. Under the base case of no shift in the composition of the road and bridge workforce and no major shift in the sector's technological base, there is only anticipated to be a modest workforce capability gap over the forecast horizon (provided the sector can retain its existing workers). However, the potential widespread adoption of artificial intelligence technologies in the road and bridge sector would require a IT workforce skilled in these new technologies and significant support from other quantitative and analytical disciplines. Technological and digital change will impact on other sectors of the economy to varying degrees, so there is likely to be strong competition for a small pool of domestic graduates under this scenario.

New Zealand

The demand outlook for New Zealand is similar to that for Australia, with overall construction activity projected to peak in 2018/19 before easing back and levelling off at an historically high level over the second part of the forecast horizon. For New Zealand this largely reflects the end of a major phase of reconstruction activity in Christchurch. There is now some additional uncertainty over the likelihood of some major road projects progressing following the election of the Labour Government. Conversely, we may now see stronger rail activity than previously projected over the forecast horizon. Budget constraints will limit the extent to which overall infrastructure spending can rise and therefore we're not expecting a significant shift from the overall outlook for construction activity and the associated demand for workers.

The supply outlook for New Zealand is also similar to that of Australia. Completion counts for civil engineering degrees have been strengthening, however, around a third of New Zealand's domestic engineering graduates are estimated to be working offshore 5 years after graduation. Civil engineers remain on the New Zealand Government long term skill shortage list. New Zealand has a similar issue with low participation in STEM related higher education to Australia, although as a share of its population has a much higher proportion of domestic students studying Information Technology as their predominant field of study at the degree level or higher.

Summary

Under the base case scenario the demand-supply outlook for the road and bridge sector nationally over the 10 years to 2026/27 is expected to be more in balance than over the previous 10 years. This reflects the weaker growth profile for investment activity nationally as a result of the end of the mining investment boom. This growth outlook however masks strong localised demand for skills, particularly between the road and bridge sector and the railways sector in NSW, VIC, QLD (and potentially NZ) with a synchronised strong phase of growth in activity by both sectors in these jurisdictions expected over the forecast horizon.

The quantitative analysis only considers a 10 year horizon under a base case scenario of minimal technological change and modest overall growth in demand for civil construction related workers. Section 7 of this Report considers the challenges the road and bridge sector faces beyond 2026/27 and under alternative scenarios for growth and the adoption of new technologies.

4 Department of Education and Training – Higher Education Statistics Data Cube (uCube)
5 NCVER – VET_historical_data_1981-2016.xlsx

6. Roads Workforce Capability – Industry Perspectives and Challenges

Previous workforce capability analyses undertaken for Austroads have concentrated on engineering skills. However, roads agencies may need to look beyond engineering skills in the future and look more broadly at skills in areas such as project, contract, commercial and business management, data analytics and control engineering and impacts of technologies such as Cooperative ITS and Connected and Automated Vehicles (and possible others). In other words, the skills clusters under consideration not just include a broader range of Designer skills (i.e. beyond civil engineers, surveyors and spatial scientists – although these skill sets will likely remain important) and Artisans, but also skills drawn from the Informer and Technologist clusters.

In the preceding Section, the quantitative workforce gap modelling was expanded to include this broader consideration of skills. What the quantitative modelling shows is that:

- Under the baseline scenario, workforce gaps are anticipated to arise for occupations in the Designer, Artisan and Other (Informer and Technological) clusters as demands for these skills exceed existing supply which will be affected by increasing retirements over the coming decade. These gaps are expected to grow larger in the five years to 2026/27 as high levels of demand are sustained and the existing workforce continues to decline through demographic effects.
- Under the 'Technology and Response' scenario, labour demand (and also the workforce gap given the same existing labour supply) are expected to be much *larger* for the Informer and Technological clusters as the more rapid uptake of new technologies (compared to the base case, including ITS, CAV and MaaS) requires more analysts, planners and information technology technicians. However labour demands (and workforce gaps) for artisans and designers are expected to be lower in this scenario as the application of these technologies will defer the need for some additional large-scale investment.
- Under the 'Constrained World' scenario, this situation is expected to be somewhat reversed. Designers and Artisans in this scenario would be required to undertake higher levels of construction and maintenance activity as a result of lower uptake rates for demand management technologies. This will see higher labour demands and a greater workforce gap for these skills clusters as compared to the base case. Labour demand and workforce gaps are expected to slightly lower for the Informer and Technological clusters in this scenario over the next five years as compared to the base case, but will edge higher again late in the forecast decade however.

This analysis, however, is focused on the specific demands generated by the roads sector and, as such, has some limitations. For example, the model assumes that demand and supply are already in balance in 2016/17, despite the possibility of skills shortages already existing, particularly for certain professions and trades. It also does not adequately reflect that highly experienced skills will be lost to the roads sector over the coming decade compared to the influx of new (typically lesser experienced) skills drawn from education or migration. Furthermore, the workforce gap itself does not take into account the demands that *other* industries – such as other transport segments such as railways, or industries such as mining - may pull on the roads industry over the forecast horizon. In other words, in its portrayal of workforce gaps, it is implicitly assumed that the roads industry can fill these gaps with appropriate intakes from the education sector, from migration (whether interstate in Australia, or via immigration), or from inter-industry transfers.

While a much larger quantitative model that took into account demands for *all* the occupations in the skills clusters considered from *all* industries (and all industries' call on newly minted graduates and migrants) would help resolve some (though not all) of these issues, such a task is beyond the scope of this Report. Instead, the approach undertaken here is to combine the roads-focused quantitative analysis with original *qualitative* industry consultation and liaison that looks beyond road agencies themselves and includes other industries (such as railways and mining), educational institutions, local government and the perspectives of other government agencies at the national, state and local level.

This multifaceted approach aimed to garner a better understanding of the nature of workforce and capability gaps that will likely impact the roads sector, the risks involved and the challenges ahead. Consequently, in a marked difference from previous workforce capability studies, BIS Oxford Economics has sought 'grass roots' perspectives from roads agencies themselves, the private sector, educators and government. This engagement has been aimed at not just understanding critical workforce capability issues faced by roads agencies over the next 5-10 years, but in the coming one to two decades. Importantly, the engagement has also sought to identify potential solutions to any perceived workforce capability deficits.

Accordingly, our methodology has revolved around industry liaison, via both survey and interview, aimed at gathering views from various industry players on what they see as the key risks to workforce capability now and over the forecast period. The results of the survey are shown in Section 6.1 below, followed by the findings from industry interviews.

6.1 Industry Survey Outcomes

In tandem with industry interviews, BIS Oxford Economics designed an industry survey to obtain quantitative feedback on various issues concerning roads agency and industry workforce capability in Australia and New Zealand.

The survey instrument generates quantitative ratings of industry opinion and complements the qualitative feedback from industry interviews.

Questions and ratings surveyed include:

- The level of difficulty in recruiting staff by occupation, and why
- Occupations most likely to see skills shortages over the next 10-20 years
- Key risk factors to roads agency workforce capability over the next 5-20 years and why
- Key risks to roads agency workforce capability through technological change and why
- Initiatives that should be undertaken to reduce risks to workforce capability

Roads agencies and the broader industry responded to these questions in the survey. On top of this, all Austroads roads agencies were surveyed on their existing functions and staff structure across the occupations considered for this report. The latter questions included not just their existing structure in terms of numbers of people and age profile, but also the number of retirements across all occupations and the age group of retirement, the number of redundancies by occupation and age, the number of new hires by occupation over the past three years, the source of new hires (graduates, other industry sectors etc), and the near term outlook for road construction and maintenance expenditure. Responses from these questions were useful in developing quantitative modelling for the previous Section.

The broader survey questions (responded to by both roads agencies and broader industry) and the collected responses are presented below. In addition to set questions, space for free-form comment was also provided to respondents, and these are noted where applicable.

This section is organised as follows:

- Discussion of the methodology used to collect the data
- Presentation of data on the ***perceived level of recruitment difficulty*** both 'here and now' and 'likely expected', faced by both roads agencies and broader industry
- ***Key risks to workforce capability over the next 20 years***, differentiated by short to medium-term risks (i.e. next five years) and long-term risks (i.e. for the subsequent 15 year period). We also present some data on the extent to which these risk factors have been a feature over the last five years and how this risk profile has changed over the same period
- Finally, we present results on perceived ***key technological risks impacting on workforce capability***, both at present and in the future.

6.1.1 Survey methodology

The core aim of the survey to collect data on recruitment difficulty and some of the likely long-term risks to workforce capability impacting on the roads sector in Australia and New Zealand. By standardising the survey questionnaire across the industry participants, it has been possible to search for patterns in the respondents' attitudes, opinions, and isolate some key implications of responses.

There were four overarching themes of the survey questions and several questions were proposed under each thematic area – **see Appendix C (Parts 7 to 10) for a list of questions included under each theme**.

The next section presents the results and some of the key implications of survey responses. Data and key inferences are presented by thematic topic and is ordered by responses from roads agencies across Australia and in New Zealand followed by responses from other important participants in the broader roads sector both in Australia and in New Zealand. We identify these simply as non-roads agency responses to maintain the confidentiality of participants in the survey.

6.1.2 Level of difficulty in recruiting staff – the 'Here and Now'

Generally speaking, respondents to the survey indicate that the skill requirements for project delivery in the roads industry has shifted significantly over time. The days of assessing roads projects purely through the BCR (benefit cost ratio) lens or just the technical issues surrounding route options are behind us. These days, a number of variables are taken into consideration. Accordingly, the skill sets required are wide-ranging. That being said, some responders felt that the rate of change in the very 'traditional' roads workforce has been slow, weighed by an ageing workforce that is somewhat averse to embracing technological changes.

Nonetheless, survey responses indicate that today's roads agencies require a very broad range of skills Some of these key influences over and above the traditional engineering road construction skills are described below:

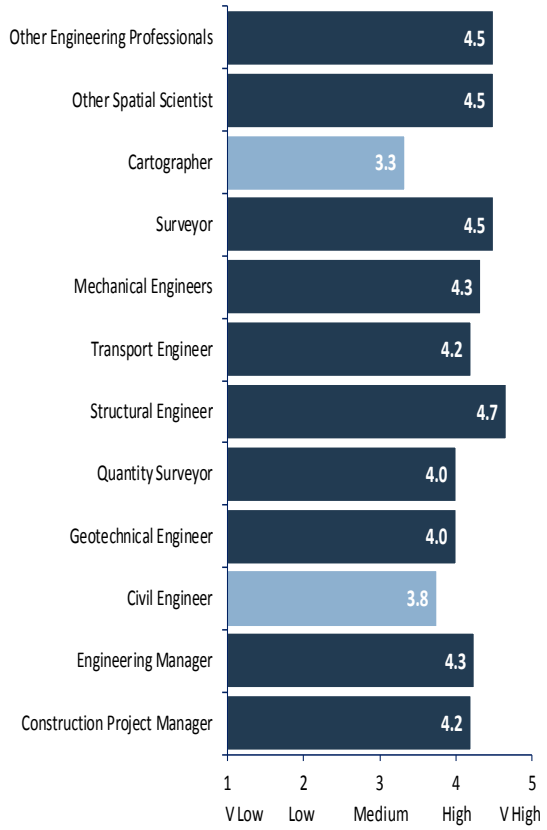
- Understanding the effects of climate change
- Understanding of changing land use and changes in population density that may affect the project.
- Economic justification to secure funding, as part of the 'business case' process
- Securing consents to be able to do the work meaning consultation and mass marketing of the outcomes and benefits of investment — i.e selling the 'story' to the general public.

We interviewed all of the major jurisdictional roads agencies in Australia, Transport New Zealand as well as broader industry participants to gauge how difficult it is to hire new recruits by skill type. The Figures over the next few pages summarise the survey results, and provide a point of comparison to roads agency and non-roads agency responses.

Key outcomes for this part include:

- Several roads agencies responded as experiencing difficulty in recruiting people with university trained design skills. Amongst all of the engineers, recruiting talented structural engineers was the hardest, primarily due to uncompetitive salaries offered by roads agencies
- By contrast, non-roads agency participants expressed higher difficulty in hiring Transport Engineers, Geotechnical Engineers and Engineering Managers mainly due to skills shortages in the talent market as evidenced by low number of applications.
- For TAFE trained design skills, roads agencies reported recruiting difficulties for Contract, Program and Project Administrator roles as well as filling Surveying and Spatial Science Associate positions. The latter was due to a skills gap in the workforce as the local market did not produce enough work ready/qualified job candidates

Figure 6.1: Road agency recruitment difficulty: University Design Skills



	Skills shortages in the talent market as evidenced by:			Skills gap in the existing workforce due to:		
	Low number of applicants	Candidates do not have the needed work experience	Candidates do not have the right technical skills	The local market is not producing enough work-ready/qualified job candidates	Competition from other employers	Salaries not being competitive for the market
Other Engineering Professionals	33%	67%	0%	25%	25%	50%
Other Spatial Scientist	25%	25%	50%	25%	25%	50%
Cartographer	50%	0%	50%	100%	0%	0%
Surveyor	60%	20%	20%	43%	29%	29%
Mechanical Engineers	0%	0%	100%	NA	NA	NA
Transport Engineer	50%	25%	25%	17%	50%	33%
Structural Engineer	33%	33%	33%	14%	29%	57%
Quantity Surveyor	50%	25%	25%	25%	25%	50%
Geotechnical Engineer	20%	60%	20%	29%	29%	43%
Civil Engineer	50%	50%	0%	0%	33%	67%
Engineering Manager	50%	25%	25%	33%	33%	33%
Construction Project Manager	14%	57%	29%	11%	44%	44%

Figure 6.2: Non-Road agency recruitment difficulty: University Design Skills

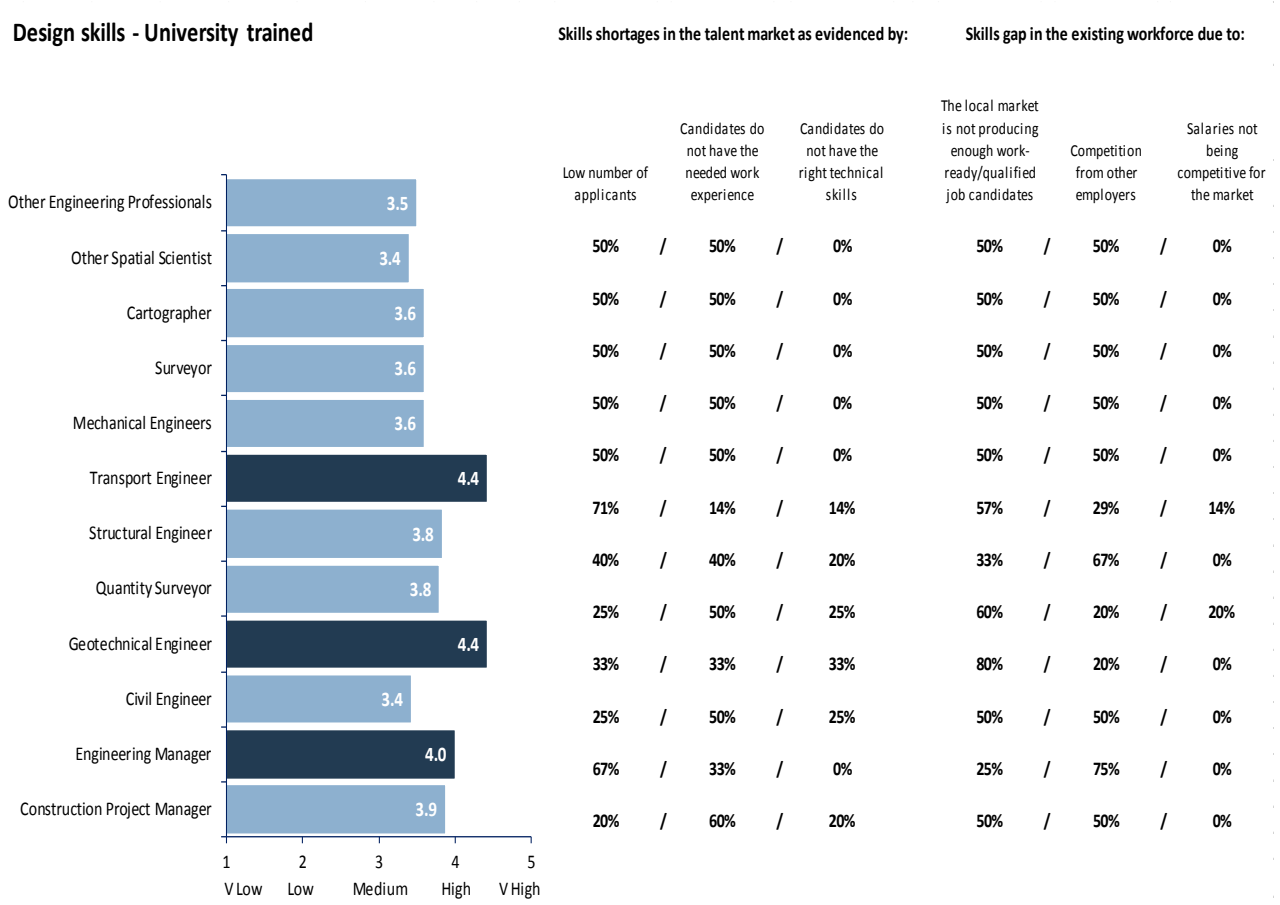


Figure 6.3: Road agency recruitment difficulty: TAFE Design Skills

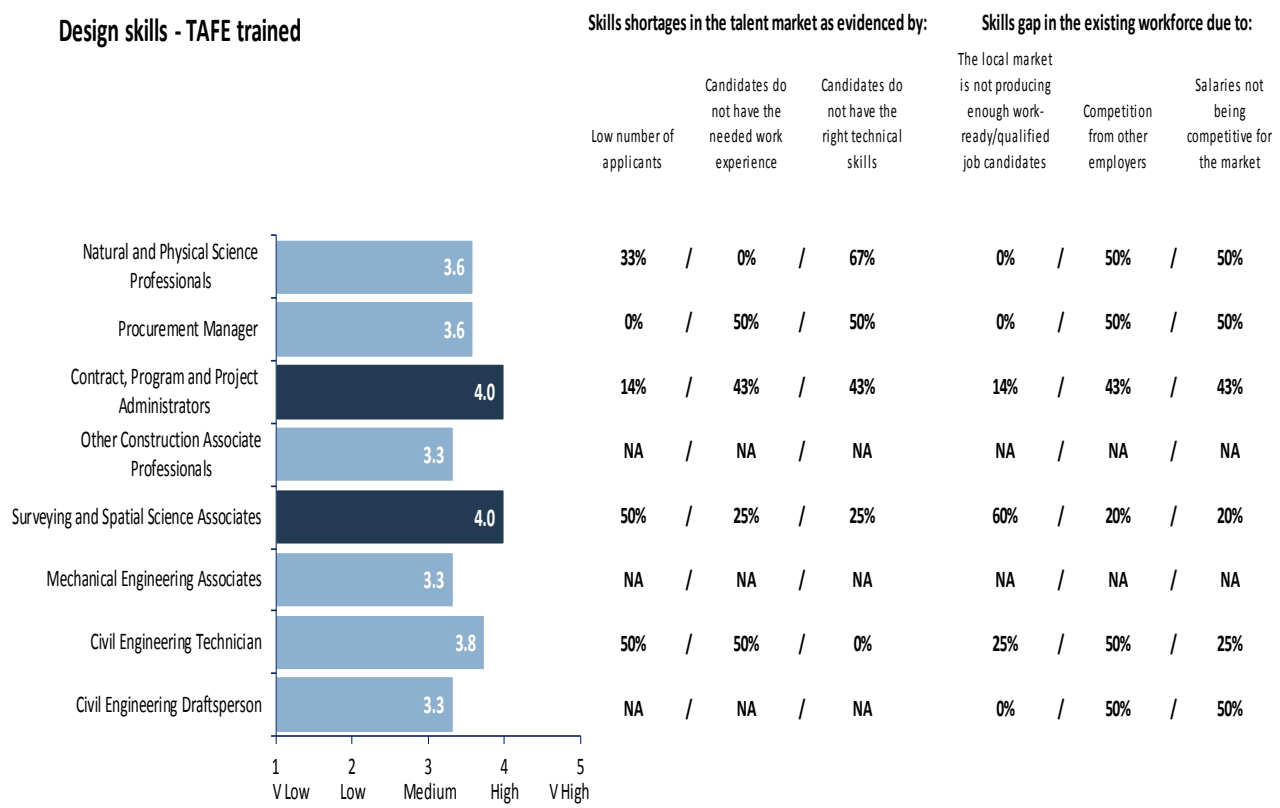


Figure 6.4: Non-Road agency recruitment difficulty: TAFE Design Skills

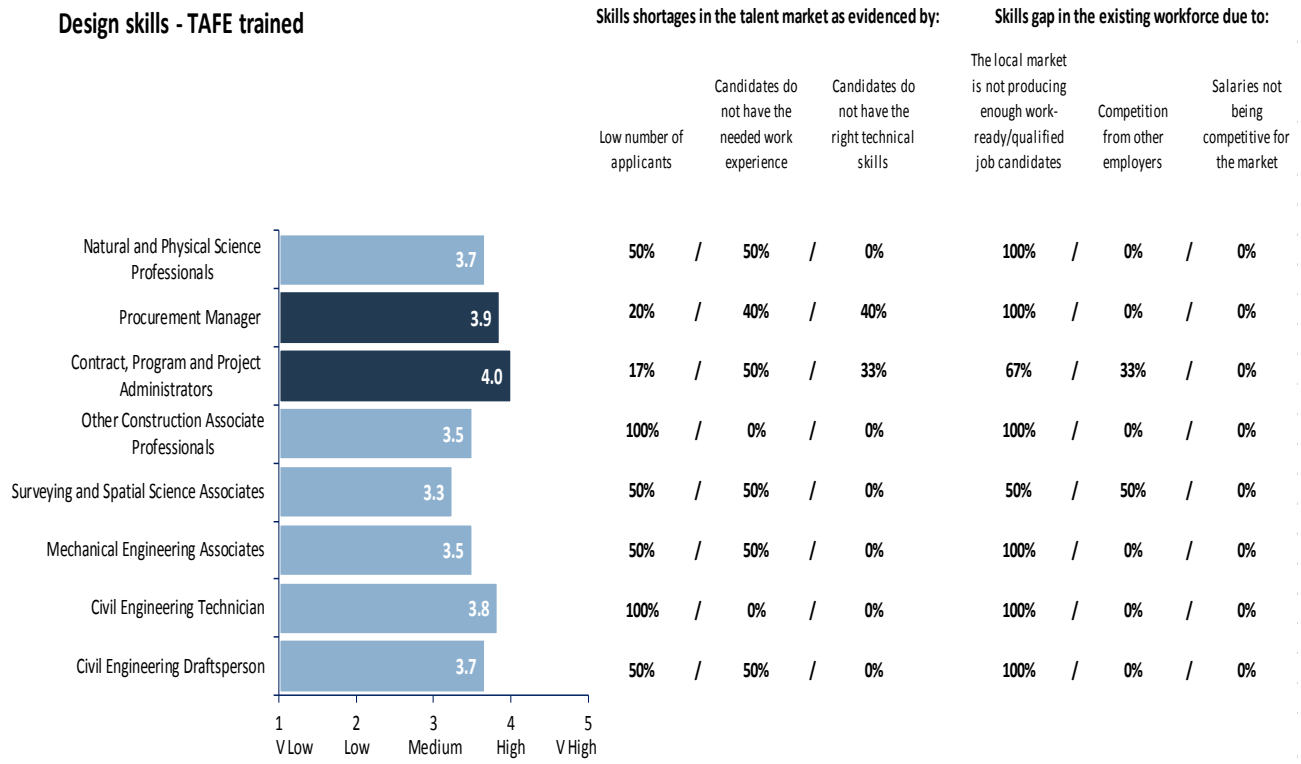


Figure 6.5: Road agency recruitment difficulty: Other Skills

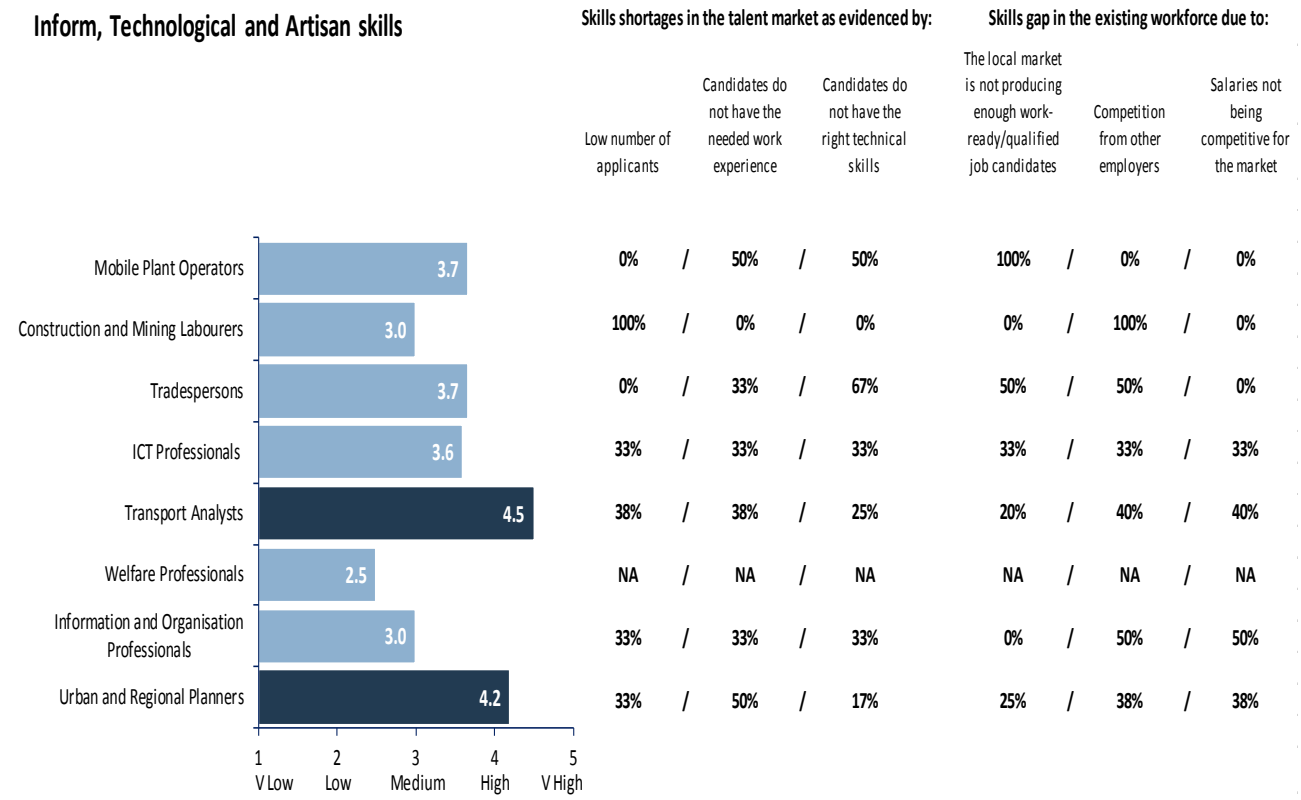
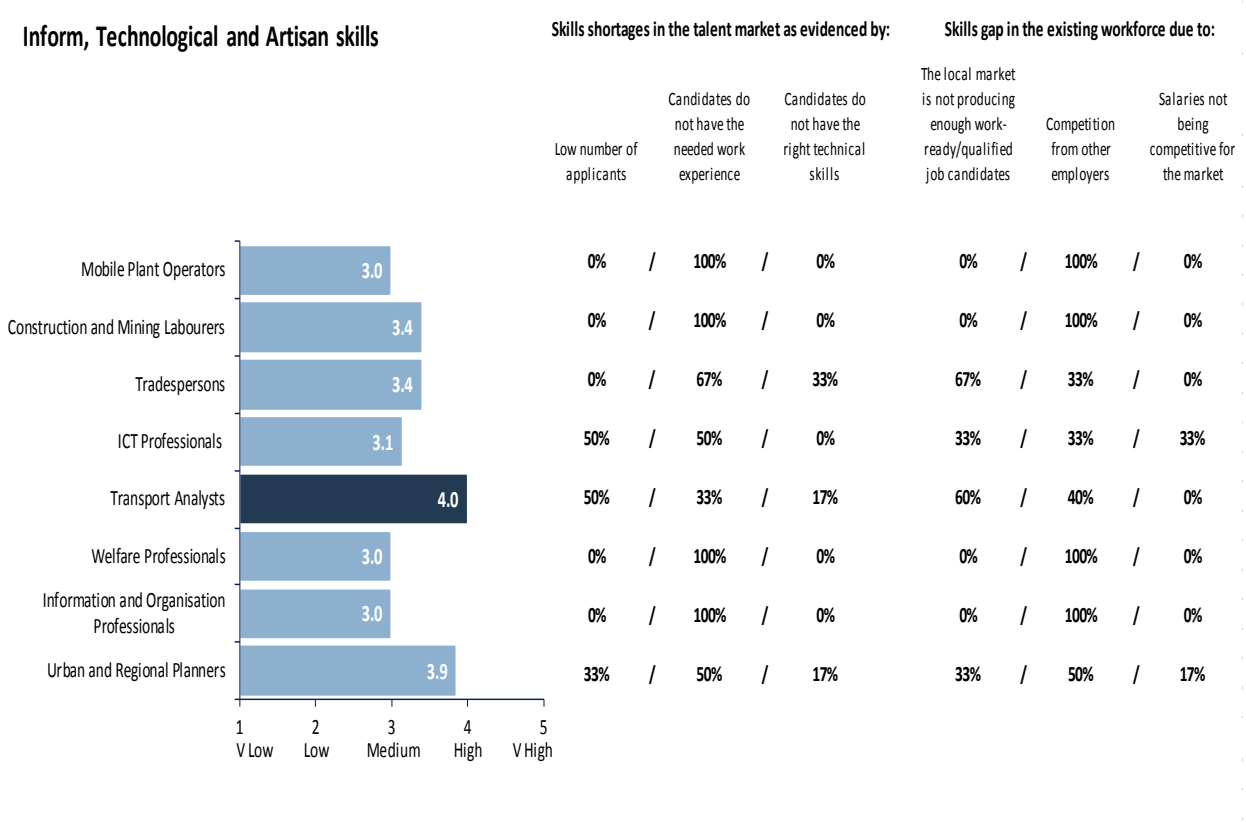


Figure 6.6: Non-road agency recruitment difficulty: Other Skills



- Non-roads agency respondents also expressed problems in hiring for Contract, Program and Project Administrator roles as there were insufficient people in the job market with the necessary skill set
- Amongst informer, technological and artisan skills, difficulty in recruiting Transport Analysts was most pronounced. Both roads and non-roads agencies reported very high recruiting difficulties. This was due to a combination of skills shortages in the talent market (low number of applicants) along with skills gap in the workforce (competition from other employers). Roads and non-roads agencies also expressed a high difficulty in recruiting urban and regional planners

6.1.3 Occupations likely to see skills shortages in the future

The next stage of the survey asked responders to grade which 'here and now' skills are likely to see shortages in the future. Their responses are summarised in the figures over the next few pages, again with a comparison of roads agency versus non-roads agency responses.

Key outcomes from this part of the survey include:

- Most roads agencies felt almost all of the design skills (university trained) recruitment are likely to come under pressure over the next 10 years. Conversely, non-roads agencies were more optimistic about filling these design skills roles. Nonetheless, they felt hiring Transport Engineers, Geotechnical Engineers, Cartographers will present the biggest challenge over the next 10 years
- Hiring Cartographers and Surveyors will present the biggest challenge as the current workforce is an aging one with insufficient new recruits coming through to replace retiring workers. Cartographers got a maximum difficulty score of 5 while Surveyors received a score of 4.8
- Longer term (i.e. over 2026/27 to 2036/37), roads agencies felt that recruiting for the following skills will present the greatest challenge (generally high to very high):
  - Cartographers
  - Surveyors

- Other Spatial Scientists
- Structural Engineer
- Engineering Manager
- Mechanical Engineer
- Other Engineering Professionals
- Quantity Surveyor
- Natural and Physical Scientist Professionals
- Tradespersons
- Urban and Regional Planners
- ICT Professionals
- Transport Analysts

- By contrast, non-road agencies did not place any of the listed skills across designer, artisan, informer and technological cluster in the high to very high range for the 2026/27 to 2036/37 period. However, of all skills, the ones that were ranked most highly in terms of future skills shortages were Procurement Managers (3.9), Contract, Project and Program Managers (3.8), Transport Analysts (3.8), Tradespersons (3.8) and Transport Engineers (3.7)

Figure 6.7: Road agency 10 year shortage outlook: University design skills

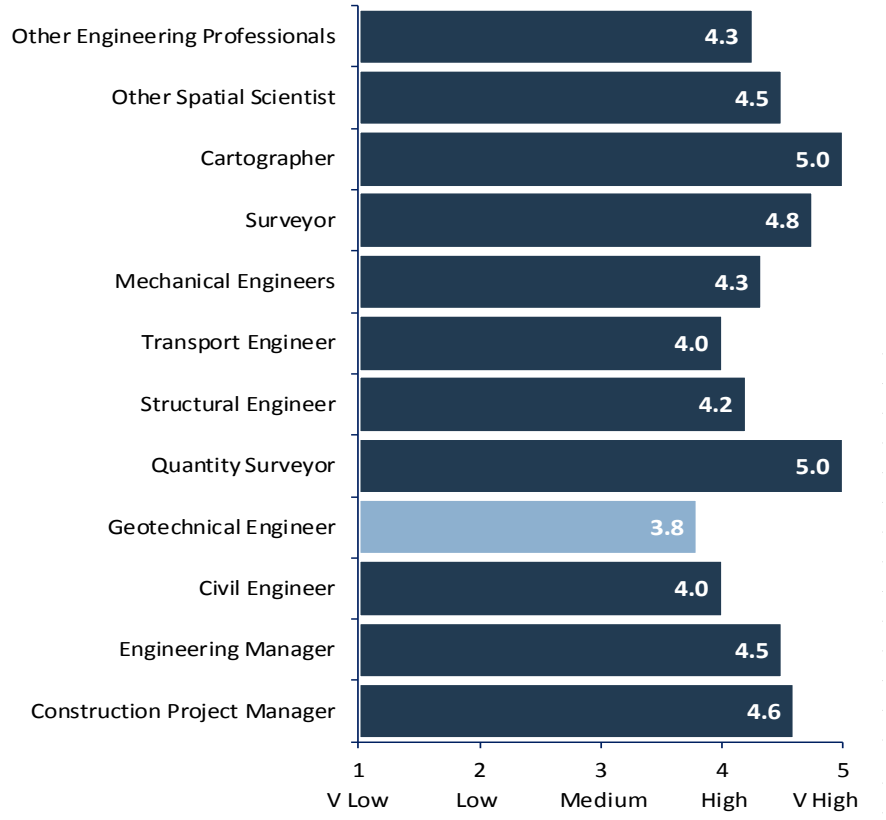


Figure 6.8: Non-Road agency 10 year shortage outlook: University design skills

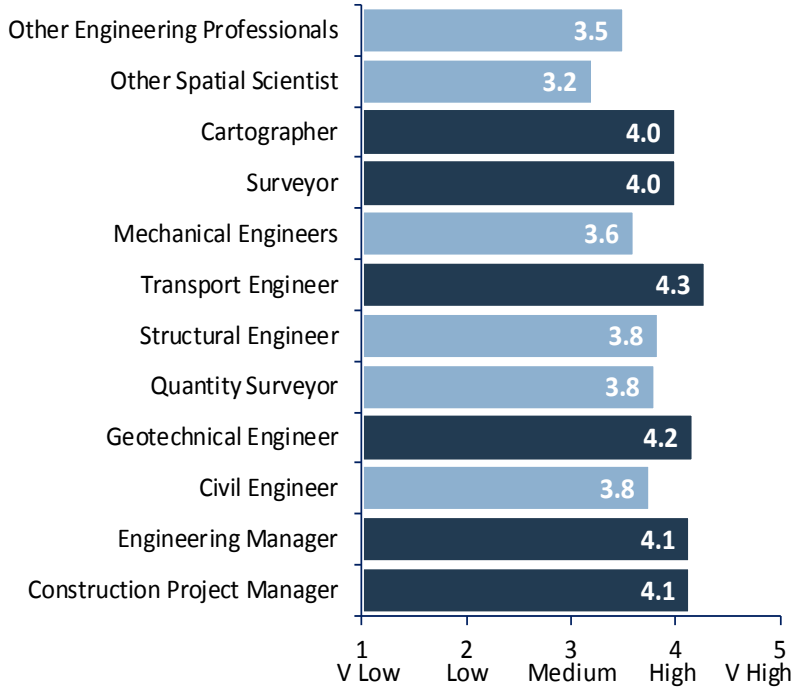


Figure 6.9: Road agency 10 year shortage outlook: TAFE design skills

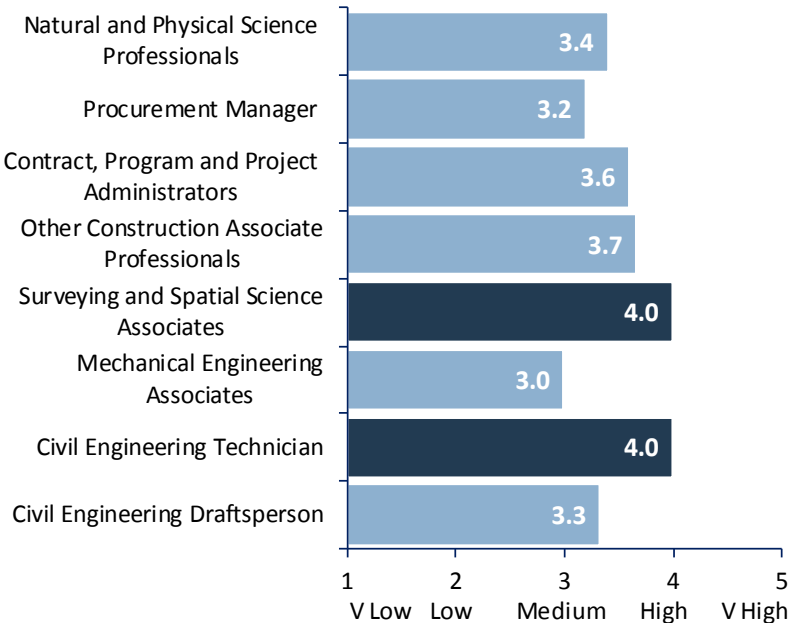


Figure 6.10:Non-Road agency 10 year shortage outlook: TAFE design skills

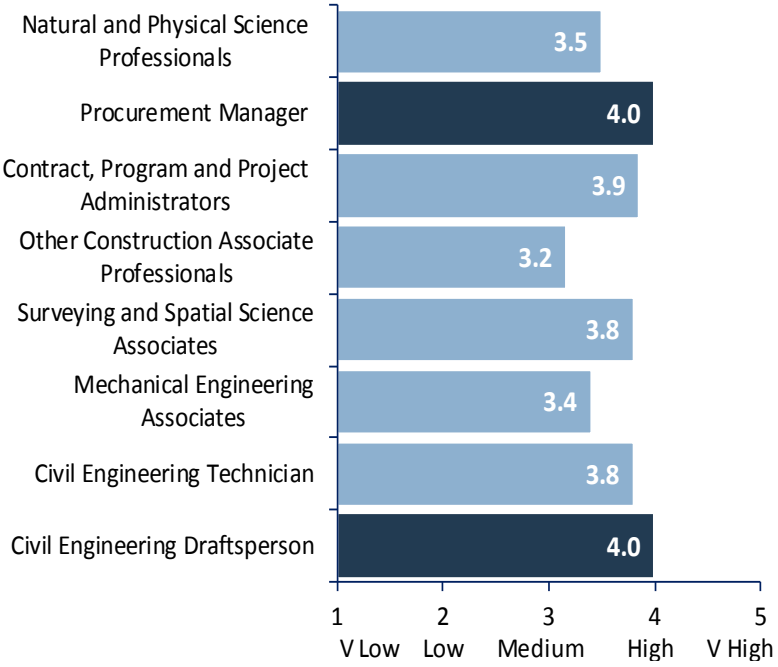


Figure 6.11:Road agency 10 year shortage outlook: Other skills

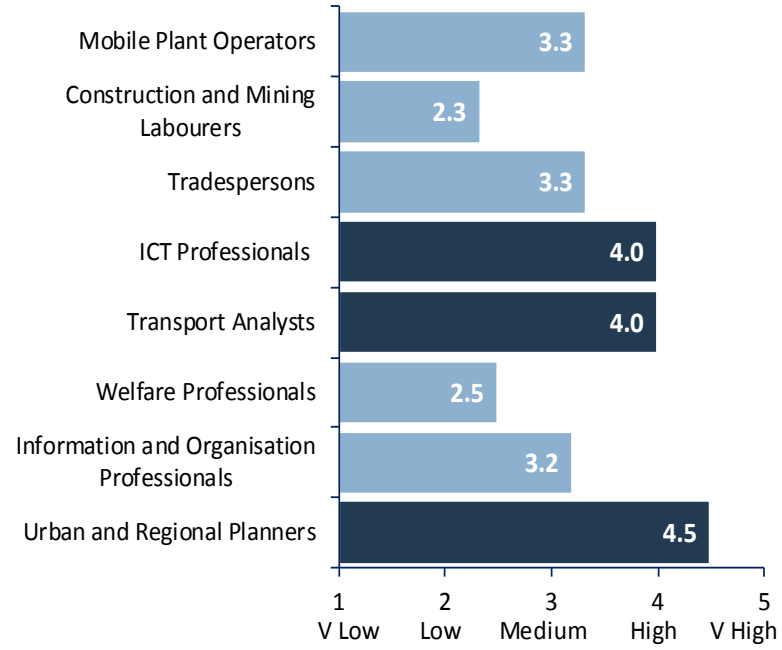


Figure 6.12:Non- Road agency 10 year shortage outlook: Other skills

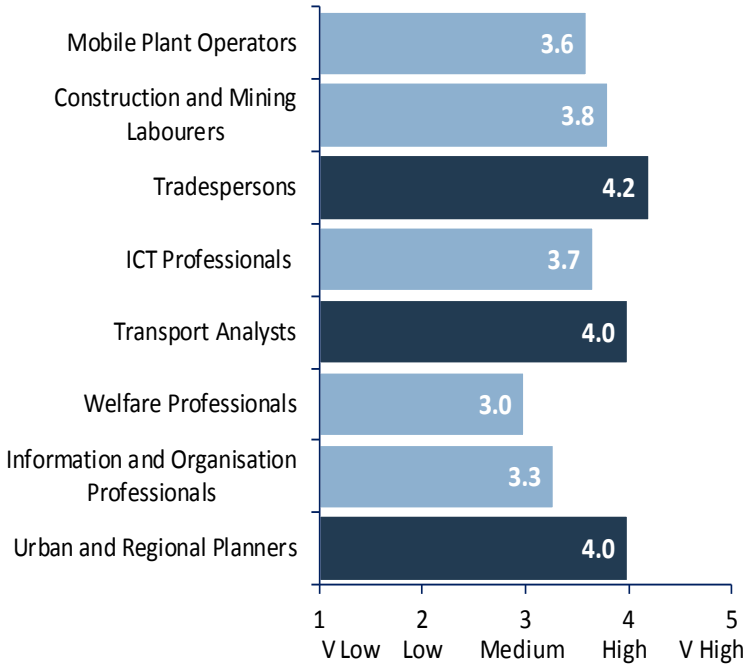


Figure 6.13:Road agency 20 year shortage outlook: University Design skills

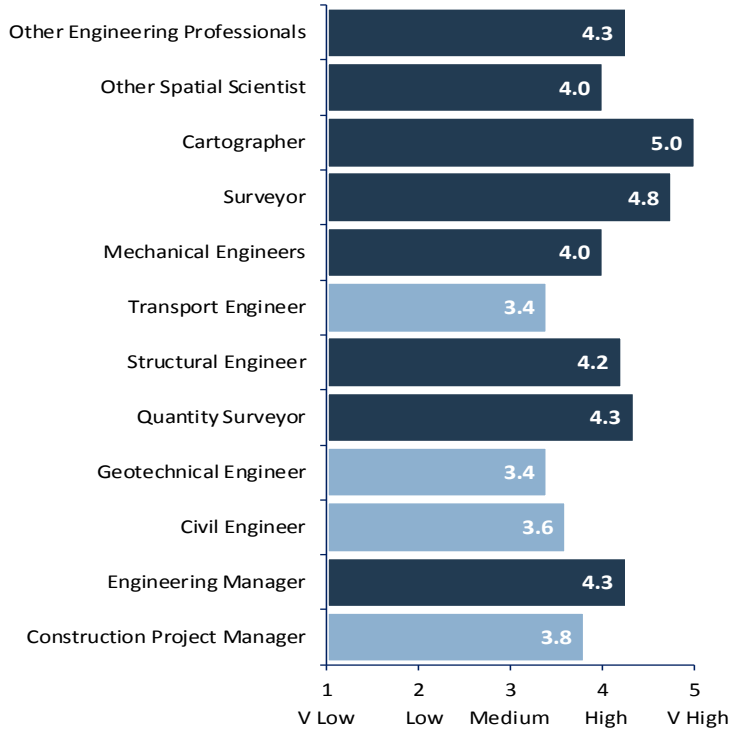


Figure 6.14:Non- Road agency 20 year shortage outlook: University Design skills

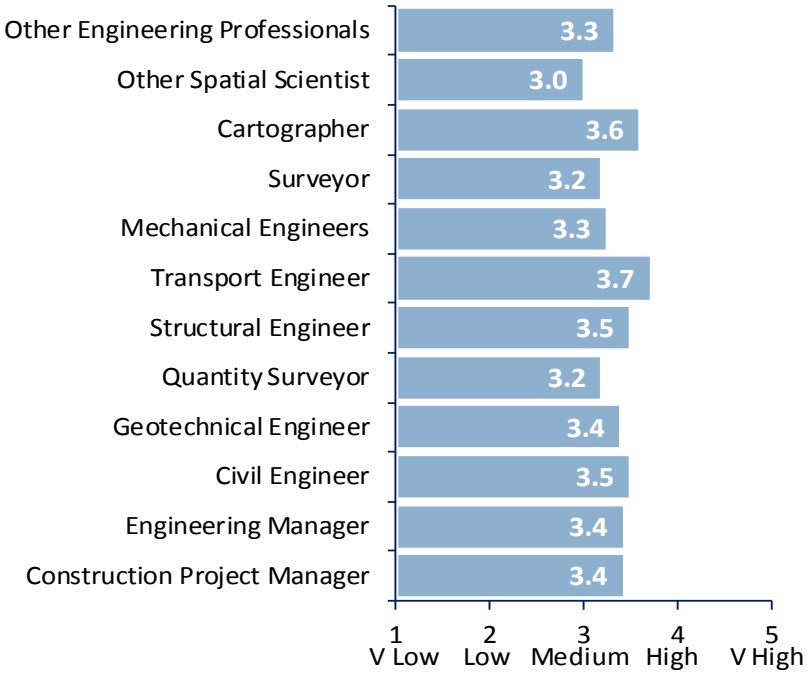


Figure 6.15:Road agency 20 year shortage outlook: TAFE Design skills

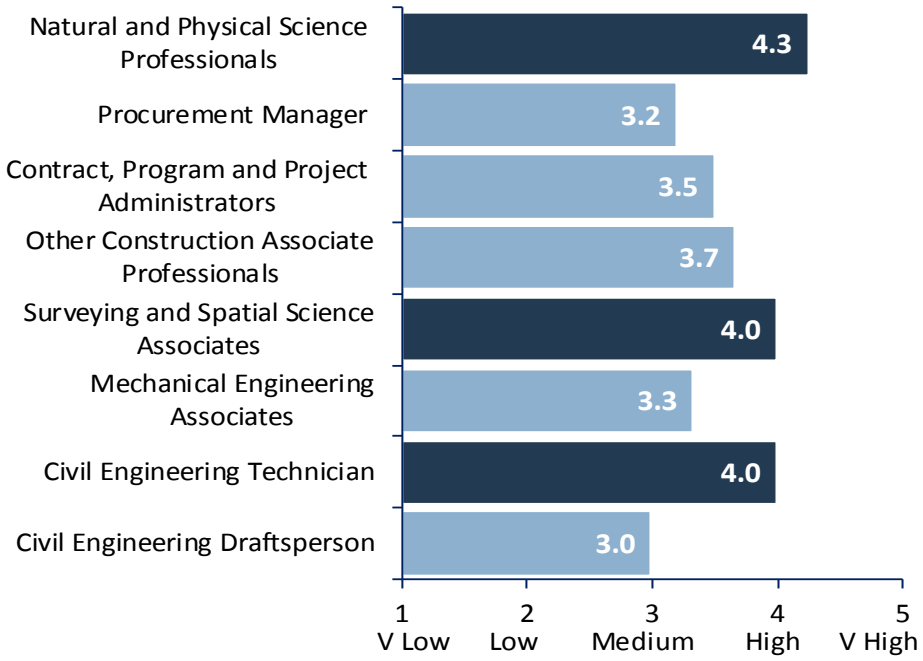


Figure 6.16:Non-Road agency 20 year shortage outlook: TAFE Design skills

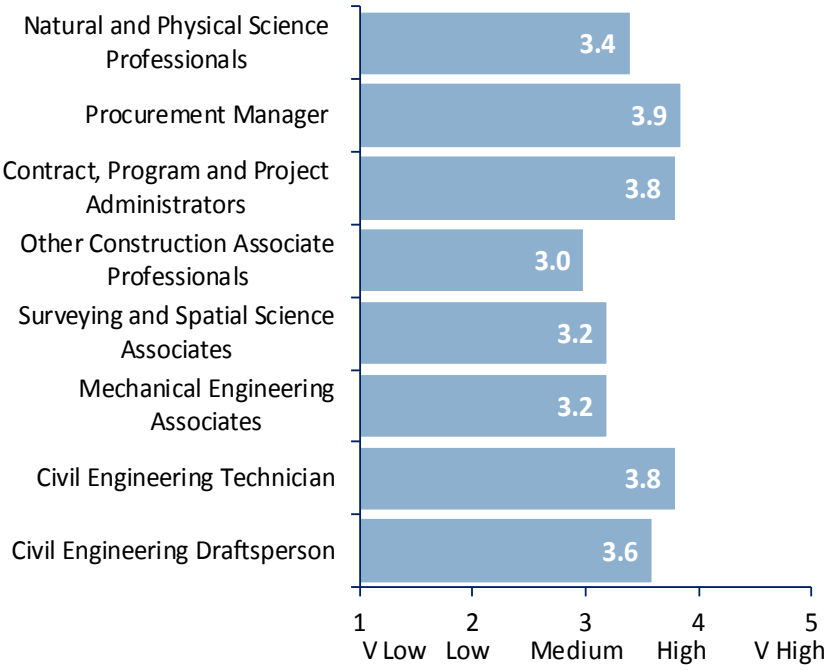


Figure 6.17:Road agency 20 year shortage outlook: Other skills

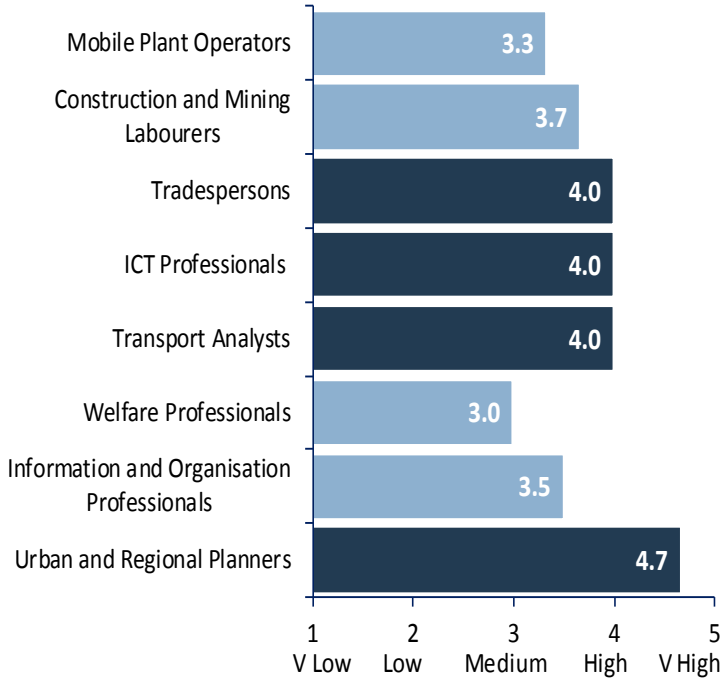
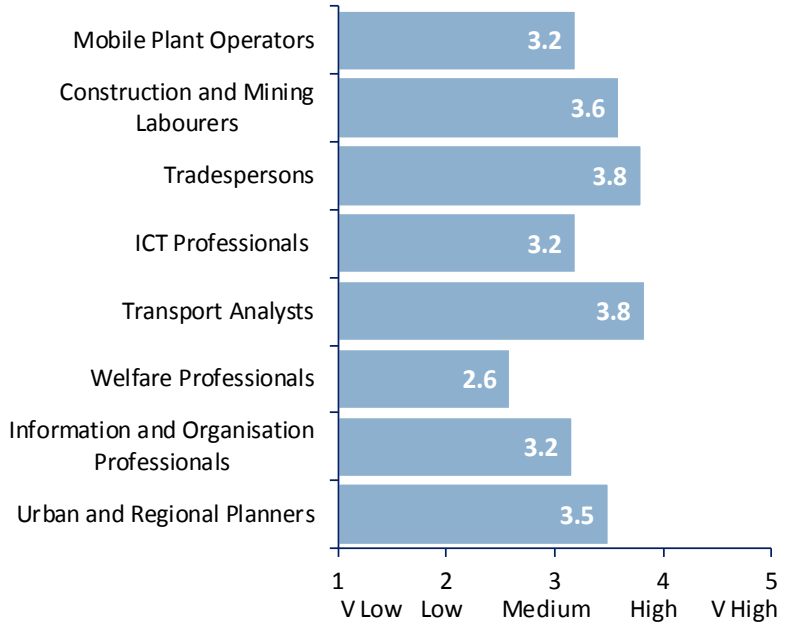


Figure 6.18:Non-Road agency 20 year shortage outlook: Other skills



6.1.4 Key Risks to Workforce Capability

In terms of risks to workforce capability respondents, both roads and non-roads agencies, identified the following as high risk factors:

- Changes to roads agency roles and functions
- Difficulty in attracting experienced staff
- Loss of knowledge as experienced staff retire.

In addition, the roads agencies identified retaining skilled staff with 4-5 year's experience from hire by other industries or government departments as a high risk factor.

More detailed risk factor metrics are presented in the following two Figures, comparing and contrasting the results from agency and non-agency responses.

Figure 6.19:Road agency workforce risks: 20 year outlook

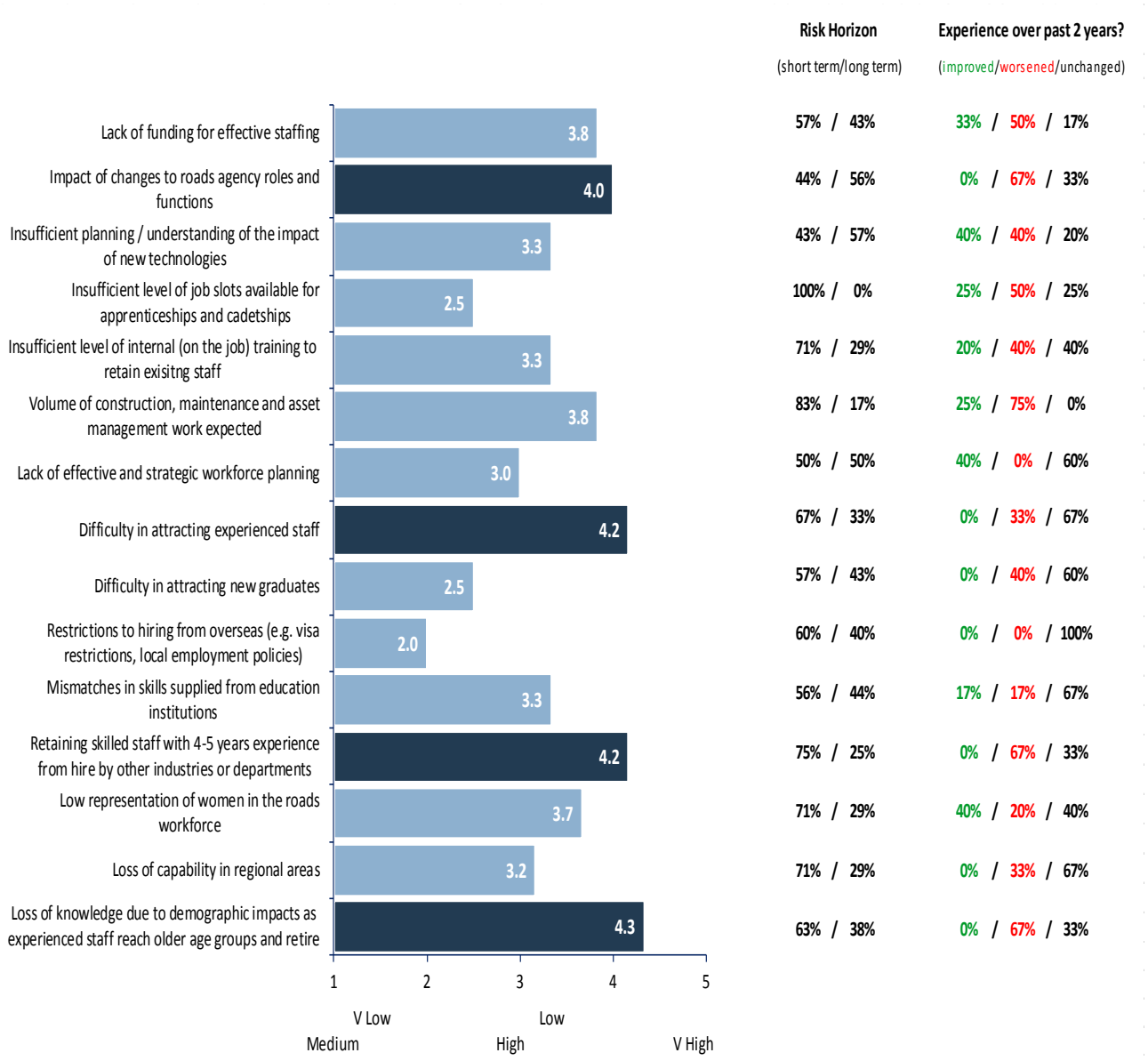
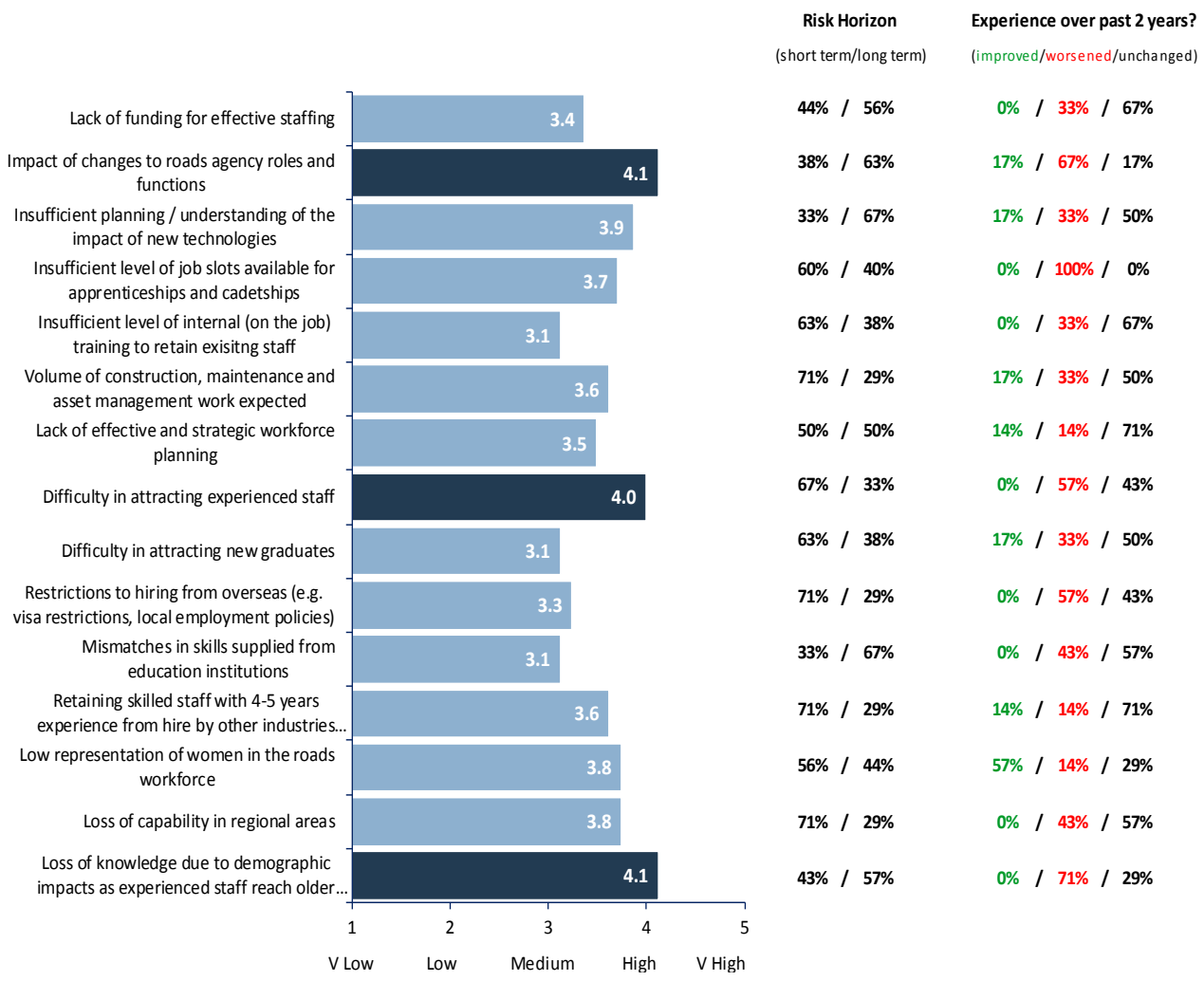


Figure 6.20:Non-Road agency workforce risks: 20 year outlook



Apart from ranking of risk factors, respondents were also asked to identify any risk factors not explicitly included in the survey questions. The following is a representative sample of these responses:

> *"The roads industry is very traditional and new technologies are slow to be developed and updated. Accordingly, we suffer from a high level of traditionalism with intransigence which should dissipate as the older generations retire."*

> *"The lack of a good construction and engineering industry profile to encourage workers to the industry and specific skill sets is a problem. This problem is likely to escalate as an ageing workforce retires and without legacy systems in place to learn and relearn - are risks to the quality and timely delivery of national infrastructure will be materially jeopardised."*

> *"Staying an informed purchaser of road engineering services is a constant serious problem."*

"I think we are going into a phase of where most of the experienced road managers/engineers/technologists are retiring and the new generation coming through is having to learn very quickly to fill the void. This is happening in an environment with great change in the transport sector where demands on infrastructure, budgets and staff are very high as well as technological advances are outrunning the road agencies. There is a gap like there has not been before between the generations whereby in the 80s, when Australia was going through recession, there were no jobs for engineers and technologists and the encouragement to enter the transport field was low. We are now suffering the consequences of those decisions. Additionally, no one predicted the level of issues that would be faced for the transport sector either. The community and governments continue to expect more and more, but that all costs resources - time, money and human. Road agencies are increasingly becoming un-informed buyers as well. This will have a consequence later down the track."

"The biggest risks associated with workforce capability and capacity is the inconsistency of funding and the lack of a constant pipeline of projects. These two factors limit industry's ability to recruit, train, develop and retain staff with the skills, knowledge and experience required to adequately and efficiently deliver infrastructure projects within Victoria."

"A major risk is the specialisation functions associated with delivery of ITS system services. For example SCATS and Freeway Management Systems, were there is no ready labour market available."

"There is difficulty in recruiting technical staff into regional areas."

"Get lots of applications, but find it difficult to attract skilled staff."

"Leadership development. Greater succession planning is required to ensure skills are retained"

"Funding and governance - political changes across Australia can have a big impact on future direction."

"RMS able to attract grads, retention is poor due to lack of career planning and private sector offerings higher salaries."

"Mismatch in core and technical skills, e.g Engineer undertaking contract management. Also is a retention risk".

"Broadly noted we are not competitive with Private sector in terms of career path and salary.

"In the future degrees in their current format will become less relevant but the capacity to learn new skills will become a critical capability".

"The requirements of the future will be market driven by consumers and disruptive players in the market rather than government strategy so the capacity to respond will become more important - also means we don't know what's coming".

"Education sector not providing the right people e.g a large number of resources needed to integrate systems and engineering. Potential lack of traffic specialists and analysts. Hard to recruit with traffic experience."

"Global view expected - need to keep up with other major cities."

"Attracting and retaining good candidates to roads industry is a big challenge."

"Loss of capability in regional areas - losing localised knowledge can be a risk when relationships/expertise is in someone's head and we can get more reliant in smaller locations on just one person who potentially has been there a long time - however turnover is lower in our regions so the risk is lower in terms of regular/high turnover."

"Low representation of women in the roads workforce – our focus is diversity and inclusions that is wider than gender, and is across a number of factors. We want to ensure a range of different perspectives, and diversity of thought and experience."

"We can attract graduates that isn't our main challenge, however we have much more scope in what graduates could offer that we are not making the most of, we currently don't have a strategy about where best to utilise graduates and what we do with graduates across a range of disciplines."

"Different skill sets that will be required along with the traditional skills, there will be an increasing need for people with multiple skill sets – e.g. engineering and commercial, engineering and technology, engineering and ability to think big picture/left field etc – so the real mix of traditional and new."

6.1.5 Key Risks to Workforce Capability from Technological Change

With technology, the common theme amongst respondents was that the roads industry was a largely 'old technology' industry and failed to attract bright graduates. In addition, new graduates liked to work at the 'high-end' technology developments, rather than traditional or 'old school' methods of data capture and analysis systems.

We are not sure as to whether this (i.e. old school technology) is indeed a reality or just an industry perception. If it is the latter, then more work need to be done to lift the profile of the roads industry so that appeals to graduates who are keen to have a career in the construction industry.

Meanwhile, technological developments allows for the capture of big datasets. The ability of the existing workforce to make the best use of these large datasets was identified as another risk factor. In other words, the roads sector, particularly the roads agencies, appear to lack staff who can interpret sophisticated datasets, analyse it and interpret them for policy making. There appears to be a dearth of talent in this space.

While it is relatively easy to get people who specialise in data science, getting recruits who also understand the business needs were definitely in short supply. This is an area where the roads sector needs to lobby the educators so that they produce well rounded graduates who can make important contributions to real world problem solutions.

The ranking of technology risk factors by roads and non-roads agencies together with its evolution profile, both historically and for the future, are presented in charts below.

Generally, non-roads agencies rated technologically-driven risk to workforce capability higher than roads agencies, with higher risks attached to the following:

- Insufficient sharing of data between or within agencies to drive solutions
- Insufficient behavioural / psychological skills to optimise management of the network
- Lack of appropriate engineering skills (i.e. process versus civil engineers)
- Inability to train existing staff to work in new, data-oriented roles
- Staff not having multi-disciplinary skills across data and other capabilities, and
- Attracting data analysts / scientists to the roads industry

Figure 6.21:Road agency technological workforce risks: 20 year outlook

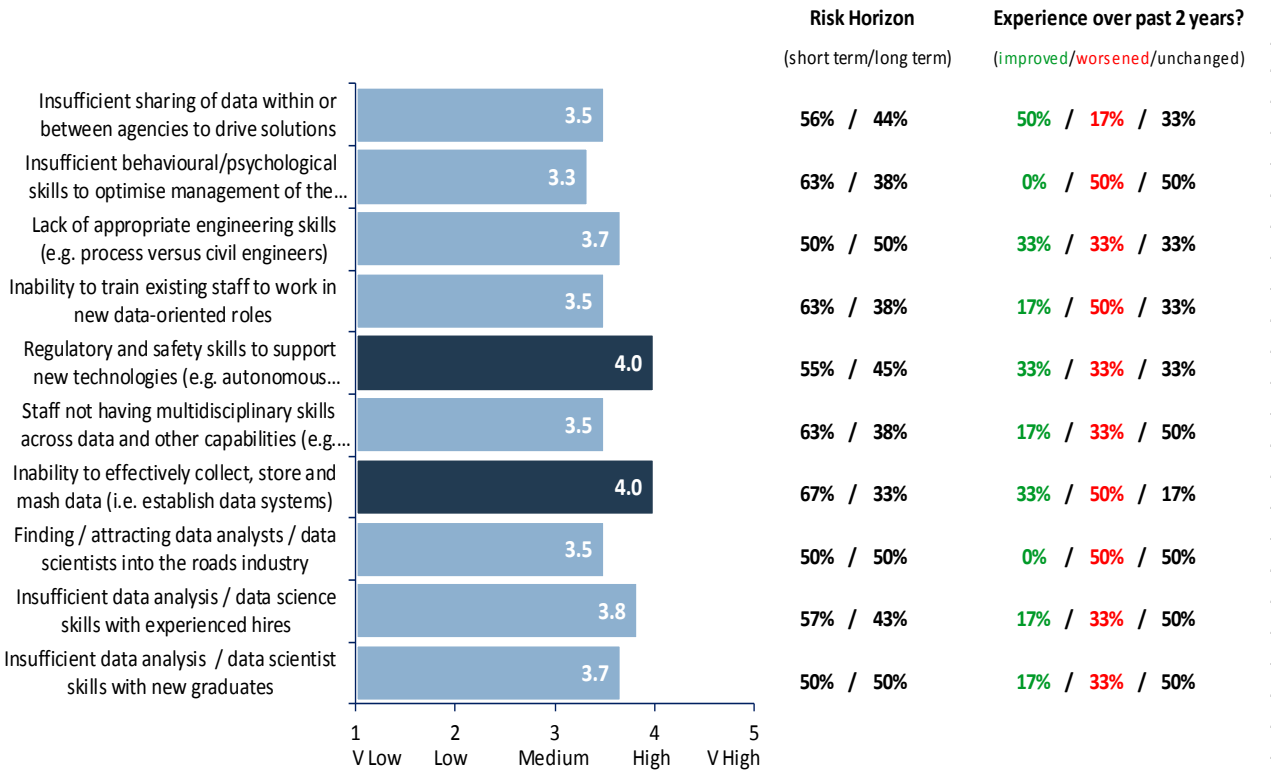
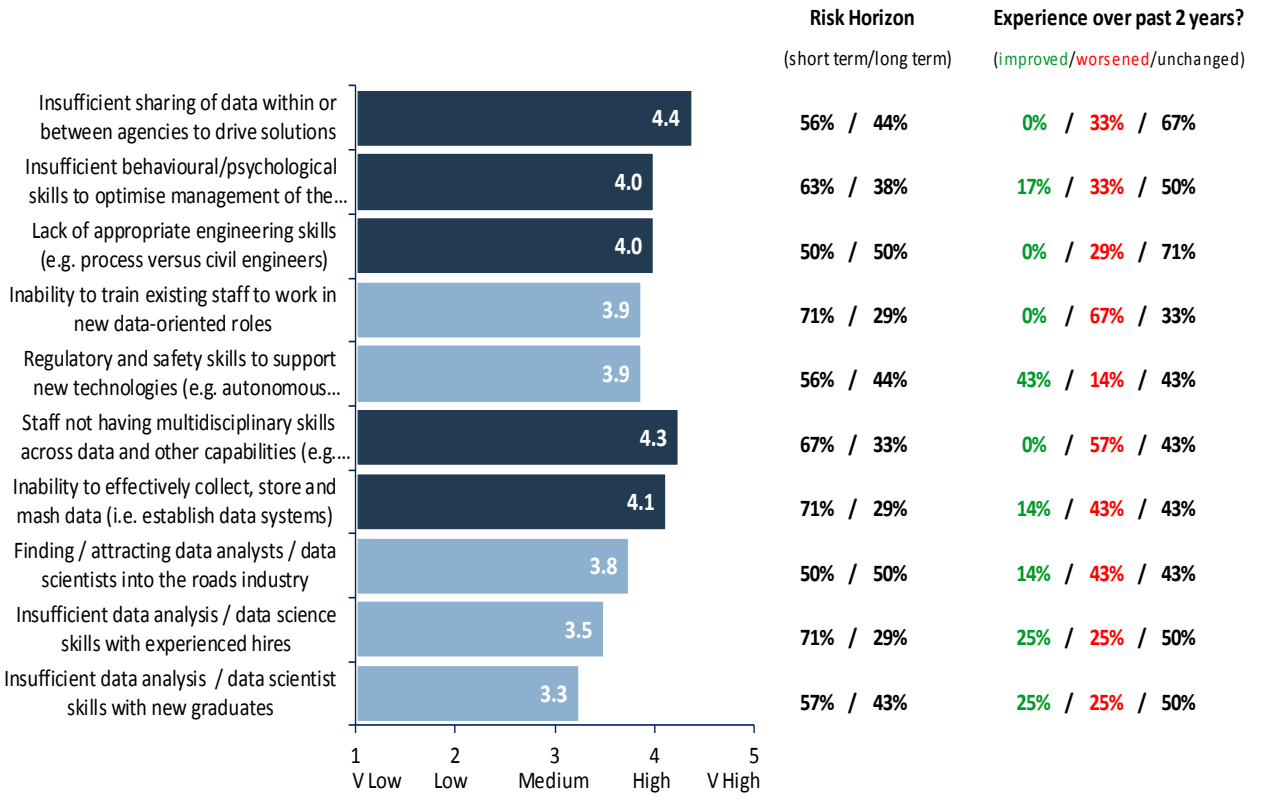


Figure 6.22: Non-road agency technological workforce risks: 20 year outlook



This part of the survey also generated some general feedback on how technological developments will potentially impact on roads agencies workforce capability into the future. Some recurring themes are summarised below:

> *"The use of big data sets is commonplace in other industries and we should be making use of them to track trends, needs, and predict demands and changes".*
>
> *"The rapid change in the technologies and the need to capture and utilise network operational data to manage and optimise the transport network has not been given adequate attention over the past years and has now impacting the on performance of the network."*
>
> *"Big data is increasing and there will be challenges in terms of capturing, storing, analysing, searching, sharing and transferring data."*
>
> *"New technologies currently not included in engineering (and other technical discipline) curriculum."*
>
> *"Technology is a major factor for predicting the future – we need enough resources and foresight to be early adapters".*
>
> *"Need technological vision for the future, particularly for ITS and smart city technology - difficult to determine as market dictates the future."*
>
> *"Policy around driverless cars and flying cars. Airspace is owned by RMS. Mapping and planning needed especially in large cities such a Sydney. Lots of potential for change."*
>
> *"While there is some acceptance that technologies will impact the way business is done. Technology has been having significant impacts in the road and construction industries for many years. While there will be more ability to collect and manage data the main skills will still be the ability to make decisions from the data. The development of systems and technology is largely advanced by private industry. Issues around autonomous vehicles like regulations, safety and insurance will be worked through like any other changes Governments make to policy. While this will be significant change particularly for cities, it should not need significant changes to skill sets. How data/information is available to the public in relation to congestion, network access and managing critical incidents will require new technology but this is more of a shift than significant change in skill sets."*

6.2 Insights from Industry Interviews

For this Report, BIS Oxford Economics has drawn upon its extensive network of industry contacts to conduct 'soundings' of industry leaders and participants. This has been used to gauge their concerns about a range of factors and risks affecting workforce capability, as well as glean their positive ideas for improvement. These issues include:

- Current and future roads agency roles
- Factors affecting capability of roads agencies now
- Occupations and skills where capability gaps may already exist
- Potential future scenarios which agencies should plan for
- Risks to capability from other industries through the outlook period
- How technological disruption will impact on agency capability
- Supplying appropriate domestic skills through education
- Future skills that agencies will need

- Other key risks to capability
- Potential solutions that can mitigate against capability risks.

As we 'took the pulse' of the industry we gained invaluable insight into industry concerns, as well as uncovering opportunities for better ways of sustaining or building roads agency workforce capability.

The breakdown of industry participation in the consultation program by type of organisation is shown in the following table.

Table 6.1: Industry Consultation by Organisation Type

Organisation Type	Number of Interviews
Industry Associations	3
Professional Bodies	2
Universities	5
Non-University Education	3
Private Contractors	3
Councils	2
Government Agencies	3
Total Non-Agency Interviews	**21**
Roads Agency Interviews	11
Total Interviews	**32**

Altogether, BIS Oxford Economics interviewed 21 non-agency organisations through September-November 2017 (including four from New Zealand), on top of 11 separate interviews with roads agency staff covering functions such operations and networks, capital works programs, new technologies, and workforce planning – making a total of 32 interviews. Most interviews were conducted by phone over 1-1.5 hours, but several were also conducted face to face in BIS Oxford Economics' Sydney offices, as well as on location at the interviewee's premises where existing travel plans allowed.

As in the general feedback from the survey, we do not identify or attribute any comments or views expressed in these interviews back to individuals or organisations. We have simply published the issues raised and the thoughtful contribution participants have generally made toward planning and policymaking for ensuring roads agency workforce capability in Australia and New Zealand.

Industry (and agency) interviews were less structured than the survey, with participants given rein to discuss, at greater depth, issues of concern. On reviewing interview responses overall, however, key critical themes emerged which could be classified as follows:

- Perceived current and future role of roads agencies
- Areas where capability is already perceived to be at risk
- Future skills-sets and capabilities expected
- Impact of new technologies on the roads industry
- Other key risks to workforce capability.

6.2.1 Perceived current and future role of roads agencies

Roads agencies are established under various jurisdictional legislation to manage the road network to provide road capacity, improve travel times, and maintain the actual road.[6] Roads agency roles have evolved over the past few decades, and this evolution was noted by both agency and non-agency participants in the industry consultation round – with other responsibilities of agencies may include driver licensing and testing, vehicle inspections and road safety. Local government is also a crucial custodian of road assets in Australia and New Zealand given the size and value of the networks under their direct responsibility. Through its role to develop and maintain key infrastructure (of which roads and bridges typically represents the highest value asset) and traffic management, local government plays a key custodian role in the roads industry.

Overall, based on recent survey results and industry soundings, the following roles are considered to be important agency functions currently, although there is some variability between Australian and New Zealand roads agencies in the extent to which these functions are undertaken 'in-house' or through partnerships with the private sector.

- Asset Management
- Delivery & Construction
- Maintenance
- Project Development
- Network Operations
- Materials Engineering.

In agency responses to the survey, there were listed other core functions which overlap these roles including safety and the environment, relationship management with governance, customer experience and behaviour, vehicle engineering and assurance, intelligent transport systems (ITS), planning and registration and licensing, amongst others. Each of these functions represents a call on particular workforce skills across engineering (various), management, communications, mathematics, science, data analysis, economics, finance, behavioural sciences.

Whereas previous capability research for roads agencies (including jurisdictional authorities and local councils) may have been focused on 'traditional' road construction and maintenance roles there is a far broader range of 'non-traditional' occupations and skill sets that agencies (or the broader roads industry) required to fulfil these functions.

As highlighted by one roads agency:

> *"This is not an engineering exercise. This is an exercise in understanding the customer and what their needs are from a mobility perspective. But we are also custodians of an asset and have a responsibility that this asset is put to its best and highest use. We need skills that are able to see both of those perspectives." – Australian roads agency*

And by another:

> *"In the past, agencies dealing with capability were typically concerned about construction. Now its more about having the capability to operate the network, into just the road. It's asset management, and answering the question: what is an asset?" – Australian roads agency*

6 Austroads (2010) The Commercial and Core Function Role of Road Agencies in Providing Data and/or Traveller Information, Austroads Publication No. AP–R352/10.

In what follows in this Section, there is a greater discussion of these roles, and the implications they hold for skills that are demanded now, and the kinds of skills that will be required in the future. There is also an acknowledgement that agencies have travelled down different paths in delivering their core functions, and this is likely to be the case in the future too. Agencies are likely to be able to learn from each other's experiences as they navigate technological, economic and social disruption over the next one to two decades.

> *"Our neighbours in New Zealand are already at that next stage. I suspect a lot of answers for roads authorities in Australia will be to look at what is happening in NZTA." – Australian roads agency*

> *"What agencies see as the broader environment over the next 10-20 years will shape their view on what resources they need… They have to be able to explain their decisions based on evidence." – Australian government agency*

Despite the potential for significant change over the next two decades, much of these functions and roles are still expected to exist in the future, but perhaps undertaken in very different ways, and perhaps with skill sets which are not yet available. A significant question becomes whether agencies, in their present form, will continue to provide them – or whether agencies themselves will transform.

As discussed further below, the nature of this transformation will also impact on skills demand. If the future involves a greater role for the private sector in delivering agency functions this will require skills in effective procurement and partnering, whilst also retaining sufficient skills in-house to remain informed purchasers of services.

> *"Look at the electricity market, water supply market – it's not one big agency that does it all now. These other infrastructure suppliers are pretty small, tight, lean operations that manage a whole lot of other service delivery people and roads will be no different. You won't need a huge agency." – Australian industry association*

> *"One of the major issues is how roads agencies strike a balance between in house resources and external expertise. ... when budgets are tight it may not always be the case that contracting in services will be the right delivery model." – Australian government agency*

As technologies drive the need for more holistic solutions across the entire transport network, roads agencies may likely see greater integration with broader Transport agencies. This is already happening in Australia and New Zealand, but could accelerate significantly in coming decades as road users focus increasingly on 'mobility as a service'. This, in turn, will drive demand for skills in communication, data analytics and 'sharing' skills, amongst others.

> *"Roads agencies will merge into transport agencies. You see departments of transportation now, multi-modal. Integration skills will be important. How do they integrate and communicate, how will the information be shared at a much bigger level." – Australian industry association*

Even if roads and broader transport agencies merge, however, there was a sense in industry interviews that there would still be a strong role for roads-related functions:

> *"There will still be a need for agencies that construct and deliver new infrastructure or refurbish or upgrade. You will also need an agency to look after maintenance and upkeep." – Australian contractor*

As roads agencies potential transform into and with transport agencies, so too is there expected to be a greater recognition of the broader importance of transport and mobility to the development of ideal cities – ideal places to live and work – which provide positive social, economic and environmental benefits to citizens. As put by one Australian university:

> *"We have to think more creatively. We are too used to thinking we have a problem, we have an engineer, the engineer solves the problem. But transport may not be the problem. The problem may be how do we design our life and our cities – we need to find the problem before we solve anything. We have trained all our engineers to think 'we have a road, we have people, how do we optimise these two things?'. But we should actually be thinking about where do we want people to live? How do we design a liveability city? These issues should come first, but they tend to come second. We tend to think about solutions before we think about problems.*

Consequently, as existing roads agencies transform to deal with future disruption, their ultimate goal becomes broader than just thinking about solutions for roads, or even solutions about transport. As what follows in the discussion below, this broader vision for agencies also brings with it the need for a broader, multi-disciplinary skill set across design, technological, informer and artisan clusters. Above all, there will also be demand for an attitude that is adaptable, flexible and creative, that is willing to learn – because so much of the future remains unknown and untaught – and is willing to embrace change.

6.2.2 Existing capability concerns

A key question asked during the interview round – as well as in surveys – was whether roads agencies (or the broader roads industry) already experience difficulty in retaining or attracting skills or if shortages of skills or capabilities were already perceived to exist.

As noted by Richardson (2007:p7) there is no simple single reliable measure for the existence of a skills shortage, and the usual practice is to rely on a range of indicators. Not only that, the term 'skills shortage' itself is difficult to define given that demand and supply of skills can be hard to measure. A good working definition suggested by Richardson is as follows (as a Level 1 shortage):

"There are few people who have the essential technical skills who are not already using them and there is a long training time to develop the skills."[7]

Government agencies in Both Australia and New Zealand undertake research to determine occupations where skills shortages exist, although in some cases the shortage may only be at a regional level. These occupations are consistent with the standard ANZSCO classifications used in Australia and New Zealand (and also utilised in this research). For Australia, the key 'roads related' occupations which are already deemed to be in shortage at the national level include:

- Construction Trades Workers (ANZSCO 33)
- Architects (2321-11) in the eastern states
- Surveyors (2322-12)
- Civil Engineering Professionals (2332 11,12,14,15)
- Construction Estimators (3121-14).

However, it is a very different picture by state and territory across Australia. In Western Australia, where construction activity has fallen significantly in the wake of the resources investment downturn, very few occupations are listed in shortage – and none from the above occupations drawn from the national list. In New South Wales and Victoria, however, where construction activity is rising strongly from surging non-mining investment, the skills shortage list is longer and, apart from the above occupations, also include other engineering professionals such as electrical engineers (233311), mechanical engineers (233512). Smaller, more remote jurisdictions, such as the Northern Territory and South Australia, also report shortages of engineering professionals. This suggests there is a regional aspect to skills shortages across Australia. While demands for skills typically vary from jurisdiction to jurisdiction, these variances may also suggest that there may be some 'stickiness' in the mobility of skills from areas of weak to high demand.

7 Richardson (2007: p9). Level 2 shortages are defined as those where a short training time is required to develop the skills.

In New Zealand the following occupations are deemed to be in long term shortage

- Construction Project Manager, Roading (133111)
- Construction Project Builder, including Site Foreman (133112)
- Quantity Surveyor (233213)
- Surveyor (232212)
- Chemical Engineer (233111)
- Materials Engineers (233112)
- Civil Engineering Professionals (2332 11,12,14)
- Electrical Engineer (233311)
- Electronics Engineer (233411)
- Mechanical Engineer (233512)
- Environmental Engineer (233915)
- Engineering Professional nec (233999)
- Civil Engineering Technician (312212)
- Electrical Engineering Technician (312312)
- Electronic Engineering Technician (312412)
- Procurement Manager (133612)
- ICT Analysts and Professionals (2611,11,12 2613, 2621, 2631, 2632).

The following were also included in New Zealand's immediate skills shortage list:

- Building surveyor (312113)
- Construction Project Manager, Roading (133111)
- Surveying or Spatial Science Technician (312116)
- Civil Engineering Draftsperson (312211)
- Electrical Engineering Draftsperson (312311)
- Mechanical Engineering Draftsperson or Technician (312511, 12).

The industry consultation program as part of this project produced similar findings regarding the perception of existing skills shortages. In general, respondents identified occupations where shortages may exist according to their level of expertise or experience.

For contractors, skill shortages were apparent in both Australia and New Zealand, with key existing shortages based in the construction program itself. This typically included 'on site' professional skills such as construction or site managers, foremen and surveyors, as well specialist skills in project controls and estimation.

> *"We are already struggling with engineering resourcing now. You have your rail specialists and your road specialists and there's quite a few engineers who can do both. Whether it's concrete works or earthworks or geotechnical iOS structural, whether its road or rail people can still manage both, and the same with the foremen and so on." – Australian contractor*

"If you're a good employer, never had a problem attracting staff. One area we are getting short is in senior project managers capable of running big projects. That's where the shortage will come. We've tried to have a succession plan, training the people coming through to be site engineers, project engineers, project managers." – New Zealand contractor

"We are already at the situation now where we don't have enough people in the industry to deliver what we have got. There's also a skills gap in that we don't have enough of the grey-haired silver people. There's a lot of people in the 5-10 year bracket doing work that used to be in the 10-15 year bracket, so things aren't being done quite as well. There are still getting done to the right standards, but not as efficiently." – Australian contractor

"There is a shortage of estimators and project controls - running the program and the cost to complete and financials to complete these projects. We employ a lot of people out of South Africa. You don't see universities or polytechs running programs on this - it tends to fall on surveyors or project engineers who we train in these disciplines. I've never seen this as part of an engineering degree." – New Zealand contractor.

Even where there are enough people to fill the roles, interviewees noted that the quality of skills have been in decline in recent years, affected by the retirement of high quality skills from the workforce which has seen people with less skills and experience take on senior roles – coupled with inadequate training.

"There a lack of practical skills, hands on skills, operator skills. Industry has grown but skills development hasn't come with it… The development of skills is very slow and we have a real skills shortage gap sitting there right now. And it's not just someone who can operate a machine or swing a hammer, but someone that is truly good at their craft which then becomes a quality issue." – Australian contractor.

More remote jurisdictions, as well as the local councils that were involved in the consultation program for this project also reported existing shortages of engineering professionals. Here, the challenge was accessing specialist skills, with road agencies at the jurisdiction and local level typically employing generalists that could cover multiple positions and training them internally in the appropriate specialisations:

"We have had [a shortage of skills] for a long time. Some of those specialist skills in particular - bridge engineers, traffic engineers - because you can't really specialise here. There is such a wide variety of issues you have no one else to rely on. So you end up broadening your skill set." – Jurisdictional roads agency

"We have significant shortages of engineers at the local government level, particularly in rural and regional areas. The mining boom exacerbated that. Queensland and Western Australia found it very difficult to retain staff. You could drive a truck in a mine for $160,000, which is a senior engineer's salary. But the drift back has now occurred and people are coming back into local government." – Industry association.

Interestingly, there were mixed views expressed on the shortage for surveyors. While being on both skills shortage lists for Australia and New Zealand, and nominated as being in shortage by interviewees, it was also noted that rapid advances in technology had made the surveying profession far more productive over time:

"Surveying has changed a lot over the last few years. A big earthworks job can be surveyed by drone and we can have data very quickly. That's been a huge leap forward in terms of technology. Our surveyors have taken the technology on and have gotten trained up on operating drones and computing results. If we were doing that on a month by month basis we would need 20 or so surveyors with weeks to get results. Now we can do it in a day. " – New Zealand contractor

> *"Availability of engineering professionals is a concern. I'm lucky enough to have a registered surveyor here but the industry in general doesn't have enough of them, and there are other specialists such as bridge designers that are quite hard to come by. If you're a smaller council you won't have a registered surveyor, you will contract out that work." – Australian council*

> *"Surveyors are very hard to get. We got ours from Western Australia. We put out a tender and have a panel of 3 surveying companies and we've gone to that panel to do work and they've come back to us to say they are too busy. When our surveyor gets saturated, its very hard to outsource the work" – Australian council*

However, increased productivity through changes in technology also brought new issues, particularly in the area of 'onsite' training:

> *"One thing I've noticed is that with improved technologies and drones, what used to be undertaken by a team of surveyors is now be done by a single surveyor. But the question I have is where are the new graduate surveyors going to get practical on-site training by an experienced colleague? That avenue for training is drying up." – Australian contractor*

Pavement engineers were seen as experiencing a critical skills shortage in both Australia and New Zealand at the local government level:

> *"One area where we need skills is in pavement engineering. Sometimes we have been caught out trying to get it done cheaply and pavements have failed prematurely, particularly bus routes. We had a contractor who supplied us with substandard materials over four years. If we had the skills in house to look at that asphalt independently, we would have cut that contractor earlier and would have had the premature failures that we now have to fix." – Australian local council*

> *"Most of the road money in councils is spent on asphalt: understanding the different mixes, how it performs, conditions you can use them. You really need some engineering background to understand that. It's not really taught that well at university. Same with traffic engineering. It's a specialist skill not taught to a great detail in university but you pick that kind of work up in a practical sense at work." – New Zealand local council*

> *"We need at least one pavement engineer. The last one we had left a decade ago. We outsource it, but it adds to the cost of each project. Recruitment and the ability to pay for a soil technician seems a bit of a pipe dream at the moment." – Australian local council.*

Meanwhile, as councils outsource more and more work is placing pressure on their own procurement processes and strategies – itself requiring a range of skills across engineering, contracting, legal skills and logistical skills:

> *"We need to have 'smart buy' capability in councils, that we know how to procure things. Procurement is a massive part of what we do. There's two aspects here. Firstly, the procurement of what you are after; the more you put into the front end, the better the services you will get. Understanding your business is important. There are legal issues with having a good contract document. Procurement specialists may not necessarily be engineers, they qualify for logistics at university and branch into supply chains or procurement." – New Zealand council.*

Contractors and local councils involved in the interview round also reported on their experiences with jurisdictional roads agencies, and whether there were already existing capability gaps within these agencies. Here, the main areas of concern were in regards to design, procurement and having adequate in-house skills to be informed purchasers of industry services.

> *"Their knowledge is only with a couple of people. If they were run over by a bus they would be floundering. The have a good person who understands the hybrid alliance model. He knows the pitfalls of different procurement models and has a lot of industry knowledge. If they lost him, they would be in a lot of trouble." – New Zealand contractor*

"The agency frequently don't have the staff with the skills to manage this. So they need a lot more skilled people to manage the work they are putting out to industry. They have a huge backlog. There is probably $4 billion in construction work over the next decade within Waikato/Bay of Plenty region alone. Not all of that will go through but there aren't the staff in the agency to physically manage that – to write tenders, to check tenders, to do contract payments, to do contract meetings. They don't have the people." – New Zealand professional association

"We have an environment now where we have pretty uninformed clients – and that sounds critical, but they are – at a very high level all the way through the agencies with remnants of the skill sets left… we have a few engineers left, but they are in a tiny minority and they are going at a fairly high rate. They retire and are not replaced at that level, that high quality of expertise, with international recognition." – Non-university education provider.

"We have anecdotal evidence that the agency is struggling… this is first year we haven't requested the council to accept the agency grant because it hasn't been offered yet. If we don't get the grant before the end of the calendar year, we will have to wait until February which gives us only 4 months to undertake the works. This will particularly affect asphalt works, which are best done in summer as you can't lay it in wet and cold weather as it crystallises too fast." – Australian local council

"Project management capability is the one area where we feel agencies are a bit short. The experience and skill sets seem to be variable. They have technical resources there but experience still seems to be an area they're short of." – Australian contractor

"One area where they may be an issue is in design. We design roads that are adjoining state roads. The agency has problems trying to get to a final design in time or at least getting an indicative design out of them that we can tie in with our regional road." – Australian local council.

Outside of the more 'traditional' engineering roles across design, construction, contracting and procurement, industry soundings suggested two other broad areas where skills shortages may already exist in roads agencies (encompassing both local councils as well as larger jurisdiction roads agencies). These included:

- Technology-related skills and occupations to work with data – particularly in real time network operations roles, as well as
- Economics or financial skills that could help agencies meet challenges regarding declining revenue streams and support better business case development

Industry soundings findings regarding the impact of technological change on roads agencies and the broader roads industry are unpacked further in Section 6.2.4 further below. Of interest here are responses which indicated where technology-related skills may already be in short supply. The increasing ability to collect data from assets, combined with the developing science of both "tactical" and "real-time" traffic operations management (via data collected from vehicles, phones, third party platforms and public transport) as part of roads agency networks functions, were highlighted by roads agencies themselves as potential areas of shortage now, with that shortage expected to intensify as data and technology continues to develop.

"We have all moved to evidence-based policy and investment decisions. That evidence is usually in the form of data. Having skills around capture, management, analysis, reporting of data is growing, not shrinking. And you have to be an informed purchaser. You have to have a certain amount of knowledge or you don't know what it is you are buying, or what you are using. So data skills won't go away." - Australian roads agency

"Local councils in some jurisdictions are woefully behind in terms of understanding the physical value of their assets, as opposed to their accounting book value – which tends to be very different. This is a big risk for state jurisdictions given that the value of roads assets in local government hands makes up a big part of their balance sheet. The increasing availability of data will change asset management for the better at the local government level, but we need people now who can understand and set up the systems, that can go about collecting the data and then to analyse the results." - Industry association.

"We have divided our junior resource team into 'real time' (day by day) and 'tactical' (what's coming up and how do we plan around that?, but also what are our strategic policies and how do we know we are moving in the right direction?). The tactical team has been completely overrun by planned works because all of a sudden we have a major investment in infrastructure, and not all of this is being rolled out by us." – Australian roads agency

"Real time modelling is where we differ to the core skills we were used to asking people about. Civil, surveyors, construction deal with static information, but transport modellers and traffic engineers deal with a lot of data all in real time. That's where we find ourselves in the space of CAV, because its just an extension of what we do. Its real time." – Australian roads agency

"We have three or four people in the traffic operations corporate section. Its not many, and we outsource to others to expand. They are the real time data folks." – Australian roads agency

"We don't recruit for it (data scientist). The way it works is if there is a job vacancy, whoever applies and gets through the process is who we get. At the moment there is no strategy, no structure to how we find these skills. We go to market, and we hope there is someone out there." – Australian roads agency

Interestingly, not all roads agencies – particularly at the jurisdiction level – reported a current deficiency of 'data' skills, although it was acknowledged that it presented risks to capability in the future. In particular, several agencies reported that data skills were available within the agency but may need to utilised in a different context, or exposed to new challenges.

"Civil engineers are used to dealing with big data. It's the nature of real time traffic data. And doing large scale transport modelling – an extension of the same theme. Traffic engineering is just a discipline in civil. You can do highway and design or traffic analysis or both. Most civil engineers dabble with one or the other at first, then pick their poison." – Australian roads agency

"Data is not a new concept in engineering. Where the data comes from may not be from our workforce today." – Australian roads agency

Meanwhile, technological disruption is already creating economic challenges for agencies that are also anticipated to accelerate from here. In particular, roads agencies and the broader roads industry noted that there is already an increasing need to develop sound business cases for investment in roads assets as governments target greater efficiency and productivity gains, and try to do more with scarce resources. Furthermore, there was seen to be an immediate need for greater economic and financial modelling skills and capabilities to examine potential alternative mechanisms for funding and financing roads investment.

"What are the flow on effects of new vehicle technologies? Less people paying for the public transport system, so it's not economically viable. Also, people will not need their own car anymore, so there are less people paying registrations or drivers licences every year. So again, less revenue to the government. The vehicle will almost certainly be electric. That means we are no longer getting fuel excise anymore. Nearly every revenue stream you can think of will reduce per capita." – Australian roads agency.

> *"The other key challenge is coming back to fiscal reality of doing more with less. In particular, recognising the differentiation between the roads agencies, the 540 local councils, many of who have extremely constrained resources. There are two issues here. Firstly, a broader issue around pressure on roads budgets. It's hard to see any governments seriously embracing road user charging, except perhaps for heavy vehicles, in the next decade to fifteen years. So roads will continue to be funded from general government revenue. And every budget - roads, health and education - will be under pressure. We are deluding ourselves if we think other revenue is going to come in to save the day. It's just nonsense." – Australian government agency*

> *"Progressive agencies have introduced a chief economist in their ranks, not necessarily on the same level as chief engineer (a role agencies have had for 100 years). Transport economics has been run down in the academy in a large number of locations in Australia." - Australian university*

> *"The next 20 years will see increased public demands for transparency given the need for awkward decisions under a finite budget. These agencies have to continue to develop the capability to help governments, because from a broader economics and social justice perspective if they don't – and we continue to put money where it is not necessarily justified – then we are letting the country down." Australian government agency.*

While the number of people studying economics as a degree has declined significant in Australia – and more so for women than men – the discipline of economics provides a range of skills and capabilities which would be very useful not just for roads agencies but across many industries. As pointed out by Alexandra Heath, Head of Economic Analysis at the Reserve Bank of Australia, in a recent speech:

"There are a number of occupations that require higher levels of analytical thinking, maths skills and other cognitive skills. Some of these are obvious, such as engineers, scientists, IT professionals and architects. Others are, perhaps, less obvious. One of these occupations is an economist. According to the data on what skills are required for different occupations, economists require significantly more analytical and complex problems solving skills, maths and programming skills than the average skilled occupation. The ability to communicate is also important. This makes it look like a good candidate for a future-proof occupation."[8]

While possibly ahead of Australian authorities with regard to 'economic' asset management, New Zealand was, however, seen as having potential capability gaps in the procurement of business case skills (which itself could have an economics foundation) which could delay projects.

> *"There is a problem with procurement of business case skills. There are numerous organisations have skills, but the way they are procured is a problem. There is a panel of three or four consultants who do it all – that's not enough people to make a difference. In the approval process, there are not enough people with sufficient skills or the ability to make decisions running it. So it all stops." – New Zealand professional association.*

Skills in economics – as a behavioural science – were also seen as advantageous now as part of a broader understanding of current and future behaviour of users of the road network. As roads agencies aim to maximise the social benefits of road networks, optimal solutions may not simply revolve around what infrastructure to build or maintain, but rather how to influence behaviours so that the most is made of the existing asset stock.

> *"We can influence people's behaviour and their decision making along the lines of 'Re-route, Re-mode, Re-time, Re-think'. New South Wales is using 'Re-route, Re-mode, Re-time , Reduce'… This is a whole area of expertise which we just haven't had. Road authorities used to have these skills in 'road safety'. We had psychologists looking at influencing peoples decisions about making safer travel decisions. These are all non-engineers, and we have nothing like it when it comes to making other decisions around mode, time of travel, route to travel." – Australian roads agency*

8 Heath, A. (2017) Remarks to the Victorian Career Advisors conference, Reserve Bank of Australia. https://www.rba.gov.au/speeches/2017/sp-so-2017-12-01.html

"Behavioural decision-making, decision sciences. Economic psychology. Behavioural economics is the big growth area of economics and this is what it is all about. Economists need to know a lot more about psychology. This will be really important." – Australian university

"The ultimate aim is to change people's decision making. Traditionally we have used infrastructure to do that. Since the 1990s, for example, we have had a cycling infrastructure program. Cycling has doubled since that time. Based on surveys of cyclists about how they felt riding with traffic." – Australian roads agency.

6.2.3 Future skill sets and capabilities

As Australian and New Zealand roads agencies' functions evolve, and new technologies emerge, new skill sets will inevitably be required. Predicting which occupations and skills, exactly, will be in higher demand in future is a challenging task however, with many in the industry soundings suggesting that many of these roles may not yet exist, or depend heavily on the 'future world' identified by agencies themselves. As some respondents noted, in a common theme:

"Trying to land on specific roles now requires looking at multiple futures and seeing what works in those futures. We don't really know what is going to happen… The overriding issue is the uncertainty of the future in this area." – New Zealand university

"I don't know if it's possible to forecast the capability requirements for these authorities unless we work out how industry would respond to the various scenarios." – Australian contractor

"It's not about what the future will look like – because we don't know ourselves – but to think more about flexible scenarios about what could happen and what we would do in each one. To think through the possibilities and keep managing it as you go. You have to be agile. No one can predict it. That skill, not to be stuck in one way of thinking, is very important." – Australian university.

However, despite this inherent uncertainty, a broad consensus did emerge regarding the types of 'future skills' and capabilities roads agencies are likely to need. In turn, these types of skills could be classified as the following:

- Asset management
- Operations skills – in both a 'tactical sense' and in real time
- Engineering skills to procure services and products as informed purchasers – and anticipate demands wrought by technological change
- Technological skills to establish and secure useful data systems
- Analytical skills to interpret vast arrays of data and make decisions
- Economics skills to develop robust business cases and funding methods
- Behavioural skills to better anticipate human reactions to new technologies
- 'Soft skills' to communicate ideas, and solve problems in what is likely to be a highly disruptive environment.

Asset management

Asset management was amongst the most highlighted future skill set from the industry interview round, and was consistently mentioned by contractors, educators, industry and professional associations as well as the roads agencies themselves. For the latter, the importance of asset management ties directly to the key role and function of roads agencies:

> *"This is not an engineering exercise. This is an exercise in understanding the customer and what their needs are from a mobility perspective. But we are also custodians of an asset and have a responsibility that this asset is put to its best and highest use…Sometimes these intentions do not work well together. If you tried to meet every customer's needs you may not be doing the best for the whole. There's a tension between the individual and the general good. We need skills that are able to see both of those perspectives " – Australian roads agency.*

Asset management – which combines aspects of management, financial, economic, engineering, and other practices applied to physical infrastructure assets with the objective of providing the required level of service in the most cost-effective manner over the asset life – has evolved as a business discipline over recent decades. In Australia, the Asset Management Council (AMC) exists as a non-profit technical society within Engineers Australia and is a founding member of global forums and partnerships in asset management. In New Zealand, NAMS (New Zealand Asset Management Support) is a non-profit subsidiary of IPWEA NZ, partnering with industry to raise awareness of the discipline, and assist the development of guidelines and training. The release of international standards for asset management (ISO 55000) in 2014 has assisted the global development of the discipline and education courses. In Australia and New Zealand, asset management courses are run by AMC, IPWEA, ACEAM Training independently or through education institutions including the University of Tasmania, Chifley Business School and Bond University.

The core aspects of asset management are a focus on (i) providing a defined level of service from an asset (in this case, a roads or transport network) (ii) in the most cost-effective manner, (iii) over the life cycle of the asset and (iv) managing long term demand and risks in a sustainable way. Consequently, effective asset management requires a multi-disciplinary skill set encompassing engineering; economics; finance; data collection, storage and analysis.

> *“Asset management is an integrated, multidisciplinary delivery of a whole lot of different services. It ties together materials engineering, network management and financial management for long term planning. Maintenance is just one bit of it. But you need to have a perspective of why we need the asset in the first place.” – Industry association.*

Operating under a budget constraint is a crucial differentiation of asset management as a discipline from the ‘mere civil’ role of agencies in building and maintaining assets. From industry soundings, it was clear that agencies need to enhance the ‘systems’ view of their networks rather than holding an asset-centric view, and to prioritise works across the system which maximise the value of the network as a whole with the limited resources available. This prioritisation and optimisation role is expected to become more and more crucial as revenue challenges intensify over the coming decade.

> *“It’s going to be systems analysis rather than a pure engineering analysis. Engineers are going to have to change their thinking or there are going to be new systems engineer types or systems analyst type role to be able to look at the system and the patterns and prioritise things from there. Currently, we would only look at one section of road and this needs work done on it and it will cost this much. When you are looking at a system you have more of a helicopter view and will be able to see a network of problems. The analysis of that becomes quite different. You will be able to prioritise with a lot more confidence where you are spending your asset dollars.” – Australian roads agency*

> *“It’s also important that we have an economics and management background as well. Engineers lack an understanding of profitability, financial modelling, bottom line. Working with financial data and constraints. We need systems thinking. Not a lot of people are being trained to think about complex systems.” – Australian university*

As data from assets becomes more available – to local councils as well as jurisdictional road authorities – industry soundings suggest that there will be an increasing requirement for agencies to utilise the data to maximise asset management outcomes. In turn, this is expected to see a greater demand for data collection and management (incorporating strategic asset management software – or SAMS), and a multidisciplinary skill set to interpret the data and make long term asset management plans. However, it may be up to each individual agency as to how much of these skills need to be in-house or outsourced from the wider industry:

> *"We are transitioning into a much more heavily information-dependent age so those sets of skills regarding information management and databases will be vital, and agencies are having trouble managing that, let alone having masses more data available to us and we are not going to be doing traditional data capture like we have up to now." – Industry association*

> *"We've been running our own SAMS for the last 10 years and we have recently made the decision to go across to a different SAM module that requires that information. As a result we have just finished our first survey of our network. We will use the new data; change the way we do things. We've had to bring in a company with the machinery and the technology skills but the internal team won't change. We will be leveraging skills from external contractors to help us interpret the data, what it means and how to process it." Australian local council.*

Network operations

There is a close connection between asset management and network operations. In particular, the expected surge in data from infrastructure and vehicles in coming years is anticipated by industry to assist optimisation of the road asset through network operations techniques. Network operations, in the context of roads authorities, refers to the strategies employed by agencies to maximise the efficiency and safety of the road network for roads users and can involve long term, 'tactical' and real-time applications. The former typically includes modelling and forecasting of traffic patterns using algorithms steeped in historical transport data which can be used for longer term or tactical planning (for instance, modelling the likely future impact of a known disruption such as a construction project). The latter can utilise data drawn from a range of agency (e.g. intelligent transport systems or ITS, traffic lights, the Sydney Coordinated Adaptive Traffic Signal System (SCATS) etc) and non-agency assets.

> *"In the past, agencies dealing with capability were typically concerned about construction. Now it's more about having the capability to operate the network, not just the road. It's asset management, and answering the question: what is an asset? There's a lot more than roads, or traffic lights. Our data alone, you couldn't put a price on that." – Australian roads agency*

> *"What frustrated me as a civil engineer and designer, even though it paid well and was exciting to do drawings and you could see how it all fitted together in immense detail. But you only apply standards to somebody else's idea. No originality. What I found with transport planning or strategic planning is you are coming up with those original ideas. You are creating something instead of just putting flesh on the bones. It moves all the time as the environment changes. It's very dynamic. Its moves away from 'let's build a road' to 'let's build a transport solution." – New Zealand professional association*

Meanwhile, the increasing availability of 'real time' data from agency assets, mobile phones, ITS and public transport systems is likely to disrupt traditional modelling as the new data challenges conceptions of behaviour based on older, static data (and as road users already start adjusting their behaviours through accessing real time applications such as Google Maps, as well as employing new 'mobility as a service' technologies such as Uber).

> *"Modelling has a whole lot of algorithms based on past experience. The problem is past models are based on statistics from ABS, but the introduction of Google is meaning that things are changing quickly. People are changing their travel patterns. Therefore the models of old, even with pretty good algorithms, are not going to be able to keep up." Australian contractor*

Perhaps more importantly, however, real time data provides agencies greater power to offer real time responses to incidents on the network, maximising asset use over shorter, critical timeframes. This, in turn, opens up demand for different skill sets that are focused in real time transport analytics and traffic engineering, as opposed to 'traditional' civil engineering.

> *"Most transport analysts have done a base level of civil engineering, some have done post grad studies in transport modelling. Some are planners. A lot of young people are those who love computer games. In fact some of our latest software is getting close to a gaming tool. Because what gaming does if you change some of the parameters, you run the scenario. The software is enabling analysts to change parameters and see what happens. Computers are getting more powerful too. What used to take us a whole night to run on several machines, is now run in an hour on one machine." – Australian contractor*

> *"Real time modelling is where we differ to the core skills we were used to asking people about. Civil, surveyors, construction deal with static information, but transport modellers and traffic engineers deal with a lot of data all in real time. That's where we find ourselves in the space of CAV, because its just an extension of what we do. Its real time." – Australian roads agency*

> *"We are taking the theoretical model and imposing live data and top of it and seeing what is actually happening. This is transport analytics - it's no longer modelling because it's not a future prediction, its actual interaction. That is going to be one of the biggest disruptors to come into transport planning because we are going to be able to get that live data and be able to use it." – Australian contractor*

However, industry soundings also suggested that there may be risks to being able to access new sources of non-agency real time data because of its high cost:

> *"Some agencies have predictive models because they have Bluetooth tracking vehicles. But it gets to the stage sometimes where their model misses something – and guess how they fixed it? Google Maps! Everybody has Google Maps on their phone now. The problem is that roads agencies don't have the budget to pay for that lovely data." – Australian contractor*

> *"You can use third party data – Google or TomTom, Facebook – as you get more and more people into certain platforms you get more access to data and it makes things more powerful. But it becomes harder to keep up. It's expensive." – Australian roads agency*

…or (at least, traditionally) because of an unwillingness for government agencies to share:

> *"In the data space, I'm seeing a huge need for all the data to be mashed up between areas and departments. Traditionally, no one shared any of that data, it was private, it was secure, we weren't sure we could trust you as another government agency. ... That's where we see the challenge with a lot of these skills. It's getting the mindset, the sharing behaviour right." – Australian roads agency*

In turn, increasing understanding and capability in transport analytics and traffic engineering will require a deep understanding of human behaviours and how to predict or model them. While a future scenario of completely autonomous road transport is a possibility (see Section 6.2.4 below), it is far more likely that there will be a long period of co-existence between autonomous and non-autonomous road use. Consequently, human decision-making will continue to play a vital role in how traffic moves around roads networks, at least for the next two decades:

> *"We are trying to fix congestion by changing people's behaviours… The difference between a good day or a bad day in terms of congestion is only 5 per cent. In surveys we have done, 1,000 people say even if you tell me its 20 minutes faster I'll still go my usual way because I don't trust it. These behavioural science sorts of skills will make a huge difference." – Australian roads agency*

> *"Traffic engineering is a part of civil engineering, but you learn a lot on the job. The challenge is that traffic flow is very similar to water flow; the equations are the same. Except traffic has a human factor to it... this is where we have the problem. We have had the mindset of 'bring good infrastructure and they will come' but we must become more sophisticated than that. We need psychologists and behaviourists in the equation. So we need control systems engineers. It's not that we don't need structural engineers. Or pavement engineers." – Australian roads agency.*

One question left unresolved from the industry interviews was the degree to which network operations modelling would need to be undertaken in-house by roads agencies themselves (or broader transport agencies) or contracted out to the private sector. Ultimately, as in other agency functions, the decision on the degree of outsourcing would come down to the relative efficiency by which the private sector could do the work, the degree of data sharing, and how agencies (including local councils) would retain in-house capability to be 'informed purchasers' of such services. Consequently, it could be likely that partnerships models will develop between agencies and the private sector to sustain and develop network operations skill sets capabilities.

> *"We are happy to provide that service to roads agencies because we know we are up to speed with all the modelling, all the technology. We can do it more efficiently and therefore do more work. Road agencies won't have a big team of modellers. Even KPMG are investing in their own transport modellers because they recognise this space is huge." – Australian contractor*

> *"Are we asking about skill sets which are really any of our business? We don't need civil engineers or surveyors running around trying to re-skill. This is an IT thing. Big data and IT. This is not new, but an extension of the next generation of skills. It's not to say we don't need surveyors and civil engineers it's just the importance of the intelligent transport system can't be trumped anymore like they are used to doing." – Australian roads agency*

> *"We are half agency and half consulting – we have a big data platform being built with Amazon and others – and that's intentional. We need it for change management. It's important that we have staff in the agency who know how to do this stuff at the end of it." – Australian roads agency*

Engineering and broader STEM skills

While asset management philosophies and the rise of more sophisticated network operations capabilities both point to an increasing need for a multi-disciplinary roads skill set in the future, this was not to suggest that 'traditional' engineering skills would be in any less demand over the coming one to two decades. Many industry respondents in recent soundings pointed to existing shortages for engineers in the roads industry (whether in the broader industry or within agencies themselves). Furthermore, current infrastructure pipelines – combined with ageing demographics of the current engineering skills cohort – is expected to see rising demand pressures on traditional engineering skills for the foreseeable future, regardless of which future scenario plays out.

> *"NZ, Australia and international data shows that without any doubt there is a shortage of engineers. It is a given. The only countries who are getting close to what they need would be the Asian countries, China, but in the rest of the world there are shortages." – New Zealand university*

> *"I think we will actually need both skills across network operations and skills in traditional construction and maintenance. Network operations will give you the knowledge as to where to maximise the asset use, but to fix the problem we will still need engineers." – Australian roads agency*

The strong pipeline for infrastructure spending in both Australia and New Zealand was mentioned in industry interviews as a key driver of demand for traditional engineering skills. Even so, there were differences in views as to how severe any capability gaps would be.

The large increase in railways construction work expected in Australia and New Zealand is also expected to create challenges for roads agencies given the degree in which traditional engineering skills can migrate from road to rail and vice versa (see Section 4.3.5 below).

Civil engineering and related associate professional skill sets were seen as critical for future roads agency functions, not just because of their traditional skills in asset construction and maintenance, but also because they provided a core starting skill set for other disciplines and functions such as network operations and asset management. Even in terms of pure data analysis (see further below), where demand is expected to grow significantly in coming years, civil engineering was noted by several industry respondents as a good place to start.

> *"Civil engineers are used to dealing with big data. It's the nature of real time traffic data. And doing large scale transport modelling – an extension of the same theme. Traffic engineering is just a discipline in civil. You can do highway and design or traffic analysis or both. Most civil engineers dabble with one or the other at first, then pick their poison." – Australian roads agency*

> *"Transport is usually a postgraduate degree. You usually learn basics of engineering – water, building, concrete – and then you do transport later. If you are trained as an engineer, you tend to stay there." – Australian university*

> *"Civil engineering that produces transport engineers is a very wide spectrum. The problem is we produce civil and environmental engineers and industry expects them to have certain basic, fundamental skills, grounding and discipline. If we specialise too early they don't get that well-rounded degree covering the full spectrum of civil engineering which is structural, environmental, water, hydraulics, geotechnical etc." – New Zealand university*

To a degree, however, previous workforce capability studies undertaken for Austroads (as discussed in Section 3) have focused particularly on civil engineers and paraprofessionals, whilst not including other engineering skills that will be required by roads agencies. Recent industry soundings suggest that this has been a 'second-best' approach to examining capability gaps given the importance of other engineering disciplines for roads agency or broader roads industry functions. These include mechanical and electrical engineers to support agency mechanical/electrical infrastructure (including ITS) as well as supporting network operations functions, environmental engineers, automotive engineers to support agency capability around new vehicle technologies (including connected, autonomous, shared and electric vehicles: CASE) and materials engineers.

> *"Communication between infrastructure and vehicles is the ITS. This is partly a civil engineering and electrical engineering skill. But we are introducing technologies on managed motorways which are five years old, not five years in advance. We will still need civil and electrical engineers." – Australian contractor*

> *"We have a couple of people who are experts in managed motorways, how to we allow access, at what rate. They generally come out of civil engineering but the skill set suggests we shouldn't be putting civil engineers into these roles because it actual requires control systems engineering background. Typically, this is a skill which is taught in electronic or mechanical engineering. So how do we get people with control systems backgrounds?" – Australian roads agency*

> *"We will still need materials engineers… There are all sorts of changes going on in a range of materials that interface with the roading sector and transport agencies. Cement, types of surfaces, pavements, but particularly in structures. There are big differences occurring to what has traditionally been used in the past. And some engineering students may not have much engagement with this new tech." – Australian university*

However, while demand for some civil engineering roles could be quantified through examining likely future 'end use' industry forecasts for construction and maintenance (as in previous Austroads workforce capability studies) it was noted that such quantification would be difficult for measuring engineering demands from non-construction, maintenance or networks drivers. Having some people with these skills was considered important from an agency capability perspective, but not necessarily the number of people with these skills.

> *"Certification is an issue. At some point, someone has to sign off on a set of plans. There will be new legislation coming in that engineers will need to be registered. But there is a lot of grey areas. What type of engineers need to be registered? What kind of degree you need to have? From that, we have been learning about some of the different types of engineers that we need. Most of our engineers are civil engineers. But its not always construction skills we are after. It's environmental engineers, other engineers." – Roads agency*

> *"We wouldn't need a significant number of mechanical engineers. But if road authorities had none of us, that would be bad. And it doesn't even need to be a mechanical engineer, so long as it is someone who has knowledge and capability around automotives. If agencies didn't have that they would be blind – they wouldn't know what was coming very well. You don't need hundreds." – Roads agency*

> *"We're already hearing from roads agencies today that its becoming a challenge as vehicles become more advanced. Having people in the agencies that can understand the technology to ensure appropriate compliance and enforcement is taking place. That will become an increasing challenge as the risks shift from human risks on the road to risks around the design of software and hardware in new types of vehicles. But it will be difficult to know how many people with these skills will be needed." – Australian government agency.*

> *"As an engineer, what previously works in a realm of high knowledge may not work in a complex situation where we are mashing up a lot of different information, from different agencies from different vendors and newer technologies. One plus one doesn't always equal two. You need different problem solving skills to deal with those highly complex environments and a mindset that says lets learn together. It's not as easy as saying, how many engineers do we need."*

Indeed, in many instances, agency and non-agency respondents in industry soundings highlighted the need to maintain multi-disciplinary engineering and STEM teams to have the capability to deal with the increasing complexity – and breadth – of challenges facing the industry. Again, the number of people in teams was not as important as the mix of skills that could tackle, together, complex problems and issues.

> *"I have a 20-person multidisciplinary team looking at CAV. A full time comms/marketing, computer science, cyber security, traffic engineer, data analytics, five software guys, IT platform guys, electrical engineers, systems engineers, systems architects." – Australian roads agency*

> *"We try to build multidisciplinary teams to look at a problem in a different way. We are doing a lot more than just roads. We have a great opportunity to take a real systems view to how people work and live. Having all that intel is quite powerful and a multidisciplinary team can help bring it all together.*

Technological skills and 'Big Data'

According to all industry respondents from our sounding program, roads agencies (as well as transport generally, and other industries ranging from medicine to retail trade) are being exposed to greater and greater quantities of data. Some of this data is expected to come from agency infrastructure ranging from intelligent transport systems (ITS), signs, traffic signals and streetlights. Some are already embedded in new vehicles which are equipped with sensors and instrumentation which feedback information to manufacturers.

"The real power is if we can get data back from the vehicle – that is the struggle everyone is dancing around. We don't have vehicle manufacturers in Australia anymore and the overseas manufacturers plan to keep their own data. It's a huge battle in Europe at the moment. If you get a dozen vehicles over a pothole, the vehicle records the vibrations, it sends data back to our ITS to say there is a pothole there." – Australian roads agency

"Vehicles are already sending large volumes of data to their manufacturers, and this will grow over coming years. We are getting data through our phones, not just travel data, but what doctors people go to, which shops they use, a whole range of things with patterns – and people call it 'big data'. Mining big data and using it will be one of the key things in the next 5-10 years. Here, the skills are computer software people - the Googles, the Apples, they are getting people to work out what we do with all this data." – Australian contractor

A potentially rich source of data will come from third parties (e.g. Google Maps, Tomtom, Facebook) or other agencies (e.g. public transport card readers such as Opal or Myki). Agencies are also looking at mashing diverse big datasets together – health, weather, events – with transport data to discover new patterns (or even just the right questions to ask) which can improve understandings of how road assets are likely to be used and improve the efficiency the road asset.

However, there were also concerns of an emerging 'data divide' between jurisdictions; that some roads agencies may miss out on the coming 'information boom' given the high cost of digitising existing agency infrastructure coupled with the high and rising expense of accessing third party data:

"We have data collection issues, digitisation issues. None of our assets are digitised. We don't have good point cloud mapping for roads, elevation of signs. When you talk about asset data, it just doesn't really exist. All the data coming at us is not coming from us internally. We have 76 jurisdictions, whereas New South Wales has 6 regions at the state level that control all signage for example. Local government doesn't control it. Therefore they have digitisation tools which are manual tools but have a process because they have the governance that supports it. Some jurisdictions are more capable than others…. So we will do hybrid datasets as much as possible, where we can trust sources."

The surge in new data, if it emerges, while of significant benefit to roads agencies, is expected to create its own challenges to workforce capability in roads agencies, as well as the broader roads industry. In particular, the sheer volume of new data has the potential to overwhelm agencies and local councils, who would require a new breed of 'big data' analysts to sift through the information and recognise what was valuable, or themselves train machines to identify patterns and useful information from the 'noise'.

"Data is the new gold." – New Zealand university

"Data is the new oil." – Australian local council

"Data is the new oil. But that also means that data is the new polluter. We have so much data we don't know what to do with it and half of it is irrelevant. It's like pollution and taking us away from what we should be focusing on." – Australian roads agency

"We are going to be swamped. Those people who don't have a high degree of understanding about what information is critical are going to be even more swamped with data. It's going to be everywhere, streaming dashboards about their road networks. We need people who can sort the wheat from the chaff – which bits of data will actually inform good decision-making." – Australian industry association.

"In the era of big data – how do you select the bits that are meaningful? I think some programming skills – everybody needs that to be able to analyse datasets without asking someone else to do it for you. Just like everyone has Microsoft Office on their desktop, in the future everyone should have the capability to analyse big datasets on their computer. Especially in Transport, because the data really is huge, and it's a goldmine the departments are sitting on." – Australian university

> *"Not many organisations have had big data. When you get big data you start to bring multiple areas together. Big data is about getting different data sets together - events data, travel data, weather, flu – and trying to see something new. Machines can see that stuff very quickly. They can see congestion, a sensor about to fail. Mining is probably the most advanced here. They can predict when an asset is about to fail and do preventative maintenance based on signs that follow a pattern. The machine itself isn't smart. It's the data scientist who is, and can design systems that can do that." Australian roads agency*

In some industry interviews, it was noted that data scientists or analysts could come from a range of backgrounds, and not necessarily have a history of working in roads, or even the transport sector. However, the dominant view was that data analytics would still require people with more 'traditional' training and skills in engineering and spatial sciences so that characteristics or patterns in the data that were most crucial to agency function and decision-making were recognised:

> *What sort of background do analysts come from? That's the part I don't know. My gut feel is it will be a combination of engineers and GIS professionals. We don't have them yet. There are systems analysts who are stockbrokers, that kind of thing, but this is a different type of analysis. To make judgement calls, you will need some understanding of what the data is telling you. We are still feeling our way through." – Australian roads agency*

Indeed, the increasing volume of spatial data, and its important role in transport planning, network operations and asset management, was recognised by many industry respondents:

> *"You w*ill struggle to find any data which you can't spatially enable and extract some intelligence from. Many jurisdictions have disbanded their GIS teams and the logic there is because spatial skills are required everywhere so why limit it to one team? It's like having skills in spread-sheeting, but we don't have a spreadsheet tea*m. GIS is getting like that. Spatial is just becoming an inherent skill across a range of teams. For GIS we need geomatics skills, and only a few universities do it, may be more now. Not every university offers it." – Australian roads agency*

While having different characteristics to 'big data' analysis, the increasing volume of asset data and rising use of Building Information Modelling (or BIM) is likely to create further demand for data analysts with roads agencies and local councils. While previously focused predominantly in 'vertical infrastructure' (buildings), BIM is also finding a place in 'horizontal infrastructure' (e.g. transport) as a multi-dimensional asset management tool. Consequently, asset management in the roads industry is likely to become a far more data-intensive discipline in coming years, with knowledge of BIM software increasingly important:

> *"Roads and rail are only just starting to figure out what BIM is and how to use it. It would work well for tunnels - you could tag every cell in the lining. If a segment started breaking down you could go back and query why they are breaking down, perhaps trace it back to a bad batch of concrete, and we could inspect other elements from the same batch. But also mechanical, electrical, lights, everything you need to maintain. These are the smarts we need to get into asset management." – Australian contractor*

> *"Asset management will be different as well in that in the past everything was 2D. But using new software we can set out the whole project from an electronic file, so surveyors didn't need a paper copy. In the computer there is a whole lot of information now there, and we can tag all the different elements - road, pipe, grate, light pole. And we can specify types of pipe and so forth, when it was put in. So there is a whole lot of extra data we can put into the system. The next stage will be to use this in an asset management capability." – New Zealand contractor*

> *"For example, Pacific Complete have requested that all the road design be done in 3D in 100 metre sections so they will have a full record of all the key assets on that road so it can be handed over to the RMS. That's the first time that's been done in Australia at that level of detail. That's going to be the norm, and so the asset people in RMS will have to know how to use that, they are tracking the life of assets, and so on." – Australian contractor*

"NZTA is keen to get their network on BIM. They have a wish list in the next 10 years they have their total network on BIM so all the new jobs have to be able to be put into BIM format, so we will need people who know BIM software. That is coming. It's in its infancy at the moment, but will become a big area in future." - New Zealand contractor

Data itself needs to be stored and managed carefully as a 'single source of truth' for roads agencies and local councils (where soundings suggest that currently a range of 'unverified' datasets exist, set up by various individuals or departments for different functions. This will require skills in establishing and maintaining data platforms, software engineering and various other IT-related roles.

Finally, the increasing quantity of data, and the range of assets (including vehicles) from which data will be received (or, in future, pushed to as a 'Day 2'cooperative ITS), is anticipated to drive increasing demand within agencies and local councils for data/cyber security. This trend will be magnified as agencies are putting existing personal services such as licencing and registration online. In turn, this is likely to see a heightened demand for cyber security specialists.

"More importantly, agencies are using more and more ITS which will eventually connect with vehicles and cloud services. When you open up an access point like that, you are opening up an attack vector which is another door to a hacker to get in. If we have systems managing how traffic moves on our roads networks or trains, we don't want people hacking in and playing with them. Security is not something we have been brilliant at. We have got better over time, but those who would want to hack into our systems are probably one or two steps ahead of us. We may need to cluster these skills in a central government but within jurisdictions we will also need more security capability." – Australian roads agency

"Data that is passed between vehicles and roads agencies controlling the network also raises risks of cybersecurity and that's another area where roads agencies don't have a lot of expertise today. These are risks not just for vehicles on the road by their systems which interact with those vehicles. The problem is there is a lot of competition for skills in these areas of expertise. Trying to find people, and competing against private industry will be a real challenge." – Australian government agency

Soft skills

One of the most interesting findings from the industry soundings was repeated calls – across the full range of organisations interviewed – for non-technical skill sets and capabilities to meet future roads workforce capability requirements. In several interviews, having the technical STEM skill sets was just the base of the skills pyramid. What was particularly valued was having, in addition to STEM knowledge, the right attitude in the workplace, one that is flexible and accepting of change, and a pure willingness to learn on the run because, in many cases, the challenges are new, unknown and cannot be simply taught:

"When looking for new people, having hard skills and education is important, but attitude is even more important." – Australian industry association

"It's a matter of being able to produce people that can understand changes as they occur and prepare themselves for that sector. Things like agility and adaptability, those sorts of skills are seen to be important. Not so much technology based skills, but more producing people that can deal with disruption." New Zealand University

"While the assets might change, the need for transportation and mobility is absolutely fundamental and will not change. We are still going to need people that can manage, control and plan whatever system we have to move people. It may not be as important to be a structural engineer to build a bridge, but its going to be the problem solving abilities and thinking which is going to be far more critical." – New Zealand university.

"In one sense there's an issue of scale. The very large organisations, such as the City of Brisbane, and the roads agencies for State Governments have larger workforces and a hierarchy and level of specialisation that means there has been a tendency to have many silos. An engineer can specialise and doesn't need to develop broader skills. In smaller areas, the multi-faceted nature of the work and the contact with local communities means that smaller councils have had to be much more flexible and adaptable to change." – Australian industry association

"I don't think [we need to be changing our skills radically]. The skill sets we are looking at with my multidisciplinary team; it's an attitude more than a skill set. The skill sets exist. The knowledge of standards and some of the unknowns can't be taught because no-one knows about this stuff. It has to be learnt. We need people with an 'adaptable' attitude, who is not scared of change, is a self-starter and a willingness to learn. That's the skillset…. It's also the hardest workforce thing. People are going to have to accept change, and people are not going to like it." – Australian roads agency

"To find these people, you put up an exciting project for people to say hello to and the people who find it are the people who want to change. This team all came here willingly to look at new things and to change." – Australian roads agency.

Apart from attitude, the other key non-STEM skill set mentioned in industry interviews as being vital for the future was that of communication. This skill can be considered in two ways – as a distinct discipline in its own right or as a 'soft' skill which aids the transfer of knowledge and information within agencies (and particularly from potentially non-communicative technical staff). Driving demand for communications skills in the former case is the ongoing evolution of road agencies in becoming more client and stakeholder focused:

"As you go to a more commercial utility, you also have to explain your activities and expenditure and performance to customers. This brings in a whole new skill set. Media, communications, presentation of information, stakeholder management. We outsource a lot now, but the need for communications around business operations is growing all the time." – Australian roads agency

"Communication is a key skill that makes or breaks us. If you can't communicate, your idea won't get up. People won't believe in the value you are offering. For us, the communication skill – being able to bring things together and tell a story – is far more powerful." – Australian roads agency

"Local government tends to have the greatest interface with the public…We have our own coms people here. They are not engineers, but rather journalists or writers; people with similar kinds of skills. And we get them to tell the story, not in technical terms, but in layman's language. We hire them specifically for that. But also for public consultation, we need another group of people who know how to get the feedback from consultation and that's another set of skills completely." – New Zealand council

Graduate training programs need to provide client-facing or public-facing skills early in their careers and not simply be 'back room boys'. We have very smart people, but some are not comfortable about meeting clients or being in front of people. There's a social aspect, a public aspect, that people can explain why they are doing what they do, what this means to you, why they are employed, why this road goes here, why we need buses there." – New Zealand professional association

However, many agencies and non-agency interviewees also told of the need to hire people with communications skills as part of their multi-disciplinary skill set. In these cases, the communications skill itself was not necessarily taught, but could be included in some ways to engineering-focused degrees and courses to balance the technical rigour of the subject.

"We want technical skills and we want business/communication skills. In the data space there is a huge drive to add value when you merge skills together. When looking at data, just seeing the data for itself without seeing the business context is not as useful. And the same with maths. You can build a formula, but when you can communicate with people and relate it more, you can break down a problem more quickly and get quicker insights. You can have two people with two separate skills, but you wouldn't be sharing the 'hive mind', so to speak." – Australian roads agency

"Engineers love their datasets and number crunching. But there needs to be a lot more communications at university taught for engineers because they don't naturally do that. There's no point having a good idea if you can't communicate it to anyone." – Australian roads agency

"Civil engineers traditionally doing the design of roads, but now need to partner with information engineers. A whole profession around dealing with information, looking for trends, whether things are working or not working… these are people with an interest in data and data-crunching. Some of these people are not great at articulating ideas either… so you may need engineers, and data specialists, and people in the middle with communication skills holding it all together. You're probably going to need quite a few of those. Its probably not even engineers anymore, its geek interpreters or something." – New Zealand professional association

Finally, having a collaborative or sharing mindset was seen as vital, not just internally within roads agencies, councils and across government, but also due to the increasing need to partner effectively with private industry to meet agency's social, economic and environmental objectives:

"It's getting the mindset, the behaviour right. Getting a 'growth' versus a 'fixed' mindset. Where we see complex problems that require collaboration across agencies, it means seeing this as an opportunity to do more good for the community, rather than a concern about having to change processes." – Australian roads agency

"When you have increasing private sector ownership of roads, ensuring that the management of those roads is done safely is a different set of skills to manage the roads yourself in an organisation."

"Agencies can try to analyse all this data themselves or partner with industry, thinking about what deals can we do. That's what we are doing. We are saying, we've got a combination of stuff. Between the two of us we can take your problems and solve your problems for you. ... so agencies won't need teams and teams of people but they definitely need some people who understand this and can see what can be done." – Australian contractor

"With a public dataset, we share a lot of our data to Open Data. Traffic data. Crash data. Asset information. It's all deemed as public… And then people who live in the data world can use all of that and build all sorts of things that are amazing, that we had no idea they could do that. That is a skill in its own right - being able to partner. To identify ways we can bring in others to solve problems. We can be a good broker, rather than trying to do it all." – Australian roads agency

6.2.4 Impact of new technologies

One key area of focus in the industry consultation round was to gauge industry and roads agency feedback regarding the impact of new technologies on skills demand and workforce capability, and how big of a risk it was to agency capability over the coming one to two decades. As highlighted in the survey results, technological disruption was highlighted as one of the greatest risks to workforce capability within roads agencies, with the main 'disruptors' mentioned being:

- The development of connected, cooperative and autonomous vehicles (CAV)
- The development of Cooperative Intelligent Transport Systems (or C-ITS)
- The rise of 100 per cent electric-only vehicles
- Technology-assisted 'sharing' business models and the rise of 'mobility as a service' (MaaS)
- Moving data and services online

Of these, the rise of CAVs was consistently rated the biggest threat to workforce capability by industry participants, given its implications for a wide range of skill sets, ranging from engineering, to legal, economic and commercial:

> *"The obvious threat is the shift to CAV. That's the main game on the research side – we see dramatic shifts in research. Its become the largest focal area in transport research." – Australian university*

> *"Just looking at [CAV] alone, you have the regulatory environment that needs to be implemented – staff who are experts in vehicle regulation and vehicle standards – the safety assurance systems that apply within any regulatory environment, the facilitating economic development perspective which is around attracting investment … which requires a different kind of commercial sense and understanding the politics of that; the legal aspects of it such as 'who is responsible in a crash?' and the insurance industry considerations. There is the issue of the role of the agency in all of this, what sort of regulatory regime you want, either a hands off approach or establishing regulatory requirements, an assurance role, so that vehicles behave as they are supposed to do and the data which is gathered is massive, and what to do with it."*

Even so, it is difficult to disentangle the impacts of all these technological developments in isolation – in most cases, the technologies will move ahead hand in hand. Connected and autonomous vehicles are most likely to be electric in any case given recent decisions by governments in the UK and France to ban the sale of petrol and diesel vehicles by 2040 to meet climate change targets. Other countries including India, the Netherlands, Germany and China are also mooting policies to ban petrol and diesel vehicles.[9]

The connected and cooperative characteristics of CAVs will also lend themselves to 'Day 2' stages of C-ITS technologies. Future 'managed motorways' technologies will not simply give signals to vehicles to improve motorway efficiency, but will possibly interact on a much more sophisticated scale, potentially taking direct control of automated vehicles to improve traffic flow and journey times, or avoid critical incidents on the network. Furthermore, the rollout of driverless electric CAVs opens up new sharing business models that could provide mobility services to a growing spectrum of potential users, similar to current plans for mobile phones.[10]

The varying degrees of 'autonomy' in autonomous driving has been classified by the Society of Automotive Engineers (SAE) into five distinct levels:[11]

9 Chrisafis, A. and Vaughan, A. (2017) France to ban sale of petrol and diesel cars by 2040, The Guardian, https://www.theguardian.com/business/2017/jul/06/france-ban-petrol-diesel-cars-2040-emmanuel-macron-volvo

10 Hensher, D. A. (2017) Digital Public Transport in an era of Sharing and Collaborative Mobility, presentation at Roads Australia National Conference, May 31, 2017.

11 SAE (2014) Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems, SAE International. http://standards.sae.org/j3016_201401/

Table 6.2: Levels of Driving Autonomy: Society of Automotive Engineers (SAE)

Level	Description
0	All functions are controlled by the human driver.
1	This driver-assistance level means that most functions are still controlled by the driver, but a specific function (like steering or accelerating) can be done automatically by the vehicle.
2	At least one driver assistance system of "both steering and acceleration/ deceleration using information about the driving environment" is automated, like cruise control and lane-assist. It means that the "driver is disengaged from physically operating the vehicle by having his or her hands off the steering wheel AND foot off pedal at the same time," according to the SAE. The driver must still always be ready to take control of the vehicle, however.
3	Drivers are still necessary in level 3 cars, but are able to completely shift "safety-critical functions" to the vehicle, under certain traffic or environmental conditions. It means that the driver is still present and will intervene if necessary, but is not required to monitor the situation in the same way it does for the previous levels.
4	This is what is meant by "fully autonomous." Level 4 vehicles are "designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip." However, it's important to note that this is limited to the "operational design domain (ODD)" of the vehicle—meaning it does not cover every driving scenario.
5	This refers to a fully-autonomous system that expects the vehicle's performance to equal that of a human driver, in every driving scenario—including extreme environments like dirt roads that are unlikely to be navigated by driverless vehicles in the near future.

The immediate impact of CAV is already being felt in terms of the need to reform the regulatory requirement that would allow highly autonomous (Level 4 and 5 vehicles) to operate legally on Australian roads. In November 2016, Australian transport ministers agreed to a phased reform program through the National Transport Commission (NTC) so that conditionally automated vehicles can operate safely and legally on our roads before 2020, and highly and fully automated vehicles from 2020.[12] But the regulatory implications of CAV and ITS technologies are likely to have deeper, long term consequences for roads agencies in terms of their role and function, and hence the skill sets that will be required. In particular, the current prescriptive regulatory environment in the roads industry could potentially give way to a performance or outcome-based environment, similar to that which already operates in other transport sectors such as aviation and railways.

> *"We are likely to be looking at a future where the compliance approach will be different. Its likely in the roads industry that we will be moving down the path of rail or aviation where its more of a management system-type approach rather than having prescriptive rules and black and white roadside enforcement (against individual drivers, in large part) of those rules… where vehicles are controlled as fleets and run by companies in an automated way, the approach you use for compliance and enforcement is likely to change. It may move down the path of managing operators rather than targeting individuals, and moving to a safety management approach, where you are looking at an overall approach to safety and how they are managing the risks in their operations as is done in the rail and aviation space." – Australian government agency*

> *"In rail, you don't see compliance officers pulling over trains and asking to see the train driver's licence. That's up to the operator to manage the safe deployment of the vehicles. Same in aviation. In rail and aviation it's the industry which sets the vehicle standard, not government, and this is different to roads currently… The skills you want from an officer who is checking vehicles are very different to a person auditing organisations on how their safety management system is performing. These skills exist, just not so much in roads transport currently." – Australian regulatory agency*

12 National Transport Commission (2017) Automated vehicles in Australia, http://www.ntc.gov.au/roads/technology/automated-vehicles-in-australia/

While the National Transport Commission (NTC) is still working through the regulatory framework that would make highly autonomous vehicles (i.e. Level 4 or 5) 'street legal', another great challenge for road authorities will be the impact CAVs will have on road use (i.e. the behavioural response from roads users) and the demand it could potentially create for infrastructure investment – either to accommodate greater road use by a greater number of vehicles (depending on the demand response) or to retro-fit existing infrastructure that will enable CAVs to communicate effectively with road infrastructure. In both cases, the actual outcome for roads agencies is uncertain.

> *"Part of the short term challenge [of CAV] in terms of skills is this - what level of intervention do agencies need to put in to change or modify their assets to deliver on the promise of automated vehicles? Is it all going to be 'ín the vehicle' and will all vehicles talk with each other? Or will there be a need to put investment into the tens of thousands of kilometres of existing road in terms of sensors and the like? I suspect none of that is in their forward budgets." Australian government agency*

If CAV is implemented through vehicle communication with existing physical infrastructure, there would there be a significant financial cost to roads agencies to ensure the infrastructure is 'readable' and consistent between jurisdictions. With that would also come increasing demand for civil engineers and construction trades skills in line with rising maintenance work:

> *"Civil engineers only get involved in the vehicle to infrastructure side of it. The communication between the vehicle and the infrastructure, such as signs. What is our infrastructure maintenance requirement around signs? Are they dependent on physical signs or do we have digital signs? How do we deal with variable signs? What happens when there are incidents? Line marking is another one with lane assist. Do signs cause problems with CAV in making them stop (they think it's a blockage). So there are lots of issues that need to be sorted out and engineers can play a role in this, but it is not a traditional civil engineering function." – Australian roads agency*

However, the sheer scale and cost of adapting physical infrastructure to meet the new technology is perhaps more likely to see 'in vehicle' CAV solutions play out, which in turn will drive increasing demand for automotive and mechanical engineering skills within agencies, so they can better understand the development of 'in vehicle' technologies (which are taking place overseas), how they can assist this development which minimises infrastructure costs, and what they should prepare for.

> *"We will not make wholesale changes to our road networks. We have about 900,000km of road and over half of that is dirt. But not a single car company is asking for wholesale changes to the network. They know the technology has to work with the network the way it is. But they are asking for a higher level of consistency with key attributes – things like different jurisdictions have slightly different line marking or signs. And this is a key role for Austroads as car companies want us to have a consistent standard." – Australian roads agency*

> *"We have particular challenges in that 70 per cent of our road network is unsealed. Some autonomous vehicles require lines of the road. The challenge will be to be nimble enough to deal with the different technologies that are out there. If we lock ourselves in to say it's going to be this way or that way, nationally, it will be the Federation issue all over again. We need to be consistent and harmonise when it comes to this." – Australian roads agency*

> *"'In 'CASE', the 'A' is for automated driving. It's here now and already having issues with our infrastructure such as our lines and signs. We definitely have a role to work with car companies to make these technologies work." – Australian roads agency*

The infrastructure investment implications of CAV also extend beyond roads, with the technology – if priced economically – likely to draw people away from public transport systems, particularly rail.

> *"From an investment perspective, CAV potentially may limit investment in rail networks because you wouldn't be able to use them. If everyone had a single seater pod, that could join with other pods, why catch the train? If it's more cost effective and environmentally sustainable, door to door mobility, is this a better investment?" – Australian roads agency*

Indeed, while the debate as to whether adoption of CAV leads to increased or reduced demand for road space is still a very much contested subject,[13] very recent evidence from modelling and surveys indicates that vehicle kilometres travelled could rise substantially – putting increasing pressure on the existing road asset base.

Recent modelling released in the United States[14] suggests a future world where regulatory approval of autonomous vehicles creates a massive market share 'grab' by the private sector for new 'mobility as a service' (MaaS) autonomous vehicle fleets. Aggressive pricing, longer vehicle lives (through the elimination of combustion engines) and high vehicle utilisation rates (despite some initial reluctance) is forecast to drive an 82 per cent drop in the number of vehicles on the road (affecting licencing revenues) but increase vehicle kilometres travelled by 50 per cent over the decade to 2030. For roads agencies in Australia and New Zealand, this suggests the worst of all future worlds, where CAV simultaneously erodes a traditional agency revenue base whilst leading to a rapid increase in demand for road space.

Meanwhile, very recent survey-based research in the United States[15] indicates that the rise of ride hailing mobility services such as Uber and Lyft has driven a 6 per cent reduction in public transit use in major cities, and that between 49-61 per cent of ride-hailing trips either would not have been made at all or would have been substituted by walking, biking or transit. Consequently, the authors conclude that it is very likely that ride-hailing services increased vehicle kilometres travelled in the major cities considered in the study.

> *"We are already seeing issues today with mobility services, which is resulting in more car trips and more kilometres travelled. This is because it's a relatively low price point so it's cheaper than a taxi, its more convenient, and people are taking more trips." – Australian roads agency*

In other words, the rise in new technologies (at this stage of understanding) seems likely to see a greater demand for roads in future, other things being equal. In turn, this will likely drive further requirements for a range of skill sets – ranging from civil engineers and construction trades to traffic modellers – in meeting future agency requirements that are connected to volumes of road use.

> *"For agencies looking to optimise the use of the road network, we need to understand how these mobility services behave. The trips they do are different. There will be a lot more trips. Roads authorities are going to have to invest more in modelling capability, identifying possible future scenarios. We will need geomatics, GIS, modelling, IT-related skills or civil engineers who are attracted to that." – Australian roads agency*

> *"Before we think technology is going to deliver an urban nirvana, we have to remember the same thing was said about 'horseless carriages' a century ago. People capitalised on the opportunity in an unforeseen way and that gave rise to suburbia and gridlock. I don't see any decrease in road building over time." – Australian contractor*

However, it will be important for agencies to undertake more behavioural analysis and research into this issue, and whether the results from preliminary United States studies can be backed up with evidence from Australia. This, in turn, will see a need for behavioural scientists – including psychologists, economists and market researchers – to work with (or within) agencies to test current assumptions and parameters used in transport modelling, and whether the rise in new technologies is driving changes in road user behaviour.

A key function for roads agencies, in this scenario, may be to try to limit the negative impacts of new technologies by creating incentives for sharing CAV services. In turn, this is expected to drive demand for behavioural and economics skills in the roads industry.

13 And, ideally, more research into the literature on this subject is still required.
14 RethinkX (May 2017) Rethinking Transportation 2020-2030
15 Clewlow, Regina R. and Gouri S. Mishra (October 2017) Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-17-07.

> *"There's two scenarios for automated vehicles. One is where we get less road use because we start to collectivise. The other is that we don't collectivise and car companies will want to sell as many cars as possible. We get 12 year olds owning cars, lots of dead running miles as cars reposition themselves, and a retreat from public transport use." – Australian university*

> *"Agencies have a role in trying to move us to the collectivised outcome as this will provide the greatest social benefits, and they can do this through road pricing and licensing. Economics is the good overarching term for this." – Australian university*

The potentially increasing role of the private sector in owning CAV fleets under new mobility services again highlights the need for "partnering skills" within agencies:

> *"As we move to a world where vehicles are connected and automated, and run by a private industry to a large part, and where funding and pricing options become private sector oriented, there's a lot of policy and management issues about how roads agencies - which traditionally are very public sector organisations - work with the private sector." – New Zealand university*

Finally, a critical issue for roads agencies in the context of workforce capability planning is the expected pace of change which is wrought by the new technologies. Here, there was widespread agreement that while agencies and regulators should prepare for highly autonomous vehicles now (particularly as Level 4 driverless vehicles are already being tested in the United States on public roads and controlled trials of autonomous vehicles are taking place in several jurisdictions in Australia and in New Zealand) there will likely be a significant delays before they become a ubiquitous feature of transport. In part, this because of the time it will take to replace the existing fleet, even with an immediate roll out of the technology:

> *"Predicting where we end up with CAV is very difficult. RMIT research has shown that the average vehicle takes around 14 years from purchase to eventual removal from the registered fleet. So there is going to be significant time lag. Unless there is a dramatic shift to club ownership of motoring - the Google's, the Ubers — the scenarios we go down may well be determined by roads agencies themselves and what they decide to be a preferential future." – Australian university*

Meanwhile, the results of current trials suggest that there are still a lot of issues with the technology – particularly in regional and remote areas of Australia – suggesting that a complete roll out of highly autonomous vehicles is some way off yet:

> *"With the driverless bus trial there is a lot of hype. We don't think the technology is right at this point in time. There are only two designs for driverless buses (Perth has gone with the other one). The trial has opened the eyes of the manufacturers of these cars. The humidity and temperature of Darwin means the air conditioning is run 24/7 which means the drive time battery life is severely limited. The software programming and the sensors are highly sensitive and even a dragonfly stopped the vehicle in its tracks." – Australian roads agency*

> *"Because of our network is in such low condition now, you will still need people to be with automated trucks to deal with blown tyres, mechanical problems, ensuring the health of live cattle and so forth. A lot of remote communities are on poor roads." – Australian roads agency*

And public opinion, itself, may still a barrier to the take up of autonomous vehicles. While autonomous vehicles offer the prospect of increased road safety, the general public remain skeptical and unconvinced, and perhaps for valid reasons:

> *"Another part of our trial is trying to gauge public acceptance of the technology. We found it half and half in favour and against the technology. It will happen, but not as fast as what manufacturers are talking about." – Australian roads authority.*

"The answer is no. We already have enough surveys to suggest that people will not be comfortable sharing the road with autonomous vehicles. Less than half believe there are safety benefits." – Australian roads authority.

"Automated vehicles encourage urban sprawl and increase tolerance of congestion. That results in additional traffic and congestion. The gains you get in the safety space for automated vehicles but, because you have a mixed fleet, the exposure of the traditional vehicles to more vehicles actually increases crashes. So arguably in the interim we will have more congestion and more crashes. Until we get to the full fleet of automated vehicles, its not going to be pretty. This is a modelling theory, but there are other models around the world which validate that." – Australian roads authority.

Indeed, one of the greatest challenges of CAV from industry soundings was that of dealing with a long period of 'mixed use' whereby the road system would be shared by driverless and non-driverless vehicles simultaneously.

"With autonomous vehicles, the transition period becomes crucial. You can't remove signs for those that don't have driverless vehicles, but they may also have issues with the signs. I'm not sure if we end up like with do with rapid transport where we have specific driverless vehicle corridors. What will drive this will be the community." – Australian roads authority

"The first thing we will see are the semi-autonomous vehicles. The technology is already there. Once they start driving in normal traffic, that's the next stage. By 2030-35 is where there will be major changes. By 2050, a lot of this will be in place completely. In the next 20 years there will be mix of autonomous and driver vehicles on the road." – Australian contractor

However, the possibility of a long period of adjustment to CAV may at least buy roads agencies more time to plan effectively for its implementation. For some respondents it was felt that agencies were not 'behind the eight ball' in terms of planning for the arrival of new technologies, especially compared with their global counterparts.

"The projections are run by the manufactures and sellers of these things and they are making wild projections, but there is a strong realisation that they are optimistic in their projections and that while change is occurring, it may not be nearly as fast as what people think. So there will be much more time. We won't need all the skills right now, but we need to be preparing for it. I think it will grow new jobs and skills rather than lose jobs in different areas. For the next 20-30 years there will be a need for existing skills plus a new package of skills coming in. We still have a civil engineering / transport asset that needs to be looked after with traditional means but perhaps better methods of analysis. But there will be new instrumentation and technologies to get on top of." – New Zealand university

Finally, with regard to electric vehicles – a technology which is already impacting road transport – while roads agencies agreed it would have ramifications for skills (particularly those surrounding vehicle maintenance), it was less certain as to whether there would be a role to be played by roads agencies themselves, and hence what skills sets – if any – would be required by roads agencies directly.

"It's questionable what the role for agencies should be for electric vehicles. We could do nothing or be active – and both approaches would be logical. Its not a new vehicle type. It doesn't change registration. Should they be incentivised if they use power from high greenhouse gas intensive generation? It can get quite political, and no longer about transport anymore but about energy and the environment." – Australian roads agency

"[Regarding electric vehicle skill sets] I don't think any agencies are ready honestly. The driverless bus was fully electric and needed a charging station." – Australian roads agency.

"We do not believe electric vehicles have any implications for road infrastructure but there could be decisions made around charging infrastructure. San Francisco does not put any money to charging infrastructure as, firstly, they think it should be left to the market. Secondly, its seen to worsen equity as only rich people can afford electric vehicles. Thirdly, they are trying to put people into mass transit and don't want to encourage people to get back into their cars. On the other hand, some states in Australia are looking to invest in charging infrastructure in their state to attract industry (technology companies or niche manufacturing), but its not about transport anymore." – Australian roads agency.

6.2.5 Other risks to workforce capability

Apart from changes in technology itself, other key risks to roads workforce capability highlighted in the industry interview round included:

- Inability to attract skills because of low rates of pay or regional nature of the work
- Demographic and cultural challenges across age and sex
- Insufficient or mismatched skills coming through the education system
- Risk of the appropriation of skills by other industries
- Institutional roadblocks, including the procurement process

Inability to attract skills due to pay or regional differences

Unlike much of the discussion held in the industry soundings that revolved around existing or future skills shortages, another key risk highlighted was an ability to attract skills that, while not necessarily in shortage, were nonetheless difficult to acquire because of the relatively low rates of pay or the regional location of work. This issue was highlighted by all participants – not just roads agencies and local councils – across Australia and New Zealand.

"Their own in house project managers are having problems attracting people into the agency. For a project to go well, you need a good agency person embedded with the team so they can clear roadblocks with the agency. A lot of that is driven by their pay scale, they are not attracting people. They really do need to look at pay scales so they can attract good people. Non-monetary benefits don't really work." – New Zealand contractor

"Low pay means that it is hard to attract people of calibre or anyone of a specialist nature. From recent benchmarking, our professional areas tend to be underpaid compared to private industry" – Australian local council

"Transurban … were bringing people in by offering a 30-40 percent pay rise. 48 people have left the agency and gone to the other organisations.... they pick the best people, and the knock on impacts go all the way through the organisation. It's hard for us to attract, so we focus on growing talent in house." – Australian roads agency.

"We have significant shortages of engineers at the local government level, particularly in rural and regional areas. The mining boom exacerbated that; Queensland and Western Australia found it very difficult to retain staff. You could drive a truck in a mine for $160,000 which is a senior engineers salary. But the drift back has now occurred and people are coming back into local government." – Australian industry association

"Our young people have highly transferable skill sets and we don't get to keep them for long. Half of our engineering skills rests with recent graduates who then tend to move to Melbourne or Hong Kong." – Australian roads agency

> *"More than other states, we have regional centres around the state and it is very difficult to Level 6 or 7 technical people into regional areas. Even if you want construction building it's not easy. So industry as well, how are they going to do this regional stuff let alone our resourcing? Local government won't provide much… The cost of living is really high because it's quite isolated… You can outsource stuff but you have no guarantee of sustaining the skills that you need." – Australian roads agency*

Even if pay rates were not an issue, differences in the transferability and mobility of skills brings regional risks into play. Strong profiles of construction work in many metropolitan regions across Australia and New Zealand, for instance is, according to industry interviews, creating a skills drain from the regions.

Organisations in the public and private sector cope as best they can by hiring new graduates (from universities or technical colleges) and training them as replacements, but even with the same numbers of "arms and legs" there is a considerable loss of expertise and skills which is difficult to measure as staff with decades of experience are replaced by staff with little or no practical experience.

Attracting skills into regional and remote areas can be challenging at the best of times, but may worsen further as current trends towards urbanisation continue. For instance, the New South Wales Intergenerational Report: Future State NSW 2056,[16] projects that population growth is expected to be slower in the regions outside of metropolitan Sydney over the next 40 years, population ageing is expected to be greater, and the proportion of people living regionally is expected to decline slightly. If replicated across other states and territories, and in New Zealand, this suggest a future of much higher urban density (extrapolating recent trends), with many more working aged people living in metropolitan while the semi-retired retreat to the regions to "help pay the bills". While an extrapolation of long term demographic trends, the increasing 'urbanisation of skills' is incentivised by the series of infrastructure investment choices made by governments over time (e.g. heavy investment in metropolitan transport, housing and other infrastructure compared to regional areas).

> *"In terms of skill sets we find it very hard to attract professionals. And when we do or train our own we find they have been lured to the bigger jurisdictions - happened a couple of times in the last month - because it's such a big infrastructure program down there." – Australian roads agency*

Industry soundings suggest that this could work the other way, with significant investment in regional jurisdictions attracting skills back, however the longer term challenge will be retaining a skills legacy in these regions once those investment have run their course.

Despite lower pay, and the often remote nature of the work, industry soundings did, however pick up some benefits that local councils and regional agencies could point to in trying to attract skills:

> *"One thing we have going for us is the variety of work we do in this council. Most inner city councils are maintenance councils, but we get to build. We still have that job satisfaction to offer." Australian local council*

> *"Good things about us is because we are small we are nimble. So when there is a disruptive technology we can pull together a team very quickly and make things happen a lot more quickly than bigger jurisdictions. An example is the driverless bus trial we have just finished. We were told to do it and within a notch we had a trial up and running." Australian road agency*

> *"Local government are also roads agencies and deliver 80 percent of road network management in Australia, but Main Roads happens to move stuff which is more high profile and is more highly trafficked. But its only a few percent of the network. I encourage students to look at local government and spend a couple of years there before they decide their careers - because you will get a better multidisciplinary perspective, not so siloed, you can talk to others." Australian non-university institution*

16 NSW Treasury (2016), NSW Intergenerational Report, Budget Paper No. 5, https://www.treasury.nsw.gov.au/sites/default/files/2017-01/Budget_Paper_5_-_Intergenerational_Report_2016_-_full_report.pdf

"We have had [a shortage of skills] for a long time. Some of those specialist skills in particular - bridge engineers, traffic engineers - because you can't really here. There is such a wide variety of issues you have no one else to rely on. So you end up broadening your skill set." – Australian roads agency.

For other industry participants, however, the key in sustaining skills in a lower pay environment was to provide stronger non-monetary benefits, including high living standards, 'lifestyle benefits, infrastructure and learning opportunities. While not necessarily a panacea for all regions, it did appear to provide some positive offsets for some in the industry interview round.

"If people say they want to leave and work in Asia or Europe, we say 'go ahead!'. Yes, it's a problem and we have to deal with that. But sometimes they end up coming back to us much later, with a host of new skills they have picked up on their travels, because they want to settle back here and it is a nice place to be." – New Zealand professional association

"Roads organisations will need to invest more into looking beyond our coastline, through international roads associations ... how much time and effort do they put in to requiring their staff to engage with relevant expertise overseas? Going overseas and seeing how its done elsewhere, attending conferences. And that's a potential good way of keeping people in place." Australian government agency.

Demographic and cultural challenges

"There's an age gap between my generation and the generation before me. In the 1980s engineering was not as popular and has since suffered from a lack of succession planning. In my career I've had to learn at a rate of knots while I see all these people retiring and not much else between me and them." – Australian roads agency

"Roads agencies have been seeking stronger female participation. In the construction side, it is still a blokey culture. There are a lot of young women don't survive in that area. It is a cultural issue which needs to be addressed." – Australian contractor

"We have trouble attracting women into the major project space to negotiate with contractors. It's what female engineers fear and so they go for head office jobs so they don't have to do that." – Australian roads agency

"In the consulting area it is more of a unconscious bias. We are now trying to get more women graduates and promoting women. Young women don't put their hand up whereas young guys do. We have to give women the confidence to put their hand up and say they can do it. When you put two or three young women in a team, the them works better, they can be more rounded than the men and the team enjoys the work better." – Australian contractor

Apart from the difficulty in attracting or retaining skills, demography and culture are other long term challenges facing workforce capability in roads industry. The ageing of the skills base, or loss of skills through retirement, was highlighted as a key issue in recent industry soundings. Previous Austroads workforce capability studies by BIS Oxford Economics in 2006, 2009 and 2013 have also pointed to the ageing of the skills base as the key demographic issue and this has been very noticeable in the engineering profession itself. More recent data, however – as shown in Section 4 of this Report – suggests that while ageing of the skilled workforce is still an issue, it may not be as severe an issue as it was in the 2000s. For some occupations, there is a larger 'hump' of younger people coming through the professions and trades. Indeed, in some instances, the size of the hump in the 25-35 year old age groups points to the risk of another demographic challenge in decades hence when that generation itself reaches peak retirement age.

But in addition to this, there are also challenges regarding the gender mix in the roads workforce, and, according to some respondents, the mix of ethnicity as well. While not of itself reflecting skills shortages or capability gaps, less diverse workplaces in terms of gender or ethnicity may indicate that skills are being drawn from a narrow pool – resulting in a narrow range of views – which may present challenges when agencies seek solutions to problems wrought by rapid changes taking place in the roads industry over the coming one to two decades. At worst, a lack of diversity may indicate that there are systemic barriers in education, the hiring process, or within agencies themselves that are precluding the maximisation of skills development and retention.

Workforce skills capability is expected to be heavily affected as more of the baby boomer generation enters key retirement age brackets, and this is particularly noticeable in engineering professions where capacity was augmented through high rates of immigration post World War II, especially in engineering. Workforce losses through demographic ageing will naturally be at the most highly-skilled and experienced level, and will need to be replaced over the coming decade just to meet existing demand, let alone increasing demand. Productivity growth through better use of technologies may play a role in mitigating the impact on some professions (e.g. drones and other hi-tech tools developed for surveying) , as will extending careers beyond typical retirement ages (possibly utilising 'semi-retirement' approaches to skills retention such as mentoring) but there will also be a need for raising the number and quality of skilled graduates in both the professions and the construction trades – and providing further 'on the job' development through cadetships and apprenticeships.

Meanwhile, data collected for this report in earlier sections indicate that the development of skill sets for the roads industry still has some way to go regarding gender balance. Engineering completions by women remain very low in many of the professions identified as in current shortage or future risk, with very little improvement (and in some cases falling numbers) over recent years. In economics – a discipline which encompasses a mix of quantitative, business, behavioural and communication skillsets that are expected to be in increasing demand for roads and broader transport agencies in coming decades – there is also an alarming decline in female participation.[17]

For some respondents in the industry soundings, the problem was falling numbers of women studying higher level STEM subjects in high school, which is now flowing through the tertiary education sector. While further analysis is warranted, this view is in line with previous Australian research[18] showing that not only are there many more males than females studying maths and science subjects at high school (with the exception of entry level maths and biology), the total numbers of students studying these subjects has also fallen significantly over the past two decades – which is an issue given the potential for rising demand for engineering and technology skills in the roads industry. It is also in line with international education experience and the low female employment representation in large technology companies such as Google.[19] However, it should be noted that participation rates for women in maths and science subjects in New Zealand is rising (as discussed in Section 4 of this report) with females now making up more than 50 per cent of enrolments in several key maths and science related subjects.[20]

Industry soundings for this project suggest that solutions for the low female share in the roads industry skills mix may involve a mix of strategies, including targeting high school (and primary school) education policies and approaches to encourage greater female participation and, where there may exist institutional biases with industry regarding hiring, pro-actively set targets for a more diverse workforce across both gender and ethnicity:

17 Wood, D. (2017) Women are dropping out of economics, which means men are running our economy, The Conversation, https://theconversation.com/women-are-dropping-out-of-economics-which-means-men-are-running-our-economy-74698

18 Phillips, N. (2014) '20-year decline in year 12 science and maths participation, study finds', The Sydney Morning Herald, http://www.smh.com.au/technology/sci-tech/20year-decline-in-year-12-science-and-maths-participation-study-finds-20141006-10qvq2.html

19 Devlin, H. and Hern, A. (2017). 'Why are there so few women in tech? The truth behind the Google memo', The Guardian, https://www.theguardian.com/lifeandstyle/2017/aug/08/why-are-there-so-few-women-in-tech-the-truth-behind-the-google-memo

20 Education Counts 2017, Participation, https://www.educationcounts.govt.nz/statistics/tertiary-education/participation

"We are not trying to de-engineer the organisation but use our existing skills in a more sophisticated way. We need to value different skill sets. We recently deliberately targeted multi-ethnic young women, brought in seven graduates, all from very different backgrounds. That has brought fresh eyes, fresh ideas from a variety of different disciplines – legal, engineering, economics, comms, psychology – so very different. That group coming together has really brought about some positive changes." – Australian roads agency.

Insufficient or mismatched skills from the education sector

Falling levels of STEM study at high schools is part of a broader risk to workforce capability that was identified in industry consultation – that educational institutions themselves may not be providing either the right type of skills or not enough of the required skills for roads agencies or the broader roads industry. Not having enough domestic STEM graduates was a key issue, as noted previously.

Poorer skills in maths and sciences from high school graduates entering tertiary education (whether the vocational or university sector) was also highlighted. Here, a major cause for concern was the low entry standards for technical courses that later required remedial courses to help bridge the gap between student knowledge and what was required, and could possibly be contributing to rising levels in incompletions in the study for STEM-related degrees or certificate qualifications.

"In the STEM debate, it really goes back to school education system not producing people completing their school years with an appropriate level of STEM capabilities. For example, with electrical qualifications, the feedback we're getting is that it takes about 12 months of remedial education in maths so they can move on and succeed." – Australian industry association

In worst case outcomes, there was also a fear that tertiary courses were at risk of 'dumbing down' to cater for students with poorer quantitative skills.

"It should be starting in schools. To get into university you should have some quantitative skills to get into a much wider range of subjects that you do now. Otherwise it is quite limiting if you have to keep making it simpler and simpler." – Australian university

For some respondents, a solution to this problem was to add or enforce the successful completion of pre-requisite studies (e.g. higher level maths at high school) for tertiary studies, which would then send a signal to both students and the broader secondary schooling system:

"This whole training issue needs to be viewed holistically starting from high school." – New Zealand university

"The interface between secondary and tertiary is an issue. Too many tertiary courses are letting in people without any quantitative skills. That would then feed back into secondary education. The ones that we can place [into employment] tend to be those who are good at quantitative tasks. We don't train modellers because they are usually in engineering, but they are usually snatched up most quickly." – Australian university.

This issue also extended to postgraduate study, with graduates from some disciplines ill-equipped to deal with transport-related postgraduate courses given their technical nature:

"You need rigour in a first degree, but then you mature your mind later. If you go too multidisciplinary too early, you don't get the depth… especially in quantitative skills. Engineers find it easier to model and follow the equations we put up, but other people find it quite difficult and didn't think you would need calculations in transport." – Australian university

Determining what was appropriate 'multidisciplinary' training in undergraduate and postgraduate courses was another issue:

> *"But we need to be preparing graduates for a future that won't be the same as today. The problem we have is the existing skills we produce now are still important - and will remain important for a long time still - but we need to be adding other skills that can't be fitted into a normal undergraduate civil engineering degree." Australian university*

> *"Transport is not a sexy study. It is postgraduate. It is quite invisible for a lot of people, compared to accountants and engineers. Getting enough people educated in transport is difficult." – Australian university*

> *"Civil engineering that produces transport engineers is a very wide spectrum. The problem is we produce civil and environmental engineers and industry expects them to have certain basic, fundamental skills, grounding and disciple. If we specialise too early they don't get that well-rounded degree covering the full spectrum of civil engineering which is structural, environmental, water, hydraulics, geotechnical and so on." New Zealand university*

> *"I believe that those who have been trained rigorously tend to end up being the best strategic thinkers because they understand the methodology and the context and you can be legitimately cynical. But what if you have never done that stuff? And that is another issue – the lack of people in government being told by consultants that's what they should do and they don't have the skills to question it." – Australian university*

> *"We don't teach asset management at an undergraduate level, and the pushback has been for engineering is that they want to have the technical tools developed at an undergraduate level and then the specialisation at a postgrad level. That may need to change." New Zealand university*

> *"People studying asset management are fourth year civil engineering students being introduced to it as a conceptual framework to fit the bits of engineering into. Hopefully it broadens their perspectives to recognise that whatever engineer you are that it all fits into a bigger picture of how we provide infrastructure services." – Australian professional association*

Indeed, some of the biggest challenges facing transport-facing graduates is the increasing 'multidisciplinary' skill sets which are required – developing the 'hive mind' which can interface at many levels within today's (and future) roads agencies. While technical rigour remains important, there is an increasing need to support this with other skill sets across economics and finance, transport, asset management, communications and other disciplines. The problem, according to industry interviews, is that there is little in the way of redundant information, and so the multidisciplinary skill sets tend to be 'bolted on' to existing course structures through additional postgraduate study or other training programs that can be accessed by roads agency or transport staff.

> *"Industry tells us that they want more of the softer skills and bring them into the engineering degree - but we can't throw anything out because we need that as well! There is very little we can throw out because it is all still required. Maybe we could look at different ways of delivering the material but there is only so much we can do in a four year professional degree. In the transport area we have developed specialised Masters programs that provide further specialisation, but also bring in broader, softer skills. But this is not the only model." – New Zealand university*

> *"We have to think more creatively. We are too used to thinking we have a problem, we have an engineer, the engineer solves the problem. But transport may not be the problem. The problem may be how do we design our life and our cities – we need to find the problem before we solve anything. We have trained all our engineers to think 'we have a road, we have people, how do we optimise these two things'. But we should actually be thinking about where do we want people to live? How do we design a liveability city? These issues should come first, but they tend to come second. We tend to think about solutions before we think about problems." – Australian university*

One of the key 'soft skills' mentioned by industry, agencies and education institutions is that of agility, creativity and flexibility to deal with the degree of disruption expected in the transport industry in the next one to two decades. While these skills are difficult to 'teach', there are ways that educational institutions can encourage a 'disruption' mindset:

> *"You have to motivate students into being agile and changing. It's not a matter of throwing content at people. You have to have disruption in your teaching. You say, 'Now suppose this doesn't happen. How do you solve it now?'... You give them a task with incomplete information and tell them to make something of it…. The challenge is making students understand why the need to be disrupted." – Australian university*

In some cases, universities are responding to the growing need for multidisciplinary, creative problem solvers by developing innovative degrees that aim to equip students with the skills to be change agents on the global stage. One such course is Monash University's Bachelor of Science Advanced - Global Challenges (Honours) which includes additional studies relating to global challenges from year one culminating in a major project in the fourth year. Students in the course must also complete two approved internships. One of these will be international and will include travel overseas. These internships will involve a placement in government, business, or a social enterprise, contributing in a corporate outreach project, or shadowing a CEO. In this way, science students in the degree are being exposed to a greater breadth of knowledge and skills, both hard and soft, and expected to demonstrate an understanding of the qualities of leadership, social responsibility and ethics.

Other areas of innovation in education, as noted in recent soundings, is the proliferation of qualifications targeting 'big data' skills as well as ways to combine transport with other disciplines:

> *"We are looking at combining finance and transport. What if they did a dual major? They might get a better job. And it has worked for a few students. So the solution may be to combine it with more well known discipline. I note that some [transport agencies] have hired General Managers with no background in transport at all; they think that they will be better at running the organisation, but they don't understand the topic. I'm horrified at the naivety of some people regarding the portfolio they are representing." – Australian university.*

> *"We are seeing some interesting trends in New Zealand and there are new qualifications coming up, such as a mixture of architecture and structural engineering. If you are a bespoke engineer and go into infrastructure management you would be equipped for around 60 per cent of the job they are doing: business and communications and marketing and all of the other skills we don't necessarily teach engineers. The future will require us to have far more integrated education. However, we also recognise that the fundamental blocks from the traditional education remain important." – New Zealand university.*

However, in many cases it is difficult for universities to establish innovative courses such as these – or even relevant technical courses – due to risks and financial constraints. As noted by one university in the industry soundings program "the biggest barrier can be the institutions themselves", but also noting that accrediting professional institutions can also be a barrier to the development of new ways of education to "protect jobs or their terrain". During discussions with several universities and other institutions, several examples were provided where innovative courses were either cancelled or not approved due to high costs and an (initial) lack of students. These included courses that aimed to upskill existing engineering graduates into areas of high or growing demand.

> *"How do we bridge the skills gap? A lot of engineers are coming out of universities, or professionals coming out of manufacturing, which can be upskilled. They have all got that basic science understanding. There's just no coordinated approach to really upskill these people. Over the past ten years I've been fighting with the university to start looking at these opportunities which are coming. I've written many business cases. The universities are big dinosaurs. They only do things ten years after they are required." – Australian university.*

Finally, another challenge in the education space – and one that could be addressed by roads agencies themselves – was simply getting students more aware of the opportunities for work in transport-related roles while undertaking their degrees. While some agencies may already be doing this, industry soundings suggest it may not be consistent across the board:

> *"It would be a good idea for institutions to invest more time in communicating with students. Students don't have much idea of what goes on in road authorities. If their work was better understood by students then they would benefit later when students apply for jobs with these intuitions." – Australian university*

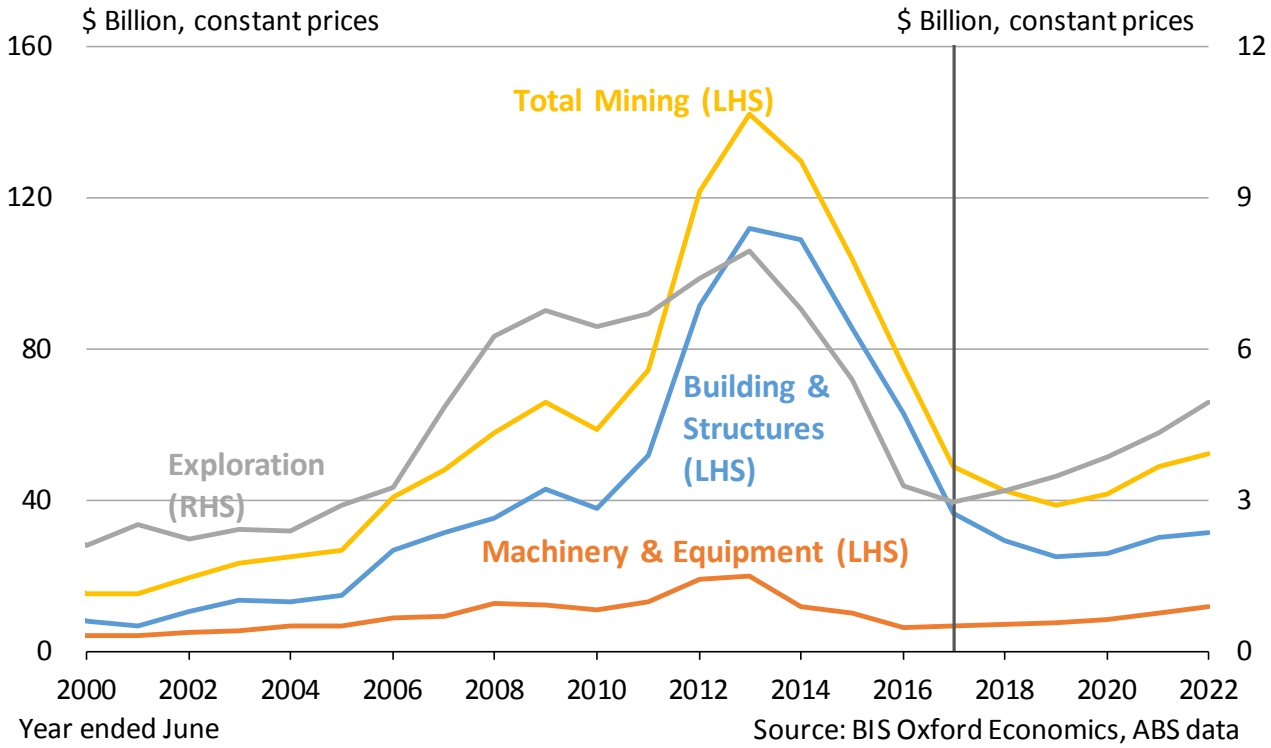
> *"We need to work out ways where we can get continual learning – learning hubs. Much better integration between agencies and the up and coming young graduates, still in the learning environment, that are being brought in and contributing, working collaboratively with agencies, rather than waiting for them to graduate… Agencies will need to get a lot more focused on this rather than saying they a hiring a couple of graduates each year. They should be developing an interface where they have these smart young people who can identify what the needs are in the agency and where they can apply what they are learning in a real environment." – Australian non-university education institution*

> *"Where are we getting skills now? It's a bit of a mixture. Some of it is natural maturity; people that have been in the data space for a long time. But they are also naturally curious and have stakeholder savviness. This is the apprenticeship style approach compared to one that's come from an educational area. The latter is what we do in partnerships now with tertiary institutions to look for our business problems and partner with these institutions to ask if we can work together and partner with data scientists, mathematicians, and civil engineers. They love it as the get a chance to apply theory to real world problems. And we love it because we get a fresh set of eyes on these issues." – Australian roads agency.*

Risk of skills appropriation by other industries

Another risk to workforce capability that was raised during industry soundings was the prospect of losing existing skills in the roads industry to other, faster growing, industries over the next one to two decades. As noted previously in this report, agencies and local councils found themselves exposed to engineering and other skills shortages during the 2000s resources investment boom in Australia. While current projections by BIS Oxford Economics do not suggest the boom in resources investment is returning anytime soon, it appears likely that the mining industry will once again be a competitor to agencies and regional local councils for skills within the next few years as resources investment (which has fallen sharply since 2012/13) begins to rise once more, as shown below on the back of improved global economic conditions and commodity prices.

Figure 6.23:Total Mining Investment, Australia, $Bn

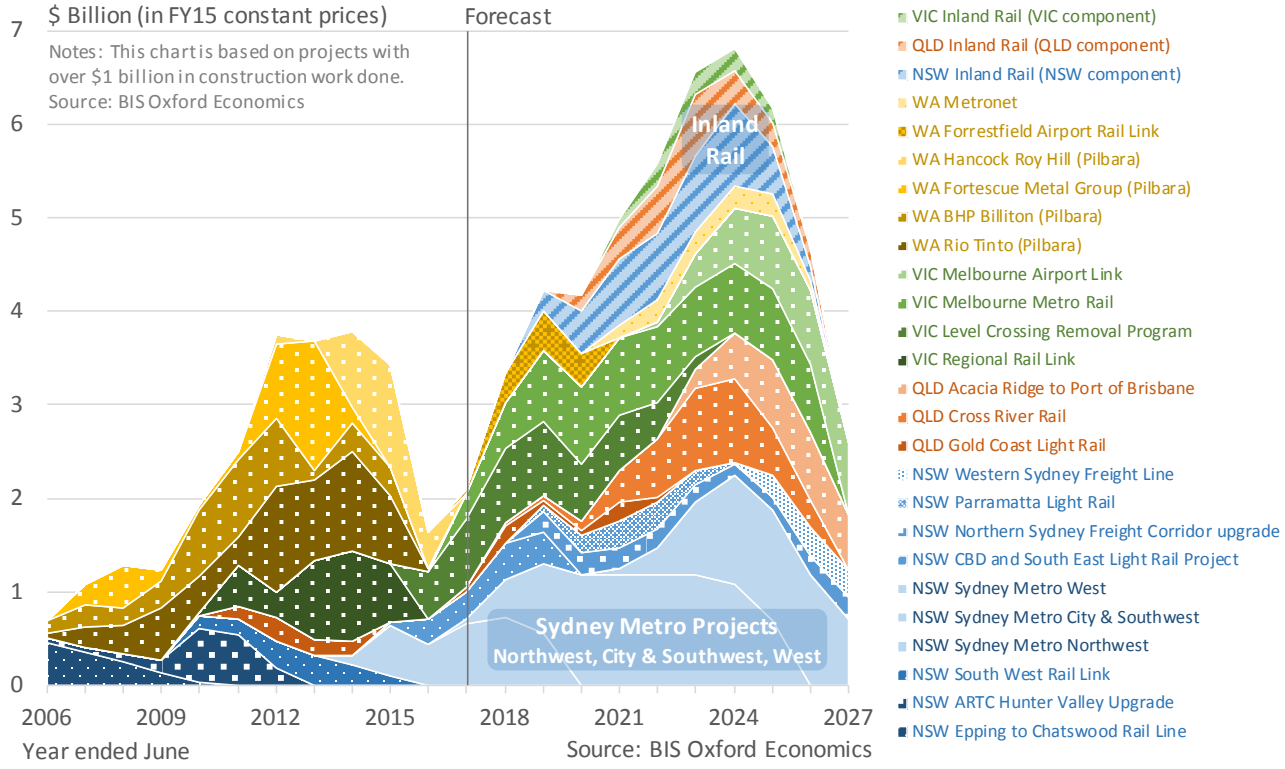


However, a far clearer and closer threat to roads workforce capability may well come from another area of transport – railways. Recent research by BIS Oxford Economics indicates that investment in rail in Australia is set to double through the next five years, with a long run pipeline of major rail projects not expected to peak until the mid-2020s. Meanwhile, in New Zealand, the new Labour-led national government is also likely to move ahead with several major projects including a new line to Marsden Point Port and the modernisation of the Auckland-Whangarei railway line (NZ$800 million) on top of NZ$984 million in investment to support national and urban rail, with much depending on the timing of the Auckland City Rail Link project. Overall, both road and rail investment in Australia and New Zealand is anticipated to drive engineering construction activity higher in these countries, with corresponding impacts on demand for skills in design, procurement, construction and ultimately maintenance, operations and asset management.

Here, the important questions (for both rail and roads industries) is whether the scale of the projected rail investment programs can be effectively resourced skills-wise, and to what extent the rail sector is likely or able to call on skills and capabilities from the roads industry (or, in the case of future skills, destined for roads industry).

While this project did not directly address the first question, the latter question was raised in the industry consultation rounds, with the most important concept being the transferability of skills between roads and rail industries. The feedback from industry suggests this is indeed a legitimate risk to roads capability going forward:

Figure 6.24:Estimated and Projected Work Done on Major Rail Projects in Australia, $Bn



"We are already struggling with engineering resourcing now. You have your rail specialists and your road specialists and there's quite a few engineers who can do both. Whether it's concrete works or earthworks or geotechnical iOS structural, whether its road or rail people can still manage both, and the same with the foremen and so on." Australian contractor

"Engineers in the roads industry have a lot of the understanding to do rail work. It may not be exactly the same, but there are many areas where there is cross over. And skills transfer is not that difficult. You could give an engineer a crash course if they happen to be working on a railway. It's the same with automotive skills. They too have certain skill sets which can be transferred." Australian university

"We are capable of being the infrastructure delivery arm for transport agencies. Roads and rail are a bit similar but once you get into buildings, it's quite different, and usually attracts a different sort of person. I've thought for years that our agency could deliver [rail] certainly. We do a lot of work for bridges at the moment. It's not such a big step to be the delivery arm of transport." Australian roads agency.

"The interesting thing is the crossover to the rail pipeline. The metros in Australia are effectively big tunnel projects. Your tunnelling resource – this is the same skillset as roads – but the fit-out will be different. Still, there's quite a lot of crossover there. Then you have greenfield rail, Inland Rail and you get crossover into the road space. You need guys who know how to deal with big earthworks projects. And you have Western Sydney Airport coming up – again, big earthworks. So you layer these things and realise that this is the same skill set that your road guys will be on. Structural, bridges… this is an interesting conundrum." Australian contractor.

One contractor noted that, given the shortages in skills already apparent to them in the roads space, it would be difficult for the rail industry to secure skills from this source (not that this was a positive for the roads industry either!):

> *"Rail is likely to be more of a tide than a really big wave. You can only take skills from the roads industry if there is spare capacity in the roads industry. And I don't think there is. At the moment you can take it from spare capacity in other industries like resources but over time there will be higher demands for engineers, skilled people, especially with technology." – Australian contractor*

That said, there are some skills sets which are more specific to rail, and which wouldn't necessarily be drawn directly from existing roads workforces, at least without some re-skilling:

> *"Road signalling is a little bit different. Traffic lights use a lot more civil-related skills that take into account behaviours. In rail, signalling and track work can be very different… monitoring of rolling stock and engines is very different. Even maintenance is very different – how the metal wheels maintain contact with the track and wear is very important… You have to think about totally different trains that run on different systems, different curvatures. This is all using similar skill sets to roads – civil engineers, electrical, mechanical – but applied in different ways." – Australian university*

Overall , the main issue for the roads industry is that the rail industry, currently, seems less far advanced with its own workforce capability planning – and this may be a consequence of the speed in which new rail projects have been developed and funded (particularly in the area of urban passenger rail and freight) following decades of lower levels of investment. The feedback from industry soundings is clear: without the rail industry quickly developing its own resource capability frameworks and systems – including the development of specialist education and training institutes as has occurred overseas – it is very likely that the rise in railways related transport investment in coming decades will draw upon resources from other industries – including roads – to deliver new infrastructure projects. As railways networks expand, this is then expected to draw on other skillsets in operations and maintenance – involving technical skills in data analysis, engineering and asset management – which may also create challenges for the sustainable procurement of roads skills in the longer term.

Institutional roadblocks to workforce capability

While the outlook for infrastructure investment presents significant risks to workforce capability, industry soundings also suggested that some agencies and governments themselves have contributed to current – and potentially future – workforce capability gaps. Here, the main concerns centred around the lack of harmonisation around private sector procurement policies between jurisdictional agencies and between local councils; the rebuilding of capability in agencies which has affected the private sector's ability to deliver; arbitrary 'rules' that may be used by some agencies which effectively precluded competition for work; and a lack of coordination between governments and agencies in delivering major projects.

For contractors, particularly, the difficulty (and uncertainty) in tendering for work with the different jurisdictions in the road space made planning for their own workforces difficult:

> *"Roads agencies, compared to other agencies, are well set up to deliver assets the way they did in the past. But it's not the present. And it's certainly not the future. You have regions and fiefdoms which have their way of doing things, you have differences in the degree of outsourcing (that various parts of all organisations either accept zealously or refuse to accept outright) and that is particularly in the technical parts of the agencies that are a nightmare to deal with. And out of that you have very ambiguous signals to industry as to what they want. Dealing with different agencies regularly you feel it is a lottery, frankly. None of it is consistent." – Australian contractor.*

> *"We encourage agencies to specify what they want and take the mystery out of it – and that is what they are doing." – New Zealand contractor*

> *"The market is failing because it isn't a market. It's one client per state, and that client is widely variable." – Australian contractor*

Agencies were also charged with being too prescriptive, rather than outcome focused, in procuring work from the private sector and not making enough use of industry 'smarts' that could potentially improve designs, utilise technology better, deliver higher-quality assets that potentially could reduce the call on workforce skills across design, procurement, construction, maintenance and asset management:

> *"Roads agencies are well set up to deal with problems of the past. The agencies often stipulate construct only contracts, specifying exactly what they want based on inputs. Not what economic and social benefits they are trying to deliver. Companies like Amazon are much clearer about the outcomes they are looking for and developing platforms so the service can evolve as technology changes." – Australian contractor*

> *"It has always been very prescriptive how you build roads. You have a lot of people in the technical branches that don't want to change what they do. And it becomes a feedback loop. If they go for someone they aren't sure about, and they don't perform, then they think more supervision is the answer." – Australian contractor*

> *"We should be driving an outcome focused procurement strategy that takes into account whole of life costs which minimise future maintenance and upkeep requirements, keeping asset quality high and pressure off operating resources and costs. They say that, but there is a big lag between senior management and procurement parts of agencies themselves." – Australian contractor*

In turn, this prescriptive approach – combined with a bow wave of new infrastructure development – has led to the need for some agencies to rebuild internal capability substantially in recent years so, at the very least, they can be more informed purchasers of private sector services. But this itself has presented capability challenges for the private sector as they, too, have scrambled for quality scarce resources in procurement, design and construction.

> *"[One roads agency] did a reasonable job of rebuilding capability more recently, but if they tried to do it now they'd struggle. And was it the path they should have taken? They could have taken a different path relying more on industry, would they have had to do that?" – Australian contractor*

In some specific cases, the public sector has brought in private sector expertise to manage the procurement and delivery of projects. While contractors recognise the need for agencies to do this, they also noted risks that this brought in terms of probity and conflict of interest issues, particularly if contracted staff are asked to review or procure work from potential competitors.

For some industry respondents, artificial rules in procurement – as a result of the prescriptive approach – sometimes produced non-competitive outcomes that did not take advantage of the full breadth of skills which could be available to the roads industry. An example of this was requiring bidders for work to have had previous experience in building roads in some jurisdictions, which ruled out the use of skills that could be drawn from other industries such as mining. In other cases, it meant that the same contractors tended to be used repeatedly, threatening the sustainability of skills development more broadly across the industry.

> *"There is a problem with the way transport planning is taken to the market. It's a closed shop. It's typical of the transport agency – you can only do this work if you already have experience doing this for us. There's probably only four to five consultants out there who can claim experience doing this…. You can't get a $10 million construction job unless you have already done a $10 million construction job, usually for the same organisation, so it tends to come down to the same contractors because there is nobody else who has actually done any of these works. So you see the same contractors again and again doing the same jobs and they say they haven't got the staff. It's kind of weird, unsustainable, self-appreciation work." – New Zealand professional association*

However, it should also be noted that this perspective was not necessarily shared by all the (relatively large) contractors included in the industry soundings:

> *"Closed shop is bullshit. You either have the skills and capability or you don't." – New Zealand contractor.*

Finally, another potential institutional barrier identified in industry soundings concerned the movement of skills and ideas between state or national jurisdictions and local government.

> *"The barrier I would identify would be the inability to cross-fertilise ideas between levels of government. Professionals in local government tend to get locked into local government. If they want to work in a state road authority it can be quite a difficult hurdle to jump, and vice versa. The more cross-pollination and seamless career development between the levels of government and into the private sector would be really beneficial." – Australian association*

6.3 Summary of Results From Industry Consultation

In summary, the findings from industry consultation suggest that roads agencies – and the broader roads industry – are already facing significant challenges with regards to workforce capability, with further significant risks and threats ahead. If these challenges are not adequately addressed it is highly likely that workforce gaps may be *worse* than that estimated by the quantitative modelling, with consequences for agencies' ability to effectively optimise the management and use of the roads network whilst meeting roads users mobility needs.

In particular, the key challenges identified include:

- Some skills are already considered in deficit according to survey and interview responses. As well as those occupations currently included on Australian and New Zealand skills shortages lists (see Section 6.2.2), industry consultation specifically rated transport analysts, planners and a range of designer cluster skills (engineers, surveyors, spatial scientists, cartographers and procurement managers) as being very difficult to source now.
- However, the main challenge here is not a further boom in demand for traditional skills due to a sharply rising road construction and maintenance profile, but rather maintaining capability in these areas (in the face of competition from other sectors and an ageing workforce profile) whilst also requiring new skills given shifting agency roles and functions due to emerging technologies, and risks to funding.
- The workforce gap modeling assumed that skills could potentially be sourced from other industries. However, it is more likely that it the roads 'existing workforce' itself will be under threat from rising work in other sectors, as well as the roads 'future workforce'.
- Existing roads workforces – and future workforce acquisition – could also be at risk from deeply ingrained institutional factors affecting agencies such as regional nature of the work, lower pay compared to industry, cultural biases in the hiring process and, in some cases, direct roadblocks in the form of restrictive procurement practices and a 'prescriptive'-heavy approach to contracting and regulation.
- New technologies such as CAV have the capacity to alter road agency's regulatory style from prescriptive to outcome based approaches, which will entail a shift in skills required – in general, less skills required on roads policing and more skills required in auditing, vehicle standards etc as has already happened in other transport sectors such as air and ports.
- Furthermore, In an increasingly technology-oriented world with a rising need for communication of ideas between designers, informers within agencies – and between agencies and their stakeholders – agencies will be competing against all other industries for suitable informer and technologist cluster skills. Soundings indicate that forecasting demand for these skills is difficult and highly uncertain but it is important agencies have a mixture of skills to meet challenges ahead and to face an uncertain world.

- Agencies are likely to have time to adapt, however, to some of the new technological developments. Manufacturers forecasts for successful on-road operations of Level 4 and 5 CAV, for instance, may be optimistic in light of results from recent trials of the technology in Australia and overseas. It may be more likely that there will be a long period (spanning decades) of mixed use of autonomous and semi-autonomous vehicles on roads. Industry respondents were generally positive in respect to how they perceive roads agencies are responding to new technology challenges. In particular, agencies in Australia and New Zealand do not appear to be "behind the eight ball" compared to their overseas counterparts, with plans already in place for building the necessary regulatory environment to meet new technologies, as well as testing new vehicles and systems on networks. Rather, the more immediate challenge for roads agencies may be meeting demand for 'traditional' designer cluster skills given rising demand from other sectors.
- 'Big data' and intelligent transport system (ITS) technologies (e.g. managed motorways) are already here, however, and the application and usefulness of these technologies is likely to expand rapidly, particularly in environments where agency funding may be constrained. From the qualitative and quantitative research undertaken for this study, it is likely that these technologies – and their usefulness in reducing agency costs and optimizing asset use and value through more effective asset and demand management – will drive demand for technologist skills (to design, implement, manage and secure data systems) as well as informers (data analysts, economists, planners) who can crunch the data, develop policies, and communicate strategy within agencies and across their stakeholders. Designers themselves (engineers, spatial scientists), via their skills in correctly interpreting big data, are likely to provide a crucial link between technologists and informers. Consequently, the "engineer of the future" will likely have a different range of skills beyond traditional civil functions in a more technological, data-infused future.
- In this respect, the education sector in Australia and New Zealand may not be providing the right mix of skills for roads agencies and the broader road industry now or for the future. Industry consultation specified that future workers will ideally possess a range of both hard and soft skills, who can deal with disruption, who are creative, and who can communicate. But the roads industry will still need people who are highly quantitative, and who can apply their skills in a range of situations. Here, the challenges may extend back into secondary and primary education, where there may be disincentives in place for studying STEM subjects.
- However, it will be up to roads agencies themselves to determine how much of this workforce gap will need to be met by themselves, and whether there is a role for increased partnering with the private sector as well as other public agencies in meeting their objectives. With changes in technology and capability come potential changes in agency role and function, a process which has been observed in other (formerly highly public sector) industry sectors across transport and utilities. Developing partnerships and a sharing culture is, in itself, a 'soft' skill which agencies are likely to need more of in future. Establishing greater partnerships between agencies and the private sector, as well as across tiers of government (e.g. between state jurisdictional agencies and local councils) may also help accelerate innovation that could potentially assist in ameliorating future workforce gaps.

7. Ensuring Workforce Capability: A Road Map

The quantitative (Section 5) and qualitative (Section 6) approaches undertaken for this report both indicate that roads agency workforce capability across Australia and New Zealand, while challenging now, is likely to come under further significant pressure in coming decades.

Quantitative modelling of workforce gaps indicates that the most substantial risks to workforce capability will not be driven by further rapid increases in traditional roads activities from here (i.e. construction and maintenance) but rather from *sustained high levels* of traditional activity in an environment where both technological ('big data', CAV, C-ITS and MaaS) and institutional changes (agency role, function and funding) are also placing new pressures on workforce capability. Here, ageing of the existing workforce against high future demands will require agencies to recruit more people across a broader range of skills than previously considered in Austroads workforce capability research.

Meanwhile, qualitative research undertaken for this study – through both survey and interview – highlight the 'pinch points' and challenges for roads agency workforce capability, at both a jurisdictional and local government level over coming decades. In particular, this research – the first of its kind undertaken for an Austroads workforce capability report – indicates where workforce capability gaps are likely to be already felt, which occupations agencies and the broader roads industry (across contractors, professional associations, education providers and other government agencies) expect the greatest risk to workforce capability in future, and what the key risks and challenges to workforce capability will be.

Table 7.1: Potential timing of workforce capability threats

0-5 years (to 2022)	5-10 years (to 2027)	10-20 years (to 2037)
Demand / supply pressures		
Rising level of roads activity	Sustained high roads activity	Rising maintenance tasks
Competing industry demands	Competing industry demands	Unknown
Rapidly ageing workforce	Rapidly ageing workforce	Ageing workforce
Falling rates of migration	Stabilising rates of migration	Unknown
Falling STEM study in schools	Unknown	Unknown
Vehicle technologies (C.A.S.E.)		
ITS only	Emerging C-ITS	C-ITS
Mostly semi-autonomous vehicles	Emerging Level 4 and 5 CAV	Increasing share of Level 4 and 5 CAV
Ride sharing services (e.g. Uber)	Emerging MaaS systems	Advanced MaaS systems
Mostly non-electric vehicles (EVs)	Increasing share of EVs	Majority of new vehicles sold are EVs
Other technologies		
Big data and BIM	Big data and BIM / systems	Machine learning and AI
Agency role and function		
Roads and Transport	Increasing Transport integration	Transport and Liveable Cities
Highly prescriptive regulation	Increasing outcomes approaches	Non-prescriptive regulation
Engineering & network operations	Increasing ops & asset mgment	Optimising transport networks and use
Funding / road user charging		
Licencing and fuel taxes	Introducing heavy vehicle RUC	Introducing broad-based RUC

While many risks and challenges to capability in the roads sector are happening concurrently, some risks are particularly high in the short term (next 0-5 years) while other risks are likely to intensify over the next one to two decades (5-20 years), as illustrated in Table 7.1.[21] For jurisdictional and local government roads agencies, it will be important to prioritise actions to meet critical threats to workforce capability in a timely manner whilst still recognising that some threats – particularly concerning new technologies – will require considerable planning and preparation in advance. For instance, according to consultation for this study, roads agencies and local government are already experiencing workforce gaps in 'traditional' areas such as civil and materials engineering, design and procurement as a consequence of rising levels of activity in roads and other competing industry sectors, coupled with existing difficulties in recruiting.

But there are also emerging threats. Now, and in future years, agencies (both local and at the state jurisdictional level) will experience increasing challenges associated with the rise of 'big data' and the transitioning of agency functions from traditional, static construction and maintenance activities to that of dynamically optimising network operations and asset management. This calls not only for different or re-assigned designer cluster skill sets (i.e. engineering and spatial skills) but also a raft of new skills across informer and technological clusters, including behavioural scientists (psychologists and economists), data analysts and technologists. Over the next 20 years, once most (currently known) future technologies – including C-ITS, CAV, ride sharing / MaaS, and electric vehicles – have become mainstreamed in the roads industry, the workforce challenges facing the roads industry will be changed again. Preparing for these technologies inevitably means investment now across a range of skills to understand better what these future challenges and demands will look like and, based on consultation with all roads agencies for this report, this is indeed already happening. But it is also likely to drive a need to develop a new class of skills, combining the 'hard' and 'soft' skills features of existing occupations so that roads agencies will have the creativity and flexibility to adapt to disruptive, uncertain futures. This, in turn, implies building partnerships with other industry stakeholders – particularly private industry and the education sector – to guide a diverse range of long-term skills development across the roads and broader transport industry.

7.1 Challenges and potential solutions

Apart from identifying risks and challenges, however, the outcomes from the research has also yielded solutions to minimising risks and securing a positive legacy for workforce development and capability in coming decades. This is the objective of this Section – given the nature of the challenges ahead, how can roads agencies and the broader industry prepare and implement actions that will best ensure long-term workforce capability across the sector. In what follows below, the challenges and potential solutions have been organised into 'traditional' (i.e. designer and artisan clusters) and 'non-traditional' (informer and technologist clusters) although there can still be considerable overlap in the challenges and solutions.

7.1.1 Meeting 'traditional' skills challenges

While this study has been highly concerned with the rise of 'non-traditional' skills demand within roads agencies and the broader roads industry, a key finding remains that 'traditional' (particularly designer cluster) skills sets remain at the forefront of workforce capability pressures now and in the coming decade. In turn, these pressures are being driven by:

- High and sustained levels of 'traditional' roads activity across construction and maintenance
- Rapid increases in competitive demands from the rail industry initially, but also potentially from other sectors such as mining
- High rates of existing roads agency workforce attrition as highly experienced 'baby boomers' move into retirement

21 It should be noted that the timings for these developments, whilst based on findings for this report via industry consultation and independent research, are illustrative and may not hold true in all scenarios or for all agencies. Indeed, there may be healthy disagreement in the suggested timings for technological development or changes in funding for roads agencies, for example. The purpose is to indicate that some threats will become more focused in future, but the exact timing of that future remains highly uncertain.

- Difficulties in retaining existing staff, particularly in regional areas
- Emerging risks to potentially supply via migration and education.

In meeting these 'traditional' workforce capability challenges, BIS Oxford Economics research coupled with the many positive ideas that emerged from the consultation process offer a way forward for roads agencies to consider. While not 'silver bullets' individually, together the following solutions may provide ways to minimise the risks surrounding 'traditional' roads agency workforce capabilities, particularly over the coming decade.

- Maximising the industry skills base
- Using procurement as a skills strategy
- Strategies to secure skills in regional areas
- Strengthening workforce retention strategies.

Maximising the industry skills base

'Traditional' (principally designer and artisan cluster) skill sets tend to have a large degree of overlap between public sector agencies and the private sector. For artisan skill clusters – such as labourers and plant operators – while not all jurisdictional state roads agencies maintain a large construction and maintenance workforce, there are exceptions (e.g. RoadTek in Queensland) as well as many others who work in construction and maintenance at the local government level. These, in turn, work alongside a large private sector skills base under the direction of industry contractors. Meanwhile, there is also a significant transferability of traditional designer cluster skills – involving various engineering occupations, spatial scientists, contract and procurement managers – across the public and private sectors in the roads industry, and more broadly. In this sense, strategies that aim to ensure traditional workforce capability in roads agencies should ideally also have a broader remit in that they add to capability across the industry as a whole, from which roads agencies can secure their share.

Over the past two decades, roads agencies have increasingly partnered with the private sector in delivering infrastructure projects and maintenance. In future, as the roles and functions of agencies continue to evolve, there will be further opportunities to collaborate with the private sector across further skill sets, and the success or otherwise of this collaboration will hold important ramifications for the development of workforce capability for the industry as a whole.

For example, the recent 're-tooling' in skills as New South Wales (and Victorian) governments have embarked on a very large and long lasting program of infrastructure development provides important lessons for effective partnering with the private sector, and maximising the use of skills. While this focuses primarily on being an informed purchaser, design, procurement and construction skills, these lessons could apply in future to other agency functions including data analysis, network operations and asset management.

> *"As a government agency, we shouldn't do anything that the market can do better, unless there is a form of market failure or there a particular safety or consumer protection need. If it's the delivery of a service, and the market can do it better, then we should be doing what we can to allow the market to do that in a way that's safe and supports competition." – Australian roads agency*

Conversely, during recent soundings the broader roads industry indicated they could meet the growing capability challenge if they were given greater certainty from agencies regarding what they wanted and when. On the project delivery side, having a known project pipeline, coordinated across all jurisdictions (recognising the challenge of getting multiple projects designed, procured and delivered simultaneously) was considered crucial. Harmonisation different rules and processes across jurisdictions was also considered to be very important.

> *"Agencies need to consider their long term pipelines carefully if they want industry to develop skills that will deliver quality assets. Pipeline planning is critical to skills development." – New Zealand contractor*

> *"Industry will go higher and higher up the food chain, but we will not invest if we don't have the confidence that government values what we've got." – Australian contractor*

Having plenty of notice via a coherent, long term project pipeline may also be welcomed by the general public, who want to know what's going on when the future shape of their city is at stake (as well as their taxpayer dollars): social media has raised the stakes of the government keeping citizens informed.

A number of industry observers noted that infrastructure project pipeline visibility has improved in some states and agencies, but not consistently so. For example, Roads and Maritime Services (RMS) now publishes its pipeline, with beneficial impact (for example, people have moved to North Coast to work on the Pacific Highway project; while concrete suppliers use the publication to plan concrete and quarry supply). By the same token, a number of agency pipelines are still not published to a similar degree or detail and are instead 'talked about'. In some cases, contractors have found out from non-official sources (e.g. newspaper articles that major projects were to be built). Traditional construction programs rely heavily on effective and early communication with industry for skills and resources to be ensured.

However, to be most effective in planning for 'traditional' skills demand, agencies will need to move away from a parochial pipeline focused only on roads towards a much broad development pipeline – encompassing a full range of infrastructure and building segments across public and private sectors. Currently, each agency has its capital budget, and feedback from industry soundings is that this potentially fosters a 'silo mentality'. Cities planning is becoming increasingly complex, however, with many integrated projects. Therefore, it will become increasingly important for roads agencies to link into hub/precinct approached with all stakeholders involved. Transport for London is quoted as a good example: it operates off a Masterplan, with a single authority, allowing big commerce and financiers to all plug into the same masterplan.

An aggregated pipeline approach would allow for broader government and private sector engagement and research into how the *overall* demand for traditional skills is likely to pan out, and whether there is the ability to re-prioritise the pipeline to help minimise risks to traditional workforce capability. While it may not be a roads agency role to comment on the pipeline of rail projects, for example, an aggregated long term pipeline approach will allow roads (and broader) agencies to note well in advance where skills pressures are likely to be tightest so appropriate industry-wide skilling strategies can be put into place.

Using an aggregated pipeline to help smooth out construction cycles may also improve the additional benefit of allowing smaller regional jurisdictions and councils to retain staff who may not necessarily return once the boom is over:

> *"It's quite cyclic. When the boom hits, the demand goes up, private industry will suck a fair bit of the talent pool out. When the boom dies, that staff is let go and that pool becomes available for local government until the boom hits again. But once you have had the big project money, it becomes harder to return back to local government." – Australian local council*

Meanwhile, moves to become less prescriptive in partnering with private industry (which may occur given technological developments that may make future roads agencies behave more like current aviation or rail agencies) could also help mitigate risks to workforce capability. Providing an 'outcomes based' performance framework, where the private sector could invest in design and 'industry smarts' could provide workforce efficiencies both in construction and longer-term asset management:

> *"Private industry tends to innovate better than government – that is a benefit we can get from the market if they work for us. As long as we engage them properly. They are often more able to invest in R&D and trial innovative things more than we can. We're government and can only spend money a specific job for the benefit of the community, not trialling out some new things to see if they are cool or not. If we work with private industry appropriately, we can build in incentives around innovation that can benefit all parties." – Australian roads agency*

> *"This prescriptive approach means that agencies rely more on their internal knowledge. But technology is changing faster than agencies are keeping up, so they are not in a good position to prescribe technological solutions." – Australian contractor*

But, so long as there was certainty and a harmonised approach in what agencies wanted the market to deliver, prescriptive or non-prescriptive approaches could both work:

> *"If they want to go more prescriptive that's okay. If they want to go less prescriptive that's okay too. Just don't randomly mix it up. If they want to be more prescriptive in technological platforms, say, then they need to build up their capability, expertise, regulation, legislation. And they don't need to do it themselves. The market can make itself to respond." – Australian contractor*

Furthermore, there was recognition that many of the skills required by roads agencies could be delivered by engineering associates and other people skilled through the vocational training sector, rather than the universities. This was particularly true in regional and remote regions, where it was often difficult to attract or afford university trained professionals. This, in turn, requires a focus on the needs of the vocational sector (which is also responsible for delivering many of the 'artisan' skill sets – construction trades and machinery operators – that are also a key part of the roads industry). Here, there was a concern that the education system is turning out too many university-trained graduates and not enough associates or trades workers. In part, this was perceived to be due to changing aspirations, with "parents wanting a better career for their children than they had". Consequently, greater engagement with the vocational sector would also be beneficial – at the least, agencies and the broader industry should be communicating and coordinating likely demands for skills in these occupations as a consequence of infrastructure programs, changing technologies (impacting on some construction trades), and changing agency functions.

Finally, for the roads industry to make the best use of available skills, it will be important that agencies do not place artificial roadblocks in the way that prevent skills being transferred from other industries. Here, recent industry soundings suggest that there may be cause for concern in some jurisdictions that may not be making the most of any latent skills capabilities available, particularly in the professional occupations. Recent research for Infrastructure NSW suggests that government agencies in that state may not have made the most of the opportunity to recruit engineers (and other designer cluster professionals) from the mining industry as resources investment faded due to a lack of prior experience in transport.[22] Such 'rules', while ostensibly aimed at minimising risks to agencies, may also effectively operate at the procurement level in transport agencies in other jurisdictions, despite a different philosophy being espoused at the executive level. Similarly, research for this study suggests that there may be other cultural and gender heuristics and biases in recruitment for agencies which may prevent the development of a more diversified skills base that can best meet the range of challenges ahead.

Using procurement as a skills strategy

Recent industry soundings highlighted that the procurement process itself could be used as a tool that could enhance broader industry workforce capability, not just in the roads sector but across the construction industry. Mirroring similar findings in other recent capability research,[23] private industry participants in the industry soundings for this study indicated that the procurement process itself should be reformed, and include broader measures of "value for money" than just focusing on direct costs.

Part of this broader measure of "value" may involve including a greater emphasis on workforce skills development as a criterion during the procurement phase – such as the Skills Exchange model that has been used successfully on large construction projects in South Australia and New South Wales.[24]

22 BIS Oxford Economics (2017a)
23 Ibid
24 Ibid, pp80-81. Similar projects have been undertaken in other Australian jurisdictions as well as the United States and the United Kingdom.

The main features of the Skill Exchange model is that it is a partnership with the vocational education sector which is designed to bring education to the workplace itself, where it is more likely to be utilised by staff, further developing their skills and competencies and providing qualifications. There is still some way to go, according to recent industry soundings, for models such as these to become more common in procurement for roads projects but, as competition for skills and resources intensifies in coming years, it is expected that the pendulum would swing back towards more 'alliance-style' procurement methods. Even so, there may still be differences between what agencies aspire to at a senior level, and how procurement teams actually operate.

> *"The private sector will respond, but they will have to expect that it won't be the lowest price for construction because there is an additional component there [for innovation and skills development] … however, what the executive are saying and what is reality, are two different things." – Australian contractor*

Securing skills in regional areas

While large jurisdictional agencies had arguably greater capacity to source the skills they need, local councils and smaller jurisdictions repeatedly mentioned in interviews that they struggled to attract skills given the remoteness or regional nature of the work, and an inability to pay higher wages for employees on a full time basis. Consequently, it is expected that these organisations will be at the greatest risk of skills shortages over the coming one to two decades given the impact of declining revenues and large infrastructure pipelines being rolled out in larger jurisdictions (and focused particularly in urban areas).

One potential solution, highlighted at both the local government level, as well as jurisdictions themselves, is establishing a form of super agency that could pool resources, and could be drawn upon by smaller agencies as required:

> *"We can't afford to have specialists in one key area like bigger jurisdictions do. The whole nation will have to grapple with this at some stage because a lot of the roads agencies are becoming uninformed buyers and they don't have that in-house expertise like they did. It may be that jurisdictions will have to come together and have a national specialists group that services all areas. Agencies will have to pool those resources." – Australian roads agency*

> *"[The jurisdictional roads agency] have offered to inspect our bridges, and they cycle through bridges on state roads, but they are also facing budget cuts. If our regional council organisation jumped in and said they should be doing our bridges whilst they are up here they could do that and receive income from it." – Australian local council*

In various degrees, pooling is already happening in some jurisdictions as roads agencies contract with local governments to provide sustainable employment. In other jurisdictions, councils and roads agencies are increasingly reliant on contracting in capability at the regional level, which makes effective procurement and partnering skills with the private sector vital.

> *"There is an alliance between TMR and LGAQ. TMR maintains some of the sections of local council roads and individual councils will maintain sections off state roads. In New South Wales, there are 30 regional councils who are contracted to RMS to maintain state roads. That contract is building capability for council staff. There's more funding, there's more certainty, and better collaboration between state agencies and local councils. There also a strong relationship between Main Roads WA and the councils." – Australian association*

> *"From a council perspective, new procurement arrangements allow state governments to bring in capability in regional areas where they may not have the resources. But there is uncertainty as to whether either party is getting a good deal from this arrangement." – Australian council*

Despite these efforts, regional councils and jurisdictions will likely face persistent challenges over the next decade in securing skills and resources. Consequently, they may need to complement pooling approaches with other strategies to maintain capability. These other strategies may include focusing on developing engineering associates through the vocational education system, and highlighting other, non-monetary benefits of working in regional areas including lower cost of living (particularly housing), quality of life, more varied work as a generalist as opposed to a specialist, and the satisfaction of working with smaller, nimble teams who can 'get things done'. Industry interviews also noted that perhaps more could be done to provide greater opportunities for travel and learning from jurisdictional or international peers in order to retain staff. Having educational opportunities within regional jurisdictions was also seen as important.

Strengthening workforce retention strategies

Industry consultation for this study indicates that one of the biggest perceived risks to roads agency workforce capability over the coming decade will be retaining skilled staff – particularly those with 4-5 years experience – from hire by competing industries or departments. In surveys, roads agencies rated workforce retention the equal second highest risk factor over the next two decades behind demographic impacts (See Section 6.1.4), although it was a much lower order (though still significant) risk from non-agency respondents. In interviews with roads agencies, there were similarly many comments highlighting the risk to capability if existing staff were to leave, most notably in some of the smaller, more regional, agencies.

From industry soundings and further research, workforce retention risks tended to fall into the following categories:

- Loss of graduate staff following initial internship or cadetship (graduate retention)
- Loss of staff with 4-5 years experience (middle experience levels)
- Loss of staff through early retirement (high experience levels).

Each of these categories represents a different workforce career stage, and so potential solutions to strengthening the workforce retention strategy will likely be different at each stage. At the **graduate** level, industry soundings suggested that roads agencies have withdrawn somewhat in terms of the number of cadetships offered to university and vocational training students, although more research is necessary to confirm or refute this. What is equally, if not more important, however, is the ability or desire for roads agencies to retain graduates upon completion of their internships or cadetships.

> *"We don't have the scale or flexibility to do workforce planning to that extent. We are down to 133 full time equivalents so there is no ability to have people occupying positions at a junior level with a view to promoting them, and things are so tight now we don't have the capacity to be mentors. So the only way we can replace these people when they leave is to try to find another individual." – Australian roads agency*

Are graduate retention rates in decline? Evidence collected as part of this study is mixed, with some agencies reporting lower graduate retention rates in more recent years, while other agencies noted that if graduates did not receive a permanent role at the end of their cadetship they were offered up to two more six-monthly 'rotations', with the intention that all graduates would be retained even if it took an extra rotation or two. While a more detailed analysis of roads agency graduate retention rates over time is not within the scope of this study, it would be a fruitful area of future research. Feedback from industry soundings suggest that new graduates are increasingly seeking more dynamic 'starter' roles that allow them to experience a wider range of the agency and its functions. Competitive compensation packages (including superannuation) were also seen as important, as are having access to education facilities where graduates can finish or undertake further study:

> *"On education, it used to be that if you wanted to finish your engineering education you needed to go interstate. But there are private schools which have started up which make a difference" – Australian roads agency*

However, it is the risk of losing staff with middle-range levels of experience (i.e 4-5 years+) that was seen as the greatest retention issue facing roads agencies, particularly given sunk investment in on-the-job education and training and high industry competition for this level of skill. For smaller and more regional agencies, the challenge was seen as keeping (mainly younger) staff who wanted to move to bigger cities or sectors either to boost their incomes or further their career development opportunities.

> *"In terms of skill sets we find it very hard to attract professionals. And when we do or train our own we find they have been lured to the bigger jurisdictions - happened a couple of times in the last month - because it's such a big infrastructure program there" – Australian roads agency*

Here, a range of strategies may be required to improve retention rates (although it was also noted by some respondents that it may be better to simply let staff go with the intention of bringing them back into the agency at a future date, along with their improved and updated skills). The success of either strategy depends crucially on increasing the attractiveness for experienced staff to work in agencies through a range of approaches. This may include strengthening options for ongoing training and development (e.g. access to highly experienced mentors, further study, ability to attend national or global conferences in their field, ability to be seconded into other agencies or the private sector, or vice versa), maintaining a workplace culture that rewards success, innovation, collaboration and teamwork, strong communication and feedback, and promotes a healthy work/life balance. Retention in smaller, regional areas may also be assisted by more effective promotion of lower costs of living (particularly housing) and other non-salary lifestyle benefits compared to major state capitals – as well as promoting a typically more diverse range of tasks (i.e. generalist) rather than being cornered into specialization in a very large organization.

Finally, at the very end of spectrum is the loss of very highly skilled staff through retirement. While not all potential retirees (i.e. those aged 60+) may yet be in a strong financial position to retire, this may change in coming decades given the operation of compulsory superannuation guarantees in Australia since the early 1990s. Here, it will become increasingly important for agencies to codify the opportunity for highly skilled older staff to continue in ongoing part-time or mentorships roles within agencies. This will not only retain their skills to the agency, but the presence of mentors is also likely to increase the attractiveness of staying within the agency for graduates and staff with 'middle level' skills.

> *"Most retirements occur at 65-70. Many retire at 65 and become part time consultants. This is filling a gap that's really needed in the industry. I do like the flexible work arrangements for retirees because their knowledge is still very valuable" – Australian roads agency*

7.1.2 Meeting 'non-traditional' skills challenges

Longer term, analysis undertaken for this report suggests that roads agencies will be under increasing pressure to ensure workforce capability across a range of 'non-traditional' skill sets. This includes a broader range of designer cluster skills and occupations, a growing number of skills required from the informer and technologist clusters, and an increasing need for a mixture of skills, both 'hard' (e.g. quantitative) and 'soft' (e.g. collaborative, communicative) to meet a more diverse range of agency objectives and functions.

While this situation is expected to be in state of evolution through coming decades as new technologies become entrenched, there is also more immediate pressures being brought to bear now. This being driven by the emergence of 'big data' – which has the potential to revolutionise agency functions such as network operations and asset management – as well as undertaking research to understand better what the demands will be from future technologies such as C-ITS, CAV and MaaS.

Here, given the longer time frame for some of these developments under consideration, there is a greater opportunity for roads agencies to interact with new skills producers – the education sector itself – to not only ensure a greater flow of skills into the roads and broader transport industries, but also have direct input into the types of skills that would be best developed. This in turn, will require agencies to continue to track developments in technology (to best identify which future 'scenario' will prevail) and plan their 'non-traditional' workforce requirements accordingly. In keeping up with technological developments in an uncertain world agencies will need to make ongoing investments in staff with a broad and diverse range of skills, but particularly those that have an interest in disruption and change.

> *"We used an agile process to start this team. I didn't know the number of hours of anything. We just put types of skill sets in the room. We won't know how long things will take – its part of the innovation. To find these people, you put up an exciting project for people to say hello to and the people who find it are the people who want to change. This team all came here willingly to look at new things and to change." – Australian roads agency*

In so doing, it also needs to be recognised how much of this skills base will need to be directly employed by roads agencies, and how much could fall into the domain of private industry through appropriate partnering or contracting approaches.

Stronger engagement with the education sector

Industry soundings revealed that the education sector continues to adapt to develop core skills useful for the roads industry in face of rapid changes in technology and demands. Furthermore, some institutions are making strides in developing a range of soft skills (e.g. flexibility and agility in dealing with disruption) as well as multidisciplinary skill sets (e.g. transport, engineering and economics) which will be highly useful for future roads agency roles and functions, as detailed in Section 6.2 of this study.

Arguably, however, the recent industry soundings suggest that agencies will need to do a lot more to engage with educational institutions to help shape the development of skills they will need, as well as to increase student awareness of the varied careers that are now available – particularly in 'non-traditional' areas of study including 'big data', non-civil engineering, science, mathematics and statistics, and the behavioural sciences including economics. Here, the general feedback from education institutions, particularly, was that many students (outside of civil engineering, surveying and transport) were simply *unaware* of the opportunity to work in roads or broader transport agencies. Some academics involved in the soundings mentioned that projects selected by students in Masters courses had little social benefit, and this wasteful situation could have been avoided (to the roads agency benefit) if these students were engaged instead with 'real world' transport challenges.

Here, the rise of 'big data' challenges with the roads space could be seen as an opportunity to partner with relevant tertiary educational institutions and courses (ranging from transport, economics, engineering to computer science, IT and statistics) in developing innovative and practical education programs that could provide the long term mix of 'non-traditional' skill sets that agencies may need. Given constraints on university budgets as evidenced in industry interviews, it may be worthwhile to consider whether roads (or broader transport) agencies could even sponsor specific existing or new courses, or at the least, target numbers of agency staff that would benefit from studying to provide universities with a certain baseload funding. Sponsorship of courses would also help provide roads agencies with a direct promotional route to students studying 'non-traditional' subjects, and position agencies as being dynamic, leading centres in their own right in this space.

Growing the future supply of 'non-traditional' professionals involves more than just growing the number of people with professional qualifications, however. It also requires these people to move into equivalent professional roles in agencies. Less than two-thirds of engineering graduates in Australia, for instance, are currently employed in engineering occupations. Consequently – and as highlighted in the previous section – an important part of any policy aimed at boosting skills capacity through education should target the retention of skills, such as offering cadetships and other career pathways with both the public and private sectors, recognising that the bulk of skills formation – especially in new, non-traditional areas – is formed on the job.

> *"It's an attitude more than a skill set... The knowledge of standards and some of the unknowns can't be taught because no-one knows about this stuff. It has to be learnt. We need people with an 'adaptable' attitude, who is not scared of change, is a self-starter and a willingness to learn. That's the skillset…. It's also the hardest workforce thing." – Australian roads agency*

Partnering with industry

Finally, as with more 'traditional' skill sets and functions, it will be up to agencies (and perhaps, the public sector more broadly), to determine how much of the new 'non-traditional' roads workforce actually needs to be housed within roads agencies themselves. While 'big data' and new technologies may drive an increasing demand for informer and technologist cluster skills sets, there is no rule that suggests that all of this demand must be met by the public sector.

As discussed in Section 6.2, the decision on the degree of outsourcing of non-traditional skills would come down to the relative efficiency by which the private sector could do the work, the degree of data sharing, and how agencies (including local councils) would retain in-house capability to be 'informed purchasers' of such services or otherwise satisfy change management requirements.

Consequently, it is highly likely that partnerships models will need to develop between agencies and the private sector to sustain and develop skill sets and capabilities across network operations and planning, asset management, and skills associated with new technologies from C-ITS to CAV and dealing with MaaS. Currently, there is a view in several roads agencies that it may be best to invest heavily in research internally – not merely to be 'informed purchasers' but with an eye to potentially creating the intellectual property (e.g. data platforms, transport models or technical systems[25]) that can be owned and commercialised by the public sector in future. However, it may be increasingly important over time to partner with other large data collectors (e.g. Google, Amazon, Uber) and analysts so that there can be effective modelling of transport flows under new technologies and systems (both real time and strategic) and that agencies can develop appropriate policies, behaviours and strategies that see these technologies work for the benefit of all roads users and the optimisation of the road asset.

Partnering, itself, need not be an all (i.e. full contracting out) or nothing (i.e. full in-housed) proposition. There is a broad spectrum of approaches that roads agencies can use to tap into private sector expertise and experience to assist capability, ranging from offering temporary positions or secondments to targeted experts (individuals or small teams) from the private sector or educational institutions, to establishing formal alliances, other sharing models and various degrees of subcontracting. From industry soundings it is likely that the private sector will be highly interested in developing partnerships with roads and broader transport agencies given their already strong levels of investment in new technologies, 'big data' analysis and transport modelling. With agencies expected to experience funding constraints in future given the impact of new technologies on its traditional revenue base – on top of workforce constraints – it will be increasingly beneficial for agencies to maximise use of these resources through deeper engagement with industry.

7.2 Recommendations

Through the findings of this workforce capability analysis, both quantitative and qualitative, a range of actions have been identified which can assist roads agencies in navigating risks to workforce capability, now and through the coming decades. These are shown in the following table and are organised by theme, with a suggested time period where this action will become critical. It should be noted that, as arising from industry and agency consultation, some agencies are already undertaking actions similar to those proposed. However, it may not be occurring consistently across all agencies, and there may also be differences in the capability of some agencies (e.g. smaller, or more remote local councils or jurisdictional agencies) to undertake some of these recommendations. In these circumstances, it would be important for an overarching body, such as the Austroads workforce capability group, to regularly review progress on capability-enhancing initiatives and identify where there are barriers to implementation.

25 Such as the Sydney Intelligent Traffic Management System (SCATS)

Table 7.2: Challenges and Suggested Actions

Challenge / Theme	Possible Actions	Suggested Timeframe
High industry demand for 'traditional' skill sets across designer and artisan clusters	Undertake initiatives to ***free up or improve existing*** capability across roads agencies and the broader industry. This will include the following ideas and solutions submitted during the industry consultation process:	
	• Both roads agencies and the private sector may need to take stronger steps to improve in-house training systems. It is likely that gaps will emerge because existing staff have not been adequately trained or prepared for higher project management roles, particularly when higher level staff leave.	0-2 years
	• Roads agencies need to undertake further substantial investment to enhance the 'systems view' of their networks. A stronger asset management approach (i.e. subject to a budget constraint) will allow existing scarce resources to be more optimally deployed. This will, however, drive demand for other skills clusters.	0-5 years
	• Undertaking reforms to public sector procurement processes (to reduce duplication and waste), harmonising systems (e.g. standardising contracts) and adopting less prescriptive approaches would also help conserve the existing traditional skills base across industry, reducing pressure on agencies to retain staff.	0-5 years
	• Agencies should renew efforts to reduce barriers to entry to the roads industry that prevent the transferability or mobility of skills from other industries or geographies. This may require modifying existing 'traditional' rules in procuring staff or industry contractors more broadly.	Now
High industry demand for 'traditional' skill sets across designer and artisan clusters	Undertake initiatives to ***expand*** capability across roads agencies and the broader industry. This will include some of the following ideas and solutions submitted during the industry consultation process:	
	• Develop a holistic project pipeline, working with other agencies across jurisdictional boundaries and the private sector, that allows industry as a whole to develop long term plans for training and developing staff. It will be in the interest of roads agencies, the broader industry, and governments to smooth the project pipeline to minimise booms and busts in skills demand and reduce the churn of skills between the public and private sectors.	Now
	• Include diversity explicitly as a factor for consideration when recruitment, whether it be diversity in skills, gender or other background factors, and actively promote agency roles and positions to audiences outside of the usual target groups (e.g. civil engineers)	Now
	• Roads agencies should join broader industry in proactive responses to public policy debates that impact on future skills supply, such as education and skilled migration.	Now

Challenge / Theme	Possible Actions	Suggested Timeframe
Rising demand for technologically-driven 'non-traditional' skills	Here, industry soundings and interviews suggested a range of actions which need to be undertaken by public roads agencies, including:	
	• Boosting the promotion and marketing of roads agencies and their increasing data/technological requirements to STEM-focused secondary and tertiary students, as well as the behavioural sciences. This means moving outside traditional courses (e.g. civil engineering) and engaging with departments of science, mathematics and economics.	0-2 years
	• Better targeting of relatively underrepresented groups, particularly women, and people from different cultural backgrounds.	Now
	• Improving flexibility within roads agencies for existing staff to move nimbly into 'non-traditional' roles if they already possess the requisite skill sets (e.g. engineers moving into 'big data' analysis).	Now
	• Develop and foster partnerships with educational institutions and private industry to leverage skills which may already be available.	0-2 years
	• Engage with educational institutions directly to target the development of a mix of 'hard' and 'soft' skills, or an increasing number of multi-disciplinary graduates (e.g. data science / economics, or engineering / communications), as diversity may better tackle future complex technological challenges. Demanding higher level pre-requisite STEM studies for entry into tertiary studies may also help send a signal to the secondary school system. Sponsoring or partnering with specific courses (e.g. supplying 'real world' challenges) may also work to promote roads agencies as a destination for promising graduates.	0-5 years
	• Increasing demand for spatial (geomatics) skills, particularly, from roads agencies may require specific policies to increase awareness and engagement from potential students as well as boosting the small number of courses offered at universities.	0-5 years
	• Directly boosting the number of internships offered to promising students, particularly those involved in multi-disciplinary studies.	Now
Enhancing supply of skills already considered to be in shortage	Research and industry consultation indicate that industry is also experiencing shortages of skills across a range of 'traditional' and 'non-traditional' skill sets. Actions here may include:	
	• More active promotion of these known skills gaps to secondary and tertiary students, and the promotion of future agency work.	Now
	• Greater engagement with education providers (both university and non-university) to match skills requirements with existing course structures, and to promote enrolment in required courses of study.	0-2 years
	• Consider the feasibility of establishing 'shared skills' networks across the roads sector where agencies (e.g. local councils as well as larger jurisdictions) can pool resources considered to be in short supply.	Now

Challenge / Theme	Possible Actions	Suggested Timeframe
Meeting skills 'pinch points' in regional and remote areas	In securing greater skills for regional or remote regions, industry consultation in conjunction with other research suggests the following action points for consideration:	
	• Develop holistic *regional* project pipelines including public and private sector funded works – and visible to all government departments – that allow for more appropriate skills planning in those regional areas and identify when skills pressures are likely to be acute.	Now
	• Develop a national 'super agency' that can pool resources and hire out skills as required by those agencies or regions that do not have the capability to hire full time employees.	0-2 years
	• Increase focus on developing skills through the vocational education system (e.g. engineering associates) and, where possible, enhancing educational opportunities within regions	0-2 years
	• Governments to offer higher training incentives or subsidies (e.g. for travel and learning expenses, attending conferences etc) to increase the attractiveness of working in remote or regional areas and minimise differences in opportunity to urban areas.	0-2 years
	• More effective promotion of the benefits of regional and remote work to prospective graduates or the existing urban cohort including the multi-disciplinary nature of work, nimbleness in getting projects up and running, 'lifestyle benefits' and lower living costs (particularly housing).	Now
Reducing workforce attrition and loss of capability through retirement	Undertake steps to improve agency legacy systems that retain industry knowledge and skills. This may include:	
	• Improved succession planning practices to identify potential knowledge loss risks before they occur	Now
	• Allowing greater time for knowledge transfer from retiring to remaining staff	Now
	• Establishing a 'learning / relearning' culture ('learning hubs') and programs and providing options for retiring staff to join mentorship teams on a part time basis	0-2 years
Improving retention rates for graduates and 'middle experience' workforces in a period of likely heightened demand	Here, a range of strategies to improve staff retention emerged in agency and non-agency consultation including:	
	• Improve the 'on-boarding' experience of new graduates by establishing dynamic roles and experiences across many parts of the organisation as the norm. Have defined plans for graduates, with strong levels of communication and feedback.	Now
	• Provide greater opportunities for learning, such as through mentorships or 'learning hubs' and taking on board new responsibilities, with clear communication regarding potential paths for professional development and promotion	Now
	• Offer opportunities for existing staff to work in new areas within the organisation (or across other parts of government or industry) to build a diversity of skills.	Now

Challenge / Theme	Possible Actions	Suggested Timeframe
Planning under uncertainty	Industry consultation and further research undertaken for this study highlights that the environment that roads agencies will operate in over the next two decades will be highly uncertain and constantly evolving. In this regard, it will be vital that agencies maintain rigorous workforce planning systems that extends beyond the traditional skill sets, and which regular reviews workforce strategy to ensure it is still appropriate for the world that is emerging. Keeping abreast of developments in technology, understanding what state or scenario is emerging, and having the flexibility to adapt as required will be important skills in their own right for agencies to nurture and sustain. Effective workforce planning will require a team of contributors representing the diverse range of skills (traditional and non-traditional) agencies possess and the functions agencies undertake. Agencies will not know which possible future will eventually emerge, but it will be important to have plans for each scenario, and a diverse range of hard and soft skills to meet the challenges of disruption and change.	Ongoing

References

Australian Bureau of Statistics 2017, *Construction Work Done, Australia, Preliminary,* Cat. No. 8755.0, Canberra

Australian Bureau of Statistics 2017, *Engineering Construction in Australia*, Cat. No. 8762.0, Canberra

Australian Bureau of Statistics 2017, *Labour Force, Australia, Quarterly*, Cat. No. 6291.0.55.003, Canberra

Australian Bureau of Statistics 2017, *Schools, Australia, Table 42b,* Cat. No. 4221.0, Canberra.

Australian Bureau of Statistics 2016, Census of Population and Housing, Canberra.

Australian Bureau of Statistics 2016, *Deaths, Australia*, Cat. No. 3302.0, Canberra

Australian Bureau of Statistics 2014, *Standards for Labour Force Statistics*, Cat. No. 1288.0, Canberra

Australian Bureau of Statistics 2013, *Persons Not in the Labour Force, Australia,* Cat. No. 6220.0, Canberra

Australian Bureau of Statistics 2006, Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Revision 2.0), Cat. No. 1292.0., Canberra.

Australian Driverless Vehicle Initiative 2017, *Thought Leadership Paper Integrated Transport Planning,* Led by Catbagan, J., Haratsis, B., Taperell, A., Mees, M., Burrell, Australia.

Australian Driverless Vehicle Initiative 2017, *Preliminary findings from the first Australian National Survey of Public Opinion about Automated and Driverless Cars*, Australia.

Australian Driverless Vehicle Initiative 2016, *Position Paper: Economics Impacts of Automated Vehicles on Jobs and Investment*, prepared by MacroPlanDimasi, Australia.

Australian Industry Group 2017, *Construction Outlook: November 2017,* prepared by Australian Constructors Association, Sydney.

Australian Industry Standards 2017, *Rail IRC Skills Forecast 2017,* Melbourne.

Australian Industry Standards 2017, *Transport and Logistics IRC Skills Forecast 2017*, Melbourne.

Australasian Railway Association 2016, Rail Platforms for the Future, A rail industry vision with practical and achievable actions: 2017-2033, Canberra.

Austroads 2010, *The Commercial and Core Function Role of Road Agencies in Providing Data and/or Traveller Information,* Austroads Publication No. AP–R352/10, Sydney.

Austroads 2017, *Connected and Automated Vehicle Trials*, Sydney.

Belby, M. 2016, '*Planners go big: Big data means better decisions on transport infrastrucutre'*, Australian Financial Review, 25 May 2016.

BIS Oxford Economics 2017a, *NSW Construction Delivery Assessment: Capability and Capacity*, Sydney, Australia

BIS Oxford Economics 2017, *Building and Construction in New Zealand 2017-2022*, Sydney, Australia.

BIS Oxford Economics 2017, *Building in Australia 2017-2032*, Sydney, Australia

BIS Oxford Economics 2017, *Engineering Construction in Australia 2016/17-2031/32*, Sydney, Australia

BIS Oxford Economics 2017, *Long Term Forecasts 2017-2032*, Sydney, Australia

BIS Oxford Economics 2017, *Road Construction in Australia 2017-2032*, Sydney, Australia

BIS Oxford Economics 2017, *Road Maintenance in Australia 2017-2032*, Sydney, Australia

Catapult Transport Systems 2016, *Intelligent Mobility Skills Strategy,* Milton Keynes, the United Kingdom

Chrisafis, A., Vaughan, A. 2017 '*France to ban sale of petrol and diesel cars by 2040',* The Guardian, 6 July 2017.

Clewlow, Regina R., Gouri S. Mishra 2017, *Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States*, Institute of Transportation Studies, University of California, Davis.

Deloitte 2017, *Deloitte Review, Issue 20 2017*. Prepared by Deloitte.

Department of Education and Training 2017, *Skill Shortage List: Australia 2016-2017,* Canberra.

Department of Education and Training 2017, *uCube – Higher Education Data Cube*, Canberra

Department of Immigration and Border Protection (DIBP) 2017, *Subclass 457 Quarterly and Annual Reports*, Canberra.

Department of Transport Victoria 2009, *Addressing workforce issues in the road freight sector,* prepared for the 32nd Australasian Transport Research Forum by Morris, J and Kazalac, L., Victoria.

Devlin, H. and Hern, A. 2017. *'Why are there so few women in tech? The truth behind the Google memo'*, The Guardian, 8 August 2017.

Education Counts 2017, *Participation*, Wellington.

Engineers Australia 2017, *Defence industry in NSW, Engineers Australia Submission*, Canberra.

Engineers Australia 2017, *Engineers Make things Happen, The need for an engineering pipeline strategy,* Canberra.

Engineers Australia 2017, *Regional development and a global Sydney, Engineers Australia Submission*, Canberra.

Engineers Australia 2017, *The State of the Engineering Profession*, Canberra.

Engineers Australia n.d., *A profession for all, It's time for gender diversity targets*, Canberra.

Esri Singapore 2015, '*Geoanalytics eases Singapore's transport woes',* 3 November 2015.

The European Commission 2009, *Sector Report: Transport and Logistics*, commissioned under the European Community Programme for Employment and Social Solidarity.

The European Commission 2014, *Future employment in transport: analysis of labour supply and demand,* technical report by the Joint Research Centre of the European Commission, Seville.

Hawkins, A. 2017, '*Waymo is first to put fully self-driving cars on US roads without a safety driver'*, The Verge, 7 November 2017.

Heath, A. 2017, *Remarks to the Victorian Career Advisors conference*, Reserve Bank of Australia.

Hensher, D. A. 2017, *Digital Public Transport in an era of Sharing and Collaborative Mobility*, presentation at Roads Australia National Conference, May 31, 2017.

Highways UK 2017, *Highways skills shortage: the ticking time bomb,* the United Kingdom.

Institute of Transport and Logistics Studies 2014, *Infrastructure Management,* The University of Sydney Business School, Sydney.

Institute of Transport and Logistics Studies 2014, *Logistics and Supply Chain Management,* The University of Sydney Business School, Sydney.

Institute of Transport and Logistics Studies 2014, *Transport Planning and Management,* The University of Sydney Business School, Sydney.

Institute of Transport and Logistics Studies n.d., *Research and innovation in infrastructure, transport, logistics and supply chain management,* The University of Sydney Business School, Sydney.

International Organization for Standardization 2014, *Asset management – Overview, principles and terminology,* Geneva.

Infrastructure Partnerships Australia 2017, *Automated Vehicles, Do We Know Which Road to Take?*, prepared by Infrastructure Partnerships Australia, Advisian, and The Research Centre for Integrated Transport Innovation at the University of New South Wales.

Infrastructure Partnerships Australia 2016, *Driving Change: Australia's Cities Need a Measured Response*, Sydney.

Kennedy, J., Lyons, T. & Quinn, F. 2014, *The continuing decline of science and mathematics enrolments in Australian high schools.,* Queensland University of Technology, Brisbane.

Main Roads Western Australia 2017, *Workforce Planning Cycle*, prepared by Main Roads Western Australia, Perth.

National Centre for Vocational Education research (NCVER), *VET Historical Data 1981-2016*.

National Institute of Labour Studies 2007, *What is skill shortage?,* prepared by the National Centre for Vocational Education and Research, Adelaide.

National Transport Commission 2017, *Automated vehicles in Australia,* Melbourne.

New Zealand Asset Management Support 2017, *Infrastructure Asset Management Defined,* Wellington.

New Zealand Immigration 2017, *Immediate Skill Shortage List,* Wellington, New Zealand.

New Zealand Immigration 2017, *Long Term Skill Shortage List,* Wellington, New Zealand.

New Zealand Immigration 2017, *W3 – Work Applications Approved by Occupation*, Wellington, New Zealand.

NSW Treasury 2016, *NSW Intergenerational Report,* Budget Paper No. 5, Sydney.

Phillips, N. 2014 *'20-year decline in year 12 science and maths participation, study finds',* The Sydney Morning Herald, 6 October 2014.

PWC 2017, *Industry Skills Forecast and Proposed Schedule of Work: Mining, Drilling and Civil Infrastructure,* prepared by PricewaterhouseCoopers Data and Analytics Services, Sydney.

Redrup, Y 2017, *'Uber targets Sydney for flying vehicle',* Australian Financial Review, 15 August, p. 25.

RethinkX 2017, *Rethinking Transportation 2020-2030,* RethinkX Think Tank.

Roads Australia 2017, *Preparing for the Driverless Revolution*, prepared by Roads Australia, Melbourne.

SAE 2014, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems,* SAE International.

Statistics New Zealand 2017, *Value of Building Work Put in Place*, Wellington

Statistics New Zealand 2017, *National Accounts*, Wellington

Statistics New Zealand 2013, *Census of Population and Dwellings,* Wellington.

Tasmanian Transport and Logistics Workforce Advisory Group 2015, *Tasmanian Transport and Logistics Industry: Workforce Plan 2015-2018*, Hobart.

Transport and Logistics Industry Skills Council 2015, *Environmental Scan,* Australia.

Wiggins, J 2017, *'Uber 'unabashedly pro' user fees'*, Australian Financial Review, 21 August, p. 7.

Wood, D. 2017, '*Women are dropping out of economics, which means men are running our economy,'* The Conversation, 20 March 2017.

World Road Association 2017, *World Road Association Guide,* Paris.

Appendix A ANZSCO Occupation Classification

Table A 1: Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
Construction Project Manager	133111	133111	Construction Project Manager
Engineering Manager	133211	133211	Engineering Manager
Civil Engineer	233211	233211	Civil Engineer
Geotechnical Engineer	233212	233212	Geotechnical Engineer
Quantity Surveyor	233213	233213	Quantity Surveyor
Structural Engineer	233214	233214	Structural Engineer
Transport Engineer	233215	233215	Transport Engineer
Mechanical Engineers		233512	Mechanical Engineer
Surveyor	232212	232212	Surveyor
Cartographer	232213	232213	Cartographer
Other Spatial Scientist	232214	232214	Other Spatial Scientist
Other Engineering Professionals	2339	233111	Chemical Engineer
		233112	Materials Engineer
		233311	Electrical Engineer
		233411	Electronics Engineer
		233511	Industrial Engineer
		233513	Production or Plant Engineer

Table A 2: Job Cluster 1: Design (Associate Professionals not University Trained)

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
Civil Engineering Draftsperson	312211	312211	Civil Engineering Draftsperson
Civil Engineering Technician	312212	312212	Civil Engineering Technician
Associate Mechanical Engineers		312511	Mechanical Engineering Draftsperson
		312512	Mechanical Engineering Technician
Surveying or Spatial Science Technician	312116	312116	Surveying or Spatial Science Technician
Other Building and Construction Associate Professionals		312111	Architectural Draftsperson
		312112	Building Associate
		312113	Building Inspector
		312115	Plumbing Inspector
		312199	Architectural, Building and Surveying Technicians n.e.c
		312311	Electrical Engineering Draftsperson
		312312	Electrical Engineering Technician
		312411	Electronic Engineering Draftsperson
		312412	Electronic Engineering Technician
		312611	Safety Inspector
		312911	Maintenance Planner
		312912	Metallurgical or Materials Technician
		312999	Building and Engineering Technicians n.e.c

Table A 3: Job Cluster 1: Other (tangential) jobs associated with the Design Cluster

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
Contract, Program and Project Administrators	511	511111	Contract Administrator
		511112	Program or Project Administrator
Procurement Manager	133612	133612	Procurement Manager
Natural and Physical Science Professionals	234	234311	Conservation Officer
		234312	Environmental Consultant
		234313	Environmental Research Scientist
		234399	Environmental Scientists n.e.c
		234411	Geologist
		234412	Geophysicist
		234413	Hydrogeologist

Table A 4: Job Cluster 2: Informer Skills

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
Urban and Regional Planners	2326	232611	Urban and Regional Planner
Information and Organisation Professionals	224	224111	Actuary
		224112	Mathematician
		224113	Statistician
		224311	Economist
		224411	Intelligence Officer
		224412	Policy Analyst
		224511	Land Economist
		224512	Valuer
		224711	Management Consultant
		224712	Organisation and Methods Analyst
Social and Welfare Professionals	272		
Social Professionals	2724	272499	Social Professionals n.e.c
Welfare Professionals	2723	272311	Clinical Psychologist
		272312	Educational Psychologist
		272313	Organisational Psychologist
		272314	Psychotherapist
		272399	Psychologists n.e.c

Table A 5: Job Cluster 3 - Technological Skills

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
ICT Professionals	26	261111	ICT Business Analyst
		261112	Systems Analyst
		261211	Multimedia Specialist
		261212	Web Developer
		261311	Analyst Programmer
		261312	Developer Programmer
		261313	Software Engineer
		261314	Software Tester
		261399	Software and Applications Programmers n.e.c
		262111	Database Administrator
		262112	ICT Security Specialist
		262113	Systems Administrator
		263111	Computer Network and Systems Engineer
		263112	Network Administrator
		263113	Network Analyst
		263211	ICT Quality Assurance Engineer
		263212	ICT Support Engineer
		263213	ICT Systems Test Engineer
		263299	ICT Support and Test Engineers n.e.c
		263311	Telecommunications Engineer
		263312	Telecommunications Network Engineer

Table A 6: Job Cluster 4 - Artisan Skills

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
Tradespersons	32	322111	Blacksmith
		322112	Electroplater
		322113	Farrier
		322114	Metal Casting Trades Worker
		322115	Metal Polisher
		322211	Sheetmetal Trades Worker
		322311	Metal Fabricator
		322312	Pressure Welder
		322313	Welder (First Class) (Aus) \ Welder (NZ)
		323211	Fitter (General)
		323212	Fitter and Turner
		323213	Fitter-Welder
		323214	Metal Machinist (First Class)
		323299	Metal Fitters and Machinists n.e.c
	33	331111	Bricklayer
		331112	Stonemason
		331211	Carpenter and Joiner
		331212	Carpenter
		331213	Joiner
	34	341111	Electrician (General)
		341112	Electrician (Special Class)
		342211	Electrical Linesworker (Aus) \ Electrical Line Mechanic (NZ)
		342212	Technical Cable Jointer
		342311	Business Machine Mechanic
		342312	Communications Operator
		342313	Electronic Equipment Trades Worker
		342314	Electronic Instrument Trades Worker (General)
		342315	Electronic Instrument Trades Worker (Special Class)
		342411	Cabler (Data and Telecommunications)
		342412	Telecommunications Cable Jointer
		342413	Telecommunications Linesworker (Aus) \ Telecommunications Line Mechanic (NZ)
		342414	Telecommunications Technician
Construction and Mining Labourers	82	821111	Builder's Labourer
		821112	Drainage, Sewerage and Stormwater Labourer
		821113	Earthmoving Labourer
		821211	Concreter
		821311	Fencer

Austroads Occupation	ANZSCO Group Number	ANZSCO Occupation Number/s	ANZSCO Occupation/s
		821511	Paving and Surfacing Labourer
		821611	Railway Track Worker
		821711	Construction Rigger
		821712	Scaffolder
		821713	Steel Fixer
		821714	Structural Steel Erector
		821911	Crane Chaser
		821912	Driller's Assistant
		821913	Lagger
		821914	Mining Support Worker
		821915	Surveyor's Assistant
Mobile Plant Operators	72	721211	Earthmoving Plant Operator (General)
		721212	Backhoe Operator
		721213	Bulldozer Operator
		721214	Excavator Operator
		721215	Grader Operator
		721216	Loader Operator
		721912	Linemarker
		721913	Paving Plant Operator
		721914	Railway Track Plant Operator
		721915	Road Roller Operator

Appendix B Base Case Modelling Results

Table B 1: Labour Demand Forecasts by Occupation: Public Roads Sector, Australia

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	2783	3026	3023	2867	2856	2855	2785	2667	2609	2684	2647
Civil Engineers	4690	5090	5112	4849	4847	4838	4704	4494	4390	4518	4452
Mechanical Engineers	101	110	110	105	105	104	101	97	95	98	96
Surveyors and Spatial Scientists	907	995	992	940	935	936	916	880	862	887	874
Other Engineering Professionals	225	245	247	234	233	234	228	217	212	219	216
Total Design Cluster Professionals	**8705**	**9466**	**9484**	**8994**	**8976**	**8967**	**8733**	**8354**	**8167**	**8406**	**8285**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	1285	1414	1394	1327	1319	1311	1286	1249	1228	1252	1237
Mechanical Engineering Associates	18	19	19	18	18	18	18	17	16	17	17
Surveying and Spatial Science Associates	85	94	92	88	87	87	85	82	81	83	82
Other Construction Associates	3944	4298	4288	4070	4055	4049	3954	3793	3714	3818	3766
Total Design Cluster Associates	**5332**	**5824**	**5793**	**5503**	**5479**	**5466**	**5343**	**5141**	**5040**	**5170**	**5102**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	4245	4606	4586	4369	4370	4326	4211	4056	3975	4054	4007
Procurement Manager	141	153	153	145	145	145	141	135	132	135	134
Natural and Physical Science Professionals	1279	1392	1393	1321	1316	1317	1286	1230	1203	1239	1222
Total Design Cluster, Other Skills Sectors	**5665**	**6151**	**6132**	**5835**	**5831**	**5788**	**5638**	**5421**	**5310**	**5428**	**5363**
Total Design Cluster Labour	**19702**	**21441**	**21408**	**20333**	**20286**	**20221**	**19714**	**18916**	**18517**	**19004**	**18750**
Job Type - Artisan Skills											
Tradepersons	4515	4938	4919	4665	4643	4647	4544	4366	4278	4402	4339
Construction and Mining Labourers	8048	8776	8750	8294	8259	8263	8061	7732	7573	7797	7686
Mobile Plant Operators	4500	4920	4877	4630	4602	4596	4498	4334	4252	4362	4305
Total Artisan Skills	**17063**	**18634**	**18546**	**17590**	**17504**	**17506**	**17104**	**16432**	**16103**	**16561**	**16329**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	4000	4303	4319	4117	4134	4087	3954	3785	3696	3770	3725
Information and Organisation Professionals	1562	1688	1680	1601	1601	1590	1549	1490	1459	1492	1474
Welfare Professionals	43	46	46	43	43	43	43	41	40	41	41
Social Professionals nec (inc. Transport Analysts)	81	87	88	83	83	82	80	76	74	76	75
ICT Professionals	1357	1472	1473	1400	1399	1392	1355	1299	1271	1303	1286
Total Other Skills	**7043**	**7597**	**7604**	**7244**	**7259**	**7194**	**6981**	**6691**	**6540**	**6682**	**6601**
Total Labour (Design, Artisan and Other)	**43807**	**47672**	**47559**	**45166**	**45050**	**44921**	**43798**	**42040**	**41161**	**42247**	**41680**

Source: BIS Oxford Economics, ABS

Table B 2: Workforce Attrition by Occupation: Public Roads Sector, Australia

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	2783	2703	2622	2542	2461	2380	2295	2210	2125	2040	1955
Civil Engineers	4690	4593	4496	4400	4303	4205	4100	3994	3888	3781	3675
Mechanical Engineers	101	99	97	95	94	92	90	89	87	85	83
Surveyors and Spatial Scientists	907	878	848	818	788	758	731	704	677	649	622
Other Engineering Professionals	225	219	213	207	201	195	189	183	177	172	166
Total Design Cluster Professionals	**8705**	**8491**	**8276**	**8061**	**7846**	**7630**	**7405**	**7179**	**6954**	**6728**	**6502**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	1285	1242	1199	1155	1112	1069	1029	990	951	912	873
Mechanical Engineering Associates	18	17	17	17	16	16	16	15	15	15	15
Surveying and Spatial Science Associates	85	82	78	75	71	68	64	60	56	52	48
Other Construction Associates	3944	3774	3604	3433	3261	3090	2918	2746	2574	2403	2231
Total Design Cluster Associates	**5332**	**5115**	**4897**	**4679**	**4461**	**4242**	**4027**	**3812**	**3597**	**3382**	**3166**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	4245	4114	3982	3850	3718	3586	3453	3319	3186	3053	2919
Procurement Manager	141	135	130	125	119	114	108	102	96	90	84
Natural and Physical Science Professionals	1279	1256	1234	1212	1189	1167	1141	1115	1088	1062	1036
Total Design Cluster, Other Skills Sectors	**5665**	**5506**	**5346**	**5187**	**5027**	**4867**	**4701**	**4536**	**4370**	**4205**	**4039**
Total Design Cluster Labour	**19702**	**19112**	**18520**	**17928**	**17334**	**16738**	**16133**	**15527**	**14921**	**14314**	**13707**
Job Type - Artisan Skills											
Tradepersons	4515	4432	4349	4265	4182	4098	4008	3918	3828	3737	3647
Construction and Mining Labourers	8048	7899	7751	7602	7453	7304	7144	6983	6822	6661	6500
Mobile Plant Operators	4500	4417	4334	4251	4168	4084	3995	3905	3815	3725	3634
Total Artisan Skills	**17063**	**16749**	**16434**	**16119**	**15803**	**15486**	**15146**	**14806**	**14465**	**14123**	**13781**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	4000	3907	3815	3722	3629	3536	3435	3333	3232	3131	3029
Information and Organisation Professionals	1562	1518	1473	1429	1384	1339	1292	1244	1197	1149	1102
Welfare Professionals	43	42	41	40	39	38	37	36	35	33	32
Social Professionals nec (inc. Transport Analysts)	81	79	78	76	74	72	70	68	67	65	63
ICT Professionals	1357	1329	1301	1273	1245	1216	1180	1143	1107	1070	1033
Total Other Skills	**7043**	**6875**	**6707**	**6539**	**6370**	**6201**	**6013**	**5825**	**5637**	**5448**	**5259**
Total Labour (Design, Artisan and Other)	**43807**	**42736**	**41661**	**40585**	**39507**	**38426**	**37293**	**36158**	**35022**	**33885**	**32747**

Source: BIS Oxford Economics, ABS

Table B 3: Skills Gap^ by Occupation: Public Roads Sector, Australia

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	324	401	325	396	475	490	456	483	644	692
Civil Engineers	0	497	616	449	544	633	604	500	502	737	777
Mechanical Engineers	0	11	13	9	11	12	11	9	8	12	13
Surveyors and Spatial Scientists	0	117	144	122	147	178	185	176	185	238	252
Other Engineering Professionals	0	26	34	27	32	39	39	34	34	48	50
Total Design Cluster Professionals	**0**	**975**	**1207**	**933**	**1130**	**1338**	**1328**	**1175**	**1213**	**1678**	**1784**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	172	195	172	207	243	257	258	277	340	364
Mechanical Engineering Associates	0	2	2	2	2	2	2	1	1	2	2
Surveying and Spatial Science Associates	0	12	14	13	16	19	22	23	25	31	34
Other Construction Associates	0	524	684	637	793	960	1036	1047	1140	1415	1535
Total Design Cluster Associates	**0**	**709**	**895**	**824**	**1018**	**1224**	**1316**	**1329**	**1443**	**1789**	**1935**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	492	604	518	651	741	758	737	789	1001	1088
Procurement Manager	0	17	23	20	26	31	33	33	36	46	50
Natural and Physical Science Professionals	0	136	159	110	127	150	145	116	115	177	186
Total Design Cluster, Other Skills Sectors	**0**	**645**	**785**	**649**	**804**	**921**	**937**	**885**	**940**	**1223**	**1324**
Total Design Cluster Labour	**0**	**2330**	**2888**	**2405**	**2953**	**3483**	**3581**	**3389**	**3596**	**4690**	**5043**
Job Type - Artisan Skills											
Tradepersons	0	506	570	400	461	548	536	448	451	665	692
Construction and Mining Labourers	0	877	999	692	806	959	917	749	751	1136	1186
Mobile Plant Operators	0	502	543	379	434	512	504	429	437	637	671
Total Artisan Skills	**0**	**1885**	**2113**	**1471**	**1702**	**2019**	**1957**	**1627**	**1639**	**2438**	**2549**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	396	504	395	505	551	520	452	463	639	695
Information and Organisation Professionals	0	170	206	172	217	251	257	245	262	342	373
Welfare Professionals	0	4	5	3	4	5	6	5	5	8	9
Social Professionals nec (inc. Transport Analysts)	0	8	10	7	9	10	10	8	8	12	13
ICT Professionals	0	144	172	127	155	176	175	156	164	233	253
Total Other Skills	**0**	**722**	**897**	**705**	**889**	**993**	**967**	**866**	**903**	**1234**	**1342**
Total Labour (Design, Artisan and Other)	**0**	**4936**	**5898**	**4581**	**5543**	**6495**	**6505**	**5881**	**6138**	**8362**	**8934**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 4: Labour Demand Forecasts by Occupation: Public Roads Sector, NSW

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	1132	1238	1271	1183	1166	1209	1187	1102	1066	1141	1115
Civil Engineers	2018	2207	2266	2108	2078	2155	2116	1963	1900	2033	1987
Mechanical Engineers	38	41	42	39	39	40	39	37	35	38	37
Surveyors and Spatial Scientists	368	403	413	385	379	393	386	358	347	371	362
Other Engineering Professionals	115	125	129	120	118	123	120	112	108	116	113
Total Design Cluster Professionals	**3668**	**4013**	**4119**	**3833**	**3778**	**3918**	**3847**	**3569**	**3454**	**3697**	**3612**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	307	336	344	321	316	328	322	299	289	309	302
Mechanical Engineering Associates	11	12	12	11	11	12	11	11	10	11	11
Surveying and Spatial Science Associates	30	33	34	31	31	32	31	29	28	30	29
Other Construction Associates	1525	1668	1712	1593	1571	1629	1599	1484	1436	1537	1502
Total Design Cluster Associates	**1871**	**2047**	**2101**	**1955**	**1927**	**1998**	**1962**	**1821**	**1762**	**1886**	**1842**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1208	1322	1357	1263	1244	1291	1267	1176	1138	1218	1190
Procurement Manager	56	61	62	58	57	59	58	54	52	56	55
Natural and Physical Science Professionals	539	590	605	563	555	576	565	524	508	543	531
Total Design Cluster, Other Skills Sectors	**1802**	**1971**	**2023**	**1883**	**1856**	**1925**	**1890**	**1753**	**1697**	**1816**	**1774**
Total Design Cluster Labour	**7340**	**8029**	**8242**	**7670**	**7560**	**7840**	**7697**	**7143**	**6912**	**7397**	**7227**
Job Type - Artisan Skills											
Tradepersons	1791	1959	2011	1872	1845	1913	1878	1743	1687	1805	1764
Construction and Mining Labourers	3259	3566	3660	3406	3357	3481	3418	3172	3069	3285	3209
Mobile Plant Operators	1547	1692	1737	1616	1593	1652	1622	1505	1457	1559	1523
Total Artisan Skills	**6596**	**7216**	**7407**	**6893**	**6794**	**7046**	**6917**	**6419**	**6212**	**6647**	**6495**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	1290	1412	1449	1348	1329	1378	1353	1256	1215	1300	1271
Information and Organisation Professionals	494	540	555	516	509	528	518	481	465	498	487
Welfare Professionals	22	24	25	23	23	23	23	21	21	22	22
Social Professionals nec (inc. Transport Analysts)	32	35	36	34	33	35	34	32	31	33	32
ICT Professionals	498	544	559	520	512	531	522	484	469	501	490
Total Other Skills	**2335**	**2554**	**2621**	**2439**	**2404**	**2494**	**2448**	**2272**	**2199**	**2353**	**2299**
Total Labour (Design, Artisan and Other)	**16270**	**17798**	**18269**	**17001**	**16757**	**17378**	**17062**	**15832**	**15322**	**16396**	**16020**

Source: BIS Oxford Economics, ABS

Table B 5: Workforce Attrition by Occupation: Public Roads Sector, NSW

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	1131	1099	1066	1033	1000	967	933	899	864	829	795
Civil Engineers	2017	1976	1934	1893	1851	1809	1763	1718	1672	1627	1581
Mechanical Engineers	37	36	36	35	35	34	33	33	32	31	31
Surveyors and Spatial Scientists	368	356	344	331	319	307	296	285	274	263	252
Other Engineering Professionals	114	111	108	105	102	99	96	93	90	87	84
Total Design Cluster Professionals	**3668**	**3578**	**3488**	**3398**	**3307**	**3217**	**3122**	**3027**	**2933**	**2838**	**2743**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	306	296	286	275	265	255	245	236	227	217	208
Mechanical Engineering Associates	10	10	10	10	10	9	9	9	9	9	9
Surveying and Spatial Science Associates	29	28	27	26	24	23	22	21	19	18	17
Other Construction Associates	1524	1459	1393	1327	1261	1194	1128	1062	995	929	862
Total Design Cluster Associates	**1871**	**1793**	**1716**	**1638**	**1560**	**1482**	**1404**	**1327**	**1250**	**1173**	**1096**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1208	1170	1133	1095	1058	1020	982	944	906	869	831
Procurement Manager	55	53	51	49	47	45	42	40	37	35	33
Natural and Physical Science Professionals	538	529	520	510	501	491	480	469	458	447	436
Total Design Cluster, Other Skills Sectors	**1801**	**1752**	**1704**	**1655**	**1605**	**1556**	**1505**	**1454**	**1402**	**1351**	**1299**
Total Design Cluster Labour	**7339**	**7123**	**6907**	**6690**	**6472**	**6254**	**6031**	**5808**	**5585**	**5362**	**5138**
Job Type - Artisan Skills											
Tradepersons	1791	1758	1725	1692	1658	1625	1590	1554	1518	1482	1446
Construction and Mining Labourers	3259	3199	3139	3079	3018	2958	2893	2828	2763	2697	2632
Mobile Plant Operators	1546	1518	1489	1461	1432	1403	1373	1342	1311	1280	1249
Total Artisan Skills	**6596**	**6474**	**6353**	**6231**	**6109**	**5986**	**5855**	**5723**	**5591**	**5459**	**5327**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	1290	1260	1230	1200	1170	1140	1108	1075	1042	1010	977
Information and Organisation Professionals	494	480	465	451	437	423	408	393	378	363	348
Welfare Professionals	21	21	21	20	20	19	19	18	17	17	16
Social Professionals nec (inc. Transport Analysts)	32	31	31	30	29	29	28	27	26	26	25
ICT Professionals	497	487	477	466	456	446	432	419	405	392	378
Total Other Skills	**2334**	**2279**	**2223**	**2168**	**2112**	**2057**	**1994**	**1932**	**1869**	**1807**	**1744**
Total Labour (Design, Artisan and Other)	**16269**	**15877**	**15483**	**15088**	**14693**	**14297**	**13881**	**13464**	**13046**	**12628**	**12209**

Source: BIS Oxford Economics, ABS

Table B 6: Skills Gap^ by Occupation: Public Roads Sector, NSW

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	139	204	149	165	241	254	202	202	311	319
Civil Engineers	0	231	331	215	227	346	352	245	227	406	405
Mechanical Engineers	0	4	6	4	4	6	6	3	3	6	6
Surveyors and Spatial Scientists	0	47	69	53	59	85	89	73	72	107	110
Other Engineering Professionals	0	14	20	14	16	23	24	18	17	28	28
Total Design Cluster Professionals	**0**	**434**	**631**	**435**	**470**	**701**	**724**	**542**	**521**	**858**	**869**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	39	58	45	50	72	76	62	62	91	93
Mechanical Engineering Associates	0	1	2	1	1	2	2	1	1	2	2
Surveying and Spatial Science Associates	0	4	6	5	6	8	9	8	8	12	12
Other Construction Associates	0	209	319	266	309	434	471	422	441	608	639
Total Design Cluster Associates	**0**	**253**	**385**	**317**	**367**	**516**	**557**	**493**	**512**	**712**	**746**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	151	223	167	186	270	284	231	231	349	359
Procurement Manager	0	7	11	9	10	14	15	14	14	20	21
Natural and Physical Science Professionals	0	60	85	52	54	84	84	55	49	95	94
Total Design Cluster, Other Skills Sectors	**0**	**218**	**319**	**228**	**250**	**368**	**384**	**299**	**294**	**464**	**474**
Total Design Cluster Labour	**0**	**905**	**1334**	**979**	**1087**	**1585**	**1665**	**1334**	**1327**	**2035**	**2089**
Job Type - Artisan Skills											
Tradepersons	0	201	286	180	186	287	288	189	168	322	317
Construction and Mining Labourers	0	366	521	327	338	523	525	343	306	587	577
Mobile Plant Operators	0	174	247	155	160	248	249	163	145	278	274
Total Artisan Skills	**0**	**741**	**1054**	**661**	**685**	**1059**	**1062**	**695**	**620**	**1188**	**1168**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	151	218	148	158	238	245	180	172	290	293
Information and Organisation Professionals	0	60	89	64	71	104	110	87	87	134	138
Welfare Professionals	0	2	4	2	2	4	4	3	3	5	5
Social Professionals nec (inc. Transport Analysts)	0	4	5	3	4	6	6	4	4	7	7
ICT Professionals	0	57	82	53	56	85	89	65	63	109	111
Total Other Skills	**0**	**275**	**397**	**271**	**292**	**437**	**453**	**339**	**329**	**545**	**554**
Total Labour (Design, Artisan and Other)	**0**	**1921**	**2786**	**1912**	**2063**	**3081**	**3181**	**2368**	**2275**	**3768**	**3811**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 7: Labour Demand Forecasts by Occupation: Public Roads Sector, VIC

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	482	486	509	495	522	486	442	419	402	391	389
Civil Engineers	955	964	1009	981	1034	964	876	830	797	775	771
Mechanical Engineers	21	21	22	22	23	21	19	18	18	17	17
Surveyors and Spatial Scientists	112	113	118	115	121	113	103	97	93	91	90
Other Engineering Professionals	38	39	40	39	41	39	35	33	32	31	31
Total Design Cluster Professionals	**1607**	**1623**	**1699**	**1651**	**1741**	**1623**	**1475**	**1397**	**1342**	**1305**	**1298**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	161	163	170	166	175	163	148	140	135	131	130
Mechanical Engineering Associates	3	3	3	3	4	3	3	3	3	3	3
Surveying and Spatial Science Associates	8	8	9	8	9	8	7	7	7	7	7
Other Construction Associates	661	668	699	679	716	668	607	575	552	537	534
Total Design Cluster Associates	**834**	**842**	**881**	**856**	**903**	**842**	**765**	**724**	**696**	**677**	**673**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	974	984	1030	1001	1055	984	894	847	813	791	787
Procurement Manager	30	30	32	31	32	30	27	26	25	24	24
Natural and Physical Science Professionals	217	219	230	223	235	219	199	189	181	176	175
Total Design Cluster, Other Skills Sectors	**1221**	**1233**	**1291**	**1255**	**1323**	**1233**	**1121**	**1061**	**1020**	**992**	**986**
Total Design Cluster Labour	**3663**	**3698**	**3872**	**3762**	**3967**	**3698**	**3361**	**3183**	**3057**	**2973**	**2957**
Job Type - Artisan Skills											
Tradepersons	615	621	650	632	666	621	564	534	513	499	496
Construction and Mining Labourers	1224	1236	1294	1258	1326	1236	1123	1064	1022	994	988
Mobile Plant Operators	613	619	648	630	664	619	562	533	512	498	495
Total Artisan Skills	**2452**	**2475**	**2592**	**2519**	**2656**	**2476**	**2250**	**2131**	**2047**	**1991**	**1979**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	1177	1189	1245	1210	1275	1189	1081	1023	983	956	950
Information and Organisation Professionals	353	356	373	363	382	356	324	307	295	287	285
Welfare Professionals	5	5	5	5	5	5	5	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	18	18	19	19	20	18	17	16	15	15	15
ICT Professionals	289	291	305	297	313	291	265	251	241	234	233
Total Other Skills	**1843**	**1860**	**1948**	**1893**	**1996**	**1860**	**1691**	**1601**	**1538**	**1496**	**1487**
Total Labour (Design, Artisan and Other)	**7957**	**8033**	**8412**	**8174**	**8618**	**8034**	**7302**	**6915**	**6642**	**6460**	**6423**

Source: BIS Oxford Economics, ABS

Table B 8: Workforce Attrition by Occupation: Public Roads Sector, VIC

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	482	468	454	440	426	412	397	383	368	353	338
Civil Engineers	955	935	915	896	876	856	835	813	792	770	748
Mechanical Engineers	21	21	20	20	20	19	19	18	18	18	17
Surveyors and Spatial Scientists	112	108	104	101	97	93	90	87	83	80	77
Other Engineering Professionals	38	37	36	35	34	33	32	31	30	29	28
Total Design Cluster Professionals	**1607**	**1569**	**1530**	**1492**	**1453**	**1414**	**1373**	**1332**	**1291**	**1250**	**1209**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	161	156	150	145	139	134	129	124	119	114	110
Mechanical Engineering Associates	3	3	3	3	3	3	3	3	3	3	3
Surveying and Spatial Science Associates	8	8	7	7	7	6	6	6	5	5	5
Other Construction Associates	661	633	604	575	547	518	489	460	432	403	374
Total Design Cluster Associates	**834**	**799**	**765**	**731**	**696**	**661**	**627**	**593**	**559**	**525**	**491**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	974	944	914	884	853	823	792	762	731	701	670
Procurement Manager	30	29	28	27	25	24	23	22	20	19	18
Natural and Physical Science Professionals	217	213	210	206	202	198	194	189	185	180	176
Total Design Cluster, Other Skills Sectors	**1221**	**1186**	**1151**	**1116**	**1081**	**1045**	**1009**	**973**	**936**	**900**	**864**
Total Design Cluster Labour	**3663**	**3555**	**3447**	**3338**	**3229**	**3121**	**3009**	**2898**	**2787**	**2675**	**2563**
Job Type - Artisan Skills											
Tradepersons	615	604	592	581	569	558	546	534	521	509	497
Construction and Mining Labourers	1224	1202	1179	1156	1134	1111	1087	1062	1038	1013	989
Mobile Plant Operators	613	602	590	579	568	556	544	532	520	507	495
Total Artisan Skills	**2452**	**2407**	**2362**	**2316**	**2271**	**2225**	**2177**	**2128**	**2079**	**2030**	**1980**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	1177	1150	1123	1096	1068	1041	1011	981	951	922	892
Information and Organisation Professionals	353	343	333	323	313	303	292	281	270	260	249
Welfare Professionals	5	5	5	5	5	5	4	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	18	18	18	17	17	16	16	15	15	15	14
ICT Professionals	289	283	277	271	265	259	251	243	235	228	220
Total Other Skills	**1843**	**1799**	**1755**	**1711**	**1667**	**1623**	**1574**	**1525**	**1476**	**1427**	**1378**
Total Labour (Design, Artisan and Other)	**7957**	**7760**	**7563**	**7366**	**7167**	**6969**	**6760**	**6551**	**6342**	**6132**	**5922**

Source: BIS Oxford Economics, ABS

Table B 9: Skills Gap^ by Occupation: Public Roads Sector, VIC

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	18	55	55	96	74	45	36	34	38	50
Civil Engineers	0	29	94	85	158	108	42	17	5	5	22
Mechanical Engineers	0	1	2	2	3	2	0	0	-1	-1	0
Surveyors and Spatial Scientists	0	5	14	14	24	19	12	10	10	11	14
Other Engineering Professionals	0	1	4	4	7	5	3	2	2	2	3
Total Design Cluster Professionals	**0**	**54**	**169**	**160**	**288**	**209**	**102**	**65**	**51**	**55**	**89**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	7	20	21	35	29	19	16	15	16	21
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	1	1	2	2	1	1	1	2	2
Other Construction Associates	0	35	95	104	169	150	118	114	120	134	160
Total Design Cluster Associates	**0**	**42**	**116**	**126**	**207**	**180**	**138**	**131**	**137**	**152**	**182**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	39	116	117	202	161	102	85	82	90	116
Procurement Manager	0	1	4	4	7	6	4	4	5	5	6
Natural and Physical Science Professionals	0	6	20	17	33	21	6	-1	-4	-4	-1
Total Design Cluster, Other Skills Sectors	**0**	**47**	**140**	**139**	**242**	**188**	**112**	**89**	**83**	**91**	**122**
Total Design Cluster Labour	**0**	**143**	**426**	**424**	**737**	**577**	**352**	**285**	**271**	**298**	**393**
Job Type - Artisan Skills											
Tradepersons	0	17	58	51	96	63	18	1	-8	-10	0
Construction and Mining Labourers	0	34	115	101	192	125	37	2	-16	-19	-1
Mobile Plant Operators	0	17	58	51	96	63	18	1	-8	-10	0
Total Artisan Skills	**0**	**69**	**231**	**203**	**385**	**250**	**74**	**3**	**-32**	**-39**	**-1**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	38	122	114	207	148	69	42	31	34	59
Information and Organisation Professionals	0	13	40	40	70	54	32	26	24	27	36
Welfare Professionals	0	0	1	0	1	1	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	0	1	2	2	3	2	1	0	0	0	1
ICT Professionals	0	9	28	26	48	33	14	8	6	7	13
Total Other Skills	**0**	**61**	**193**	**182**	**328**	**237**	**117**	**76**	**61**	**68**	**109**
Total Labour (Design, Artisan and Other)	**0**	**273**	**849**	**808**	**1450**	**1065**	**542**	**364**	**300**	**328**	**501**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 10: Labour Demand Forecasts by Occupation: Public Roads Sector, QLD

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	651	749	731	699	696	684	674	672	670	676	667
Civil Engineers	1082	1246	1216	1162	1158	1137	1121	1118	1115	1124	1108
Mechanical Engineers	31	35	35	33	33	32	32	32	32	32	32
Surveyors and Spatial Scientists	280	322	314	301	300	294	290	289	288	291	287
Other Engineering Professionals	52	60	58	56	56	55	54	54	54	54	53
Total Design Cluster Professionals	**2095**	**2412**	**2354**	**2250**	**2242**	**2202**	**2170**	**2165**	**2159**	**2177**	**2146**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	507	584	570	545	543	533	525	524	523	527	520
Mechanical Engineering Associates	3	4	4	3	3	3	3	3	3	3	3
Surveying and Spatial Science Associates	24	28	27	26	26	26	25	25	25	25	25
Other Construction Associates	1035	1192	1163	1111	1108	1088	1072	1069	1066	1075	1060
Total Design Cluster Associates	**1570**	**1807**	**1764**	**1686**	**1680**	**1650**	**1626**	**1622**	**1617**	**1631**	**1608**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1182	1360	1327	1269	1264	1242	1224	1221	1217	1228	1210
Procurement Manager	34	39	38	36	36	35	35	35	35	35	35
Natural and Physical Science Professionals	297	341	333	319	317	312	307	306	306	308	304
Total Design Cluster, Other Skills Sectors	**1512**	**1741**	**1699**	**1623**	**1618**	**1589**	**1566**	**1562**	**1558**	**1571**	**1549**
Total Design Cluster Labour	**5177**	**5960**	**5816**	**5559**	**5540**	**5441**	**5361**	**5349**	**5334**	**5379**	**5303**
Job Type - Artisan Skills											
Tradepersons	1344	1547	1510	1443	1439	1413	1392	1389	1385	1397	1377
Construction and Mining Labourers	2147	2472	2413	2306	2298	2257	2224	2219	2213	2231	2200
Mobile Plant Operators	1330	1531	1494	1428	1423	1398	1377	1374	1370	1382	1363
Total Artisan Skills	**4822**	**5551**	**5417**	**5177**	**5160**	**5068**	**4993**	**4982**	**4968**	**5010**	**4939**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	794	914	892	852	849	834	822	820	818	825	813
Information and Organisation Professionals	382	440	430	411	409	402	396	395	394	397	392
Welfare Professionals	4	5	5	4	4	4	4	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	13	15	15	14	14	14	14	14	14	14	14
ICT Professionals	336	387	378	361	360	353	348	347	346	349	344
Total Other Skills	**1529**	**1761**	**1718**	**1642**	**1637**	**1607**	**1584**	**1580**	**1576**	**1589**	**1567**
Total Labour (Design, Artisan and Other)	**11528**	**13272**	**12951**	**12379**	**12337**	**12116**	**11938**	**11911**	**11878**	**11978**	**11810**

Source: BIS Oxford Economics, ABS

Table B 11: Workforce Attrition by Occupation: Public Roads Sector, QLD

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	651	632	613	594	575	556	536	517	497	477	457
Civil Engineers	1082	1060	1037	1015	993	970	946	922	897	873	848
Mechanical Engineers	31	30	30	29	29	28	28	27	27	26	26
Surveyors and Spatial Scientists	280	271	262	252	243	234	226	217	209	200	192
Other Engineering Professionals	52	51	49	48	46	45	44	42	41	40	38
Total Design Cluster Professionals	**2095**	**2043**	**1991**	**1939**	**1886**	**1834**	**1779**	**1725**	**1670**	**1616**	**1561**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	507	490	473	456	439	422	406	391	375	360	345
Mechanical Engineering Associates	3	3	3	3	3	3	3	3	3	3	3
Surveying and Spatial Science Associates	24	23	22	21	20	19	18	17	16	15	14
Other Construction Associates	1035	990	946	901	856	811	766	721	676	631	585
Total Design Cluster Associates	**1570**	**1507**	**1444**	**1381**	**1318**	**1255**	**1193**	**1131**	**1070**	**1008**	**946**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1182	1145	1108	1072	1035	998	961	924	887	850	812
Procurement Manager	34	32	31	30	29	27	26	24	23	22	20
Natural and Physical Science Professionals	297	291	286	281	276	271	265	259	253	246	240
Total Design Cluster, Other Skills Sectors	**1512**	**1469**	**1426**	**1383**	**1339**	**1296**	**1251**	**1207**	**1162**	**1118**	**1073**
Total Design Cluster Labour	**5177**	**5019**	**4861**	**4702**	**4544**	**4384**	**4224**	**4063**	**3902**	**3741**	**3580**
Job Type - Artisan Skills											
Tradepersons	1344	1319	1295	1270	1245	1220	1193	1166	1139	1113	1086
Construction and Mining Labourers	2147	2108	2068	2029	1989	1949	1906	1863	1820	1777	1734
Mobile Plant Operators	1330	1306	1281	1256	1232	1207	1181	1154	1128	1101	1074
Total Artisan Skills	**4822**	**4733**	**4644**	**4555**	**4466**	**4376**	**4280**	**4184**	**4087**	**3991**	**3894**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	794	775	757	738	720	702	681	661	641	621	601
Information and Organisation Professionals	382	372	361	350	339	328	316	305	293	281	270
Welfare Professionals	4	4	4	4	4	4	3	3	3	3	3
Social Professionals nec (inc. Transport Analysts)	13	13	13	12	12	12	11	11	11	11	10
ICT Professionals	336	329	322	315	308	301	292	283	274	265	256
Total Other Skills	**1529**	**1493**	**1456**	**1420**	**1383**	**1346**	**1305**	**1264**	**1223**	**1181**	**1140**
Total Labour (Design, Artisan and Other)	**11528**	**11245**	**10961**	**10677**	**10392**	**10107**	**9809**	**9511**	**9212**	**8913**	**8614**

Source: BIS Oxford Economics, ABS

Table B 12: Skills Gap^ by Occupation: Public Roads Sector, QLD

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	117	118	104	121	128	137	156	174	199	209
Civil Engineers	0	186	178	147	165	167	175	196	218	252	261
Mechanical Engineers	0	5	5	4	4	4	4	5	5	6	6
Surveyors and Spatial Scientists	0	51	53	48	56	60	64	72	80	90	95
Other Engineering Professionals	0	9	9	8	9	10	10	11	13	14	15
Total Design Cluster Professionals	**0**	**369**	**363**	**311**	**356**	**368**	**390**	**440**	**489**	**561**	**586**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	94	97	89	104	111	119	133	147	167	175
Mechanical Engineering Associates	0	1	1	0	0	0	0	0	1	1	1
Surveying and Spatial Science Associates	0	5	5	5	6	6	7	8	9	11	11
Other Construction Associates	0	201	217	211	252	277	306	349	391	445	475
Total Design Cluster Associates	**0**	**300**	**319**	**304**	**362**	**395**	**432**	**490**	**548**	**623**	**662**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	215	219	197	230	244	263	297	331	378	398
Procurement Manager	0	6	7	6	7	8	9	10	12	14	15
Natural and Physical Science Professionals	0	50	47	37	42	41	43	48	53	62	64
Total Design Cluster, Other Skills Sectors	**0**	**272**	**273**	**241**	**279**	**293**	**314**	**355**	**396**	**453**	**476**
Total Design Cluster Labour	**0**	**941**	**955**	**856**	**997**	**1057**	**1137**	**1286**	**1432**	**1638**	**1723**
Job Type - Artisan Skills											
Tradepersons	0	228	216	174	194	193	199	222	246	284	291
Construction and Mining Labourers	0	364	344	277	309	308	318	355	392	454	466
Mobile Plant Operators	0	226	213	172	192	191	197	220	243	281	288
Total Artisan Skills	**0**	**818**	**773**	**623**	**695**	**691**	**713**	**798**	**881**	**1019**	**1045**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	138	135	114	129	133	140	159	176	203	212
Information and Organisation Professionals	0	69	69	61	71	74	80	91	101	116	122
Welfare Professionals	0	1	1	1	1	1	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	2	2	2	2	2	2	2	3	3	3
ICT Professionals	0	58	55	46	51	52	56	64	72	84	88
Total Other Skills	**0**	**268**	**262**	**223**	**254**	**261**	**279**	**316**	**353**	**408**	**427**
Total Labour (Design, Artisan and Other)	**0**	**2027**	**1990**	**1702**	**1945**	**2010**	**2129**	**2400**	**2666**	**3065**	**3196**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 13: Labour Demand Forecasts by Occupation: Public Roads Sector, SA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	186	193	172	167	161	164	171	169	172	178	181
Civil Engineers	237	246	219	213	205	209	217	215	218	227	230
Mechanical Engineers	4	4	4	4	3	3	4	4	4	4	4
Surveyors and Spatial Scientists	43	45	40	39	37	38	40	39	40	42	42
Other Engineering Professionals	9	9	8	8	8	8	8	8	8	9	9
Total Design Cluster Professionals	**479**	**497**	**443**	**431**	**414**	**422**	**439**	**436**	**442**	**459**	**466**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	82	85	75	73	71	72	75	74	75	78	79
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	7	8	7	7	6	6	7	7	7	7	7
Other Construction Associates	277	288	256	249	240	244	254	252	256	266	269
Total Design Cluster Associates	**366**	**380**	**338**	**329**	**317**	**323**	**336**	**333**	**338**	**351**	**356**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	332	345	307	299	288	293	305	302	307	319	323
Procurement Manager	10	10	9	9	8	9	9	9	9	9	9
Natural and Physical Science Professionals	76	79	71	69	66	67	70	70	71	73	74
Total Design Cluster, Other Skills Sectors	**418**	**434**	**387**	**376**	**362**	**369**	**384**	**381**	**386**	**401**	**407**
Total Design Cluster Labour	**1263**	**1311**	**1168**	**1136**	**1093**	**1113**	**1159**	**1150**	**1167**	**1212**	**1228**
Job Type - Artisan Skills											
Tradepersons	260	270	240	234	225	229	239	237	240	250	253
Construction and Mining Labourers	578	600	534	520	500	509	530	526	534	555	562
Mobile Plant Operators	342	355	316	307	296	301	313	311	315	328	332
Total Artisan Skills	**1180**	**1225**	**1090**	**1061**	**1021**	**1040**	**1082**	**1074**	**1089**	**1132**	**1147**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	255	265	236	230	221	225	234	232	236	245	248
Information and Organisation Professionals	149	155	138	134	129	132	137	136	138	143	145
Welfare Professionals	4	5	4	4	4	4	4	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	3	3	3	3	3	3	3	3	3	3	3
ICT Professionals	91	95	84	82	79	80	84	83	84	87	89
Total Other Skills	**503**	**522**	**465**	**452**	**435**	**444**	**462**	**458**	**465**	**483**	**489**
Total Labour (Design, Artisan and Other)	**2946**	**3058**	**2723**	**2649**	**2549**	**2597**	**2702**	**2681**	**2721**	**2827**	**2864**

Source: BIS Oxford Economics, ABS

Table B 14: Workforce Attrition by Occupation: Public Roads Sector, SA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	186	181	175	170	164	159	153	148	142	136	131
Civil Engineers	237	232	227	222	217	212	207	201	196	191	185
Mechanical Engineers	4	4	4	4	4	4	4	3	3	3	3
Surveyors and Spatial Scientists	43	42	40	39	38	36	35	34	32	31	30
Other Engineering Professionals	9	9	9	8	8	8	8	7	7	7	7
Total Design Cluster Professionals	**479**	**467**	**455**	**443**	**431**	**419**	**406**	**394**	**381**	**368**	**356**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	82	79	76	73	71	68	65	63	60	58	55
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	7	7	7	6	6	6	5	5	5	4	4
Other Construction Associates	277	265	253	241	229	217	205	193	181	169	157
Total Design Cluster Associates	**366**	**351**	**336**	**321**	**306**	**291**	**276**	**261**	**246**	**231**	**216**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	332	322	312	301	291	281	270	260	249	239	229
Procurement Manager	10	9	9	9	8	8	7	7	7	6	6
Natural and Physical Science Professionals	76	75	74	72	71	70	68	67	65	63	62
Total Design Cluster, Other Skills Sectors	**418**	**406**	**394**	**382**	**370**	**358**	**346**	**333**	**321**	**309**	**296**
Total Design Cluster Labour	**1263**	**1224**	**1185**	**1146**	**1107**	**1068**	**1028**	**988**	**948**	**908**	**868**
Job Type - Artisan Skills											
Tradepersons	260	255	251	246	241	236	231	226	221	215	210
Construction and Mining Labourers	578	567	557	546	535	525	513	501	490	478	467
Mobile Plant Operators	342	335	329	323	316	310	303	296	290	283	276
Total Artisan Skills	**1180**	**1158**	**1136**	**1114**	**1093**	**1071**	**1047**	**1024**	**1000**	**976**	**953**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	255	250	244	238	232	226	219	213	206	200	193
Information and Organisation Professionals	149	145	141	137	132	128	123	119	114	110	105
Welfare Professionals	4	4	4	4	4	4	4	4	4	3	3
Social Professionals nec (inc. Transport Analysts)	3	3	3	3	3	3	3	3	2	2	2
ICT Professionals	91	89	87	85	84	82	79	77	74	72	69
Total Other Skills	**503**	**491**	**479**	**467**	**454**	**442**	**428**	**415**	**401**	**387**	**374**
Total Labour (Design, Artisan and Other)	**2946**	**2873**	**2800**	**2727**	**2654**	**2580**	**2503**	**2426**	**2349**	**2272**	**2195**

Source: BIS Oxford Economics, ABS

Table B 15: Skills Gap^ by Occupation: Public Roads Sector, SA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	12	-3	-3	-4	5	17	22	30	42	50
Civil Engineers	0	14	-8	-9	-12	-4	10	14	22	36	45
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	1
Surveyors and Spatial Scientists	0	3	0	0	0	2	5	6	8	11	12
Other Engineering Professionals	0	1	0	0	0	0	1	1	1	2	2
Total Design Cluster Professionals	**0**	**30**	**-12**	**-12**	**-17**	**3**	**33**	**42**	**61**	**91**	**110**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	6	-1	0	0	4	9	11	15	20	24
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	1	0	0	0	1	1	2	2	3	3
Other Construction Associates	0	22	3	8	11	27	49	59	75	97	113
Total Design Cluster Associates	**0**	**29**	**2**	**8**	**11**	**32**	**60**	**72**	**92**	**120**	**140**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	23	-5	-3	-4	12	35	43	57	80	95
Procurement Manager	0	1	0	0	0	1	1	2	2	3	4
Natural and Physical Science Professionals	0	4	-3	-4	-5	-2	2	3	6	10	12
Total Design Cluster, Other Skills Sectors	**0**	**28**	**-8**	**-6**	**-8**	**11**	**38**	**47**	**65**	**93**	**111**
Total Design Cluster Labour	**0**	**87**	**-18**	**-10**	**-14**	**46**	**131**	**162**	**218**	**304**	**360**
Job Type - Artisan Skills											
Tradepersons	0	15	-10	-12	-16	-7	8	11	20	34	43
Construction and Mining Labourers	0	33	-22	-26	-35	-15	17	24	44	76	95
Mobile Plant Operators	0	19	-13	-16	-21	-9	10	14	26	45	56
Total Artisan Skills	**0**	**67**	**-46**	**-54**	**-72**	**-31**	**35**	**50**	**89**	**155**	**194**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	16	-8	-8	-11	-1	15	20	29	45	55
Information and Organisation Professionals	0	10	-3	-2	-3	4	14	17	24	33	40
Welfare Professionals	0	0	0	0	0	0	0	0	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	1
ICT Professionals	0	5	-3	-4	-5	-1	4	6	10	16	19
Total Other Skills	**0**	**31**	**-14**	**-14**	**-19**	**2**	**33**	**43**	**64**	**95**	**116**
Total Labour (Design, Artisan and Other)	**0**	**185**	**-77**	**-78**	**-105**	**16**	**199**	**255**	**371**	**555**	**670**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 16: Labour Demand Forecasts by Occupation: Public Roads Sector, WA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	227	247	236	227	218	219	225	219	214	215	215
Civil Engineers	280	305	291	280	269	270	277	270	264	265	265
Mechanical Engineers	8	8	8	8	7	7	7	7	7	7	7
Surveyors and Spatial Scientists	74	81	77	74	71	71	73	72	70	70	70
Other Engineering Professionals	10	10	10	10	9	9	9	9	9	9	9
Total Design Cluster Professionals	**597**	**651**	**621**	**599**	**575**	**576**	**592**	**577**	**565**	**565**	**566**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	174	190	181	175	168	168	173	169	165	165	165
Mechanical Engineering Associates	1	1	1	1	1	1	1	1	1	1	1
Surveying and Spatial Science Associates	12	13	12	12	11	11	11	11	11	11	11
Other Construction Associates	335	365	349	336	323	324	332	324	317	317	318
Total Design Cluster Associates	**522**	**569**	**543**	**523**	**503**	**504**	**517**	**504**	**494**	**494**	**494**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	418	455	434	419	402	403	414	404	395	395	396
Procurement Manager	10	11	10	10	9	9	10	9	9	9	9
Natural and Physical Science Professionals	130	142	135	130	125	126	129	126	123	123	123
Total Design Cluster, Other Skills Sectors	**558**	**607**	**580**	**559**	**537**	**538**	**552**	**539**	**527**	**528**	**528**
Total Design Cluster Labour	**1677**	**1827**	**1743**	**1682**	**1615**	**1618**	**1661**	**1621**	**1586**	**1587**	**1588**
Job Type - Artisan Skills											
Tradepersons	333	363	347	334	321	322	330	322	315	316	316
Construction and Mining Labourers	474	516	492	475	456	457	469	458	448	448	449
Mobile Plant Operators	448	488	465	449	431	432	444	433	423	424	424
Total Artisan Skills	**1255**	**1367**	**1304**	**1258**	**1209**	**1211**	**1243**	**1213**	**1187**	**1187**	**1188**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	407	444	423	408	392	393	404	394	385	385	386
Information and Organisation Professionals	137	149	142	137	131	132	135	132	129	129	129
Welfare Professionals	5	6	6	5	5	5	5	5	5	5	5
Social Professionals nec (inc. Transport Analysts)	7	8	8	8	7	7	7	7	7	7	7
ICT Professionals	114	125	119	115	110	110	113	111	108	108	108
Total Other Skills	**671**	**731**	**698**	**673**	**646**	**648**	**665**	**649**	**635**	**635**	**636**
Total Labour (Design, Artisan and Other)	**3603**	**3925**	**3745**	**3613**	**3470**	**3476**	**3569**	**3482**	**3407**	**3410**	**3412**

Source: BIS Oxford Economics, ABS

Table B 17: Workforce Attrition by Occupation: Public Roads Sector, WA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	227	220	214	207	201	194	187	180	173	166	159
Civil Engineers	280	274	268	262	257	251	244	238	232	225	219
Mechanical Engineers	8	7	7	7	7	7	7	7	7	6	6
Surveyors and Spatial Scientists	74	72	69	67	64	62	60	57	55	53	51
Other Engineering Professionals	10	9	9	9	8	8	8	8	8	7	7
Total Design Cluster Professionals	**597**	**582**	**567**	**552**	**537**	**522**	**506**	**490**	**474**	**458**	**442**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	174	169	163	157	151	145	140	134	129	124	119
Mechanical Engineering Associates	1	1	1	1	1	1	1	1	1	1	1
Surveying and Spatial Science Associates	12	11	11	10	10	9	9	8	8	7	6
Other Construction Associates	335	321	306	292	277	263	248	234	219	204	190
Total Design Cluster Associates	**522**	**501**	**480**	**459**	**439**	**418**	**397**	**377**	**356**	**336**	**315**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	418	405	392	379	366	353	340	327	314	300	287
Procurement Manager	10	9	9	9	8	8	7	7	7	6	6
Natural and Physical Science Professionals	130	128	126	123	121	119	116	113	111	108	105
Total Design Cluster, Other Skills Sectors	**558**	**542**	**526**	**511**	**495**	**479**	**463**	**447**	**431**	**415**	**398**
Total Design Cluster Labour	**1677**	**1626**	**1574**	**1522**	**1471**	**1419**	**1366**	**1314**	**1261**	**1209**	**1156**
Job Type - Artisan Skills											
Tradepersons	333	327	321	315	309	303	296	289	283	276	269
Construction and Mining Labourers	474	465	456	448	439	430	421	411	402	392	383
Mobile Plant Operators	448	440	431	423	415	406	397	389	380	371	362
Total Artisan Skills	**1255**	**1232**	**1209**	**1186**	**1162**	**1139**	**1114**	**1089**	**1064**	**1039**	**1014**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	407	398	389	379	370	360	350	340	329	319	309
Information and Organisation Professionals	137	133	129	125	121	117	113	109	105	100	96
Welfare Professionals	5	5	5	5	5	5	5	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	7	7	7	7	7	7	7	6	6	6	6
ICT Professionals	114	112	110	107	105	103	100	96	93	90	87
Total Other Skills	**671**	**655**	**639**	**623**	**607**	**591**	**573**	**556**	**538**	**520**	**502**
Total Labour (Design, Artisan and Other)	**3603**	**3513**	**3422**	**3331**	**3240**	**3149**	**3054**	**2958**	**2863**	**2767**	**2672**

Source: BIS Oxford Economics, ABS

Table B 18: Skills Gap^ by Occupation: Public Roads Sector, WA

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	27	22	20	18	25	38	39	41	48	55
Civil Engineers	0	31	23	18	13	19	32	32	33	39	46
Mechanical Engineers	0	1	1	0	0	0	1	1	1	1	1
Surveyors and Spatial Scientists	0	9	8	7	7	10	14	14	15	17	19
Other Engineering Professionals	0	1	1	1	1	1	1	1	1	2	2
Total Design Cluster Professionals	**0**	**68**	**54**	**47**	**38**	**55**	**86**	**87**	**91**	**107**	**123**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	21	19	18	17	23	33	34	36	41	47
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	2	1	1	2	2	3	3	3	4	4
Other Construction Associates	0	44	42	44	46	61	84	91	98	113	128
Total Design Cluster Associates	**0**	**67**	**62**	**64**	**64**	**86**	**120**	**128**	**137**	**158**	**179**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	50	42	40	36	50	74	77	82	95	108
Procurement Manager	0	1	1	1	1	1	2	2	3	3	3
Natural and Physical Science Professionals	0	14	10	7	4	7	13	12	12	15	18
Total Design Cluster, Other Skills Sectors	**0**	**65**	**53**	**48**	**42**	**58**	**89**	**92**	**96**	**113**	**130**
Total Design Cluster Labour	**0**	**201**	**169**	**159**	**144**	**199**	**295**	**307**	**325**	**378**	**432**
Job Type - Artisan Skills											
Tradepersons	0	36	25	19	12	19	34	33	33	40	46
Construction and Mining Labourers	0	51	36	27	17	27	49	47	46	56	66
Mobile Plant Operators	0	48	34	26	16	26	46	44	44	53	62
Total Artisan Skills	**0**	**135**	**96**	**73**	**46**	**72**	**129**	**124**	**123**	**149**	**175**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	46	35	29	23	33	54	54	56	67	77
Information and Organisation Professionals	0	16	13	12	11	15	22	23	25	29	33
Welfare Professionals	0	1	0	0	0	0	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	1	1	0	0	1	1	1	1	1	1
ICT Professionals	0	13	9	7	5	8	14	14	15	18	21
Total Other Skills	**0**	**76**	**58**	**50**	**39**	**56**	**91**	**93**	**97**	**115**	**134**
Total Labour (Design, Artisan and Other)	**0**	**412**	**323**	**282**	**230**	**327**	**515**	**524**	**544**	**642**	**740**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 19: Labour Demand Forecasts by Occupation: Public Roads Sector, TAS

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	74	79	73	68	66	67	60	59	58	57	55
Civil Engineers	83	88	81	76	74	74	67	66	64	64	62
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	28	29	27	25	25	25	22	22	22	21	21
Other Engineering Professionals	1	1	1	1	1	1	1	1	1	1	1
Total Design Cluster Professionals	**187**	**197**	**182**	**170**	**166**	**167**	**150**	**149**	**144**	**143**	**138**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	45	47	44	41	40	40	36	36	35	34	33
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	5	5	5	4	4	4	4	4	4	4	3
Other Construction Associates	89	94	87	81	79	79	71	71	69	68	66
Total Design Cluster Associates	**138**	**146**	**135**	**126**	**123**	**124**	**111**	**110**	**107**	**106**	**102**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	80	84	78	72	71	71	64	63	62	61	59
Procurement Manager	2	2	2	2	2	2	1	1	1	1	1
Natural and Physical Science Professionals	15	16	15	14	14	14	12	12	12	12	11
Total Design Cluster, Other Skills Sectors	**97**	**102**	**94**	**88**	**86**	**86**	**78**	**77**	**75**	**74**	**71**
Total Design Cluster Labour	**422**	**446**	**411**	**384**	**375**	**377**	**339**	**336**	**327**	**324**	**312**
Job Type - Artisan Skills											
Tradepersons	111	117	108	101	98	99	89	88	86	85	82
Construction and Mining Labourers	289	306	282	263	257	259	233	230	224	222	214
Mobile Plant Operators	168	178	164	153	149	150	135	134	130	129	124
Total Artisan Skills	**568**	**601**	**555**	**517**	**505**	**508**	**457**	**452**	**440**	**436**	**421**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	71	75	69	65	63	63	57	56	55	54	52
Information and Organisation Professionals	26	28	26	24	23	24	21	21	20	20	20
Welfare Professionals	1	1	1	1	1	1	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	3	3	3	3	3	3	3	3	2	2	2
ICT Professionals	23	24	22	21	20	20	18	18	18	17	17
Total Other Skills	**124**	**131**	**121**	**113**	**110**	**111**	**100**	**99**	**96**	**95**	**92**
Total Labour (Design, Artisan and Other)	**1114**	**1177**	**1087**	**1014**	**990**	**996**	**895**	**887**	**863**	**856**	**825**

Source: BIS Oxford Economics, ABS

Table B 20: Workforce Attrition by Occupation: Public Roads Sector, TAS

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	74	72	70	68	66	64	61	59	57	55	52
Civil Engineers	83	81	80	78	76	75	73	71	69	67	65
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	28	27	26	25	24	23	22	22	21	20	19
Other Engineering Professionals	1	1	1	1	1	1	1	1	1	1	1
Total Design Cluster Professionals	**187**	**182**	**177**	**172**	**167**	**162**	**157**	**152**	**147**	**142**	**137**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	45	43	42	40	39	37	36	35	33	32	31
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	5	4	4	4	4	4	3	3	3	3	3
Other Construction Associates	89	85	81	77	73	70	66	62	58	54	50
Total Design Cluster Associates	**138**	**133**	**127**	**122**	**116**	**111**	**105**	**100**	**94**	**89**	**83**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	80	77	75	72	70	67	65	62	60	57	55
Procurement Manager	2	2	2	2	1	1	1	1	1	1	1
Natural and Physical Science Professionals	15	15	15	15	14	14	14	13	13	13	12
Total Design Cluster, Other Skills Sectors	**97**	**94**	**91**	**88**	**85**	**83**	**80**	**77**	**74**	**71**	**68**
Total Design Cluster Labour	**422**	**408**	**395**	**382**	**369**	**356**	**342**	**329**	**316**	**302**	**289**
Job Type - Artisan Skills											
Tradepersons	111	109	107	105	103	101	98	96	94	92	89
Construction and Mining Labourers	289	284	279	273	268	262	257	251	245	239	234
Mobile Plant Operators	168	165	162	159	156	153	149	146	143	139	136
Total Artisan Skills	**568**	**558**	**547**	**537**	**526**	**516**	**504**	**493**	**482**	**470**	**459**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	71	69	68	66	64	63	61	59	57	55	54
Information and Organisation Professionals	26	26	25	24	23	23	22	21	20	19	19
Welfare Professionals	1	1	1	1	1	1	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	3	3	3	3	3	3	3	3	3	3	2
ICT Professionals	23	22	22	21	21	20	20	19	18	18	17
Total Other Skills	**124**	**121**	**118**	**115**	**112**	**109**	**106**	**103**	**99**	**96**	**93**
Total Labour (Design, Artisan and Other)	**1114**	**1087**	**1061**	**1034**	**1007**	**980**	**953**	**925**	**897**	**868**	**840**

Source: BIS Oxford Economics, ABS

Table B 21: Skills Gap^ by Occupation: Public Roads Sector, TAS

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	6	3	0	0	3	-2	0	1	3	3
Civil Engineers	0	6	1	-2	-2	0	-6	-5	-5	-3	-4
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	0	3	1	0	1	2	0	1	1	1	2
Other Engineering Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Professionals	**0**	**15**	**5**	**-2**	**-1**	**4**	**-7**	**-4**	**-3**	**1**	**1**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	4	2	0	1	3	0	1	2	3	3
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	1	1	1
Other Construction Associates	0	9	6	4	6	10	6	9	11	14	16
Total Design Cluster Associates	**0**	**13**	**8**	**4**	**7**	**13**	**6**	**11**	**13**	**18**	**19**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	7	3	0	1	4	-1	1	2	4	4
Procurement Manager	0	0	0	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	0	1	0	-1	-1	0	-1	-1	-1	-1	-1
Total Design Cluster, Other Skills Sectors	**0**	**8**	**3**	**0**	**0**	**4**	**-2**	**0**	**1**	**3**	**3**
Total Design Cluster Labour	**0**	**37**	**16**	**2**	**6**	**21**	**-3**	**7**	**11**	**22**	**23**
Job Type - Artisan Skills											
Tradepersons	0	8	1	-4	-4	-1	-9	-8	-8	-7	-7
Construction and Mining Labourers	0	22	4	-10	-11	-4	-24	-21	-21	-17	-19
Mobile Plant Operators	0	13	2	-6	-6	-2	-14	-12	-12	-10	-11
Total Artisan Skills	**0**	**43**	**7**	**-20**	**-21**	**-7**	**-48**	**-41**	**-42**	**-34**	**-38**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	6	2	-1	-1	1	-4	-3	-2	-1	-1
Information and Organisation Professionals	0	2	1	0	0	1	-1	0	0	1	1
Welfare Professionals	0	0	0	0	0	0	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	0
ICT Professionals	0	2	0	-1	-1	0	-1	-1	-1	0	0
Total Other Skills	**0**	**10**	**3**	**-2**	**-2**	**2**	**-6**	**-4**	**-3**	**-1**	**-1**
Total Labour (Design, Artisan and Other)	**0**	**90**	**27**	**-20**	**-17**	**16**	**-57**	**-38**	**-34**	**-13**	**-16**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 22: Labour Demand Forecasts by Occupation: Public Roads Sector, NT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	30	33	30	27	26	25	25	25	25	24	25
Civil Engineers	20	22	20	18	17	17	17	17	17	16	17
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	1	1	1	1	1	1	1	1	1	1	1
Other Engineering Professionals	1	1	1	1	1	1	1	1	1	1	1
Total Design Cluster Professionals	**51**	**56**	**52**	**47**	**45**	**43**	**44**	**43**	**43**	**42**	**43**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	8	8	8	7	7	6	7	6	6	6	6
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	22	24	23	20	19	19	19	19	18	18	18
Total Design Cluster Associates	**30**	**33**	**30**	**27**	**26**	**25**	**25**	**25**	**25**	**24**	**25**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	52	57	53	47	45	44	44	44	43	42	43
Procurement Manager	1	1	1	1	0	0	0	0	0	0	0
Natural and Physical Science Professionals	5	5	5	4	4	4	4	4	4	4	4
Total Design Cluster, Other Skills Sectors	**57**	**63**	**58**	**52**	**50**	**48**	**48**	**48**	**48**	**47**	**48**
Total Design Cluster Labour	**138**	**152**	**141**	**125**	**120**	**116**	**117**	**116**	**115**	**113**	**116**
Job Type - Artisan Skills											
Tradepersons	34	37	34	30	29	28	28	28	28	27	28
Construction and Mining Labourers	67	74	69	61	59	56	57	56	56	55	56
Mobile Plant Operators	51	56	52	46	44	43	43	43	42	42	43
Total Artisan Skills	**152**	**167**	**155**	**137**	**132**	**127**	**128**	**127**	**126**	**124**	**127**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	5	6	5	5	4	4	4	4	4	4	4
Information and Organisation Professionals	7	8	7	6	6	6	6	6	6	6	6
Welfare Professionals	1	1	1	0	0	0	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	4	4	4	3	3	3	3	3	3	3	3
ICT Professionals	5	6	5	5	5	4	4	4	4	4	4
Total Other Skills	**22**	**24**	**22**	**20**	**19**	**18**	**18**	**18**	**18**	**18**	**18**
Total Labour (Design, Artisan and Other)	**312**	**343**	**318**	**282**	**272**	**262**	**264**	**262**	**260**	**254**	**261**

Source: BIS Oxford Economics, ABS

Table B 23: Workforce Attrition by Occupation: Public Roads Sector, NT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	30	29	28	27	26	25	24	23	23	22	21
Civil Engineers	20	20	19	19	18	18	17	17	17	16	16
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	1	1	1	1	1	1	1	1	1	1	1
Other Engineering Professionals	1	1	1	1	1	1	1	1	1	1	0
Total Design Cluster Professionals	**51**	**50**	**49**	**47**	**46**	**45**	**43**	**42**	**41**	**39**	**38**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	8	7	7	7	7	6	6	6	6	5	5
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	22	21	20	19	18	17	16	15	14	13	12
Total Design Cluster Associates	**30**	**29**	**27**	**26**	**25**	**24**	**23**	**21**	**20**	**19**	**18**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	52	50	49	47	45	44	42	41	39	37	36
Procurement Manager	1	1	1	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	5	5	4	4	4	4	4	4	4	4	4
Total Design Cluster, Other Skills Sectors	**57**	**55**	**54**	**52**	**50**	**49**	**47**	**45**	**43**	**42**	**40**
Total Design Cluster Labour	**138**	**134**	**130**	**126**	**121**	**117**	**113**	**108**	**104**	**100**	**95**
Job Type - Artisan Skills											
Tradepersons	34	33	32	32	31	30	30	29	28	28	27
Construction and Mining Labourers	67	66	65	63	62	61	60	58	57	56	54
Mobile Plant Operators	51	50	49	48	47	46	45	44	43	42	41
Total Artisan Skills	**152**	**149**	**146**	**143**	**140**	**138**	**135**	**132**	**129**	**126**	**122**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	5	5	5	5	5	5	4	4	4	4	4
Information and Organisation Professionals	7	7	7	7	6	6	6	6	6	6	5
Welfare Professionals	1	1	1	0	0	0	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	4	4	4	4	3	3	3	3	3	3	3
ICT Professionals	5	5	5	5	5	5	5	4	4	4	4
Total Other Skills	**22**	**21**	**21**	**20**	**20**	**19**	**19**	**18**	**18**	**17**	**17**
Total Labour (Design, Artisan and Other)	**312**	**304**	**297**	**289**	**282**	**274**	**266**	**258**	**250**	**242**	**234**

Source: BIS Oxford Economics, ABS

Table B 24: Skills Gap^ by Occupation: Public Roads Sector, NT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	4	2	0	0	0	1	1	2	2	4
Civil Engineers	0	2	1	-1	-1	-1	-1	0	0	0	1
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Professionals	**0**	**6**	**4**	**-1**	**-1**	**-2**	**0**	**1**	**2**	**3**	**5**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	1	1	0	0	0	0	1	1	1	1
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	0	3	2	1	1	1	2	3	4	5	6
Total Design Cluster Associates	**0**	**4**	**3**	**1**	**1**	**1**	**3**	**4**	**5**	**5**	**7**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	7	4	0	0	0	2	3	4	5	8
Procurement Manager	0	0	0	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	0	1	0	0	0	0	0	0	0	0	0
Total Design Cluster, Other Skills Sectors	**0**	**7**	**5**	**0**	**-1**	**-1**	**2**	**3**	**4**	**5**	**8**
Total Design Cluster Labour	**0**	**18**	**11**	**0**	**-1**	**-1**	**4**	**8**	**11**	**13**	**20**
Job Type - Artisan Skills											
Tradepersons	0	4	2	-1	-2	-2	-1	-1	-1	0	1
Construction and Mining Labourers	0	8	4	-3	-4	-5	-3	-2	-1	-1	2
Mobile Plant Operators	0	6	3	-2	-3	-3	-2	-1	-1	-1	1
Total Artisan Skills	**0**	**18**	**9**	**-6**	**-8**	**-10**	**-6**	**-4**	**-2**	**-2**	**4**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	1	0	0	0	0	0	0	0	0	0
Information and Organisation Professionals	0	1	0	0	0	0	0	0	0	0	1
Welfare Professionals	0	0	0	0	0	0	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	0
ICT Professionals	0	1	0	0	0	0	0	0	0	0	0
Total Other Skills	**0**	**3**	**1**	**-1**	**-1**	**-1**	**0**	**0**	**0**	**1**	**2**
Total Labour (Design, Artisan and Other)	**0**	**38**	**21**	**-7**	**-10**	**-12**	**-2**	**4**	**9**	**12**	**27**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Table B 25: Labour Demand Forecasts by Occupation: Public Roads Sector, ACT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	2	2	2	2	2	2	2	2	2	2	2
Civil Engineers	16	14	11	12	12	13	14	15	14	14	14
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	2	2	1	1	1	2	2	2	2	2	2
Other Engineering Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Professionals	**21**	**17**	**14**	**15**	**15**	**16**	**18**	**19**	**18**	**18**	**17**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	2	1	1	1	1	1	1	1	1	1	1
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Associates	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	0	0	0	0	0	0	0	0	0	0
Procurement Manager	0	0	0	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster, Other Skills Sectors	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Design Cluster Labour	**22**	**19**	**15**	**16**	**17**	**18**	**19**	**20**	**20**	**19**	**19**
Job Type - Artisan Skills											
Tradepersons	28	23	19	20	21	22	24	25	25	24	23
Construction and Mining Labourers	9	8	6	6	7	7	8	8	8	8	8
Mobile Plant Operators	2	2	2	2	2	2	2	2	2	2	2
Total Artisan Skills	**39**	**33**	**27**	**28**	**29**	**31**	**33**	**35**	**35**	**34**	**33**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	0	0	0	0	0	0	0	0	0	0
Information and Organisation Professionals	14	12	9	10	10	11	12	13	12	12	12
Welfare Professionals	1	1	1	1	1	1	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	0
ICT Professionals	2	1	1	1	1	1	1	1	1	1	1
Total Other Skills	**16**	**14**	**11**	**12**	**12**	**13**	**14**	**15**	**14**	**14**	**14**
Total Labour (Design, Artisan and Other)	**78**	**66**	**53**	**55**	**58**	**62**	**66**	**71**	**69**	**67**	**66**

Source: BIS Oxford Economics, ABS

Table B 26: Workforce Attrition by Occupation: Public Roads Sector, ACT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	2	2	2	2	2	2	2	2	2	2	2
Civil Engineers	16	16	16	15	15	15	14	14	13	13	13
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	2	2	2	2	2	2	2	1	1	1	1
Other Engineering Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Professionals	**21**	**20**	**20**	**19**	**19**	**18**	**18**	**17**	**17**	**16**	**16**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	2	2	2	1	1	1	1	1	1	1	1
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Associates	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	0	0	0	0	0	0	0	0	0	0
Procurement Manager	0	0	0	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster, Other Skills Sectors	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Design Cluster Labour	**22**	**22**	**21**	**21**	**20**	**20**	**19**	**19**	**18**	**18**	**17**
Job Type - Artisan Skills											
Tradepersons	28	27	27	26	26	25	24	24	23	23	22
Construction and Mining Labourers	9	9	9	8	8	8	8	8	8	7	7
Mobile Plant Operators	2	2	2	2	2	2	2	2	2	2	2
Total Artisan Skills	**39**	**38**	**38**	**37**	**36**	**35**	**35**	**34**	**33**	**32**	**31**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	0	0	0	0	0	0	0	0	0	0
Information and Organisation Professionals	14	13	13	13	12	12	11	11	11	10	10
Welfare Professionals	1	1	1	1	1	1	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	0
ICT Professionals	2	2	2	2	1	1	1	1	1	1	1
Total Other Skills	**16**	**16**	**15**	**15**	**14**	**14**	**14**	**13**	**13**	**12**	**12**
Total Labour (Design, Artisan and Other)	**78**	**76**	**74**	**73**	**71**	**69**	**67**	**66**	**64**	**62**	**60**

Source: BIS Oxford Economics, ABS

Table B 27: Skills Gap^ by Occupation: Public Roads Sector, ACT

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	0	-1	0	0	0	0	0	0	0	0
Civil Engineers	0	-2	-4	-4	-3	-2	0	1	1	1	1
Mechanical Engineers	0	0	0	0	0	0	0	0	0	0	0
Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Professionals	**0**	**-3**	**-6**	**-4**	**-3**	**-2**	**0**	**1**	**2**	**2**	**2**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Mechanical Engineering Associates	0	0	0	0	0	0	0	0	0	0	0
Surveying and Spatial Science Associates	0	0	0	0	0	0	0	0	0	0	0
Other Construction Associates	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster Associates	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	0	0	0	0	0	0	0	0	0	0
Procurement Manager	0	0	0	0	0	0	0	0	0	0	0
Natural and Physical Science Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Design Cluster, Other Skills Sectors	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Design Cluster Labour	**0**	**-3**	**-6**	**-5**	**-4**	**-2**	**0**	**2**	**2**	**2**	**2**
Job Type - Artisan Skills											
Tradepersons	0	-4	-8	-6	-5	-3	-1	1	1	1	1
Construction and Mining Labourers	0	-1	-2	-2	-2	-1	0	0	0	0	0
Mobile Plant Operators	0	0	-1	-1	0	0	0	0	0	0	0
Total Artisan Skills	**0**	**-5**	**-11**	**-9**	**-7**	**-4**	**-1**	**2**	**2**	**2**	**2**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	0	0	0	0	0	0	0	0	0	0
Information and Organisation Professionals	0	-2	-4	-3	-2	-1	0	2	2	2	2
Welfare Professionals	0	0	0	0	0	0	0	0	0	0	0
Social Professionals nec (inc. Transport Analysts)	0	0	0	0	0	0	0	0	0	0	0
ICT Professionals	0	0	0	0	0	0	0	0	0	0	0
Total Other Skills	**0**	**-2**	**-4**	**-3**	**-2**	**-1**	**0**	**2**	**2**	**2**	**2**
Total Construction Labour	**0**	**-10**	**-21**	**-17**	**-13**	**-7**	**-1**	**5**	**5**	**6**	**6**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

(c) Capability shortfall is derived by subtracting new supply from workforce gap. A positive number implies a shortage of labour while a negative capability shortfall implies excess supply.

Table B 28: Labour Demand Forecasts by Occupation: Public Roads Sector, New Zealand

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	366	373	378	376	374	371	374	373	369	369	367
Civil Engineers	672	684	694	689	686	680	686	683	677	676	672
Mechanical Engineers	25	25	25	25	25	25	25	25	25	25	25
Surveyors and Spatial Scientists	92	94	95	94	94	93	94	94	93	93	92
Other Engineering Professionals	50	51	52	51	51	51	51	51	51	50	50
Total Design Cluster Professionals	**1205**	**1226**	**1245**	**1236**	**1231**	**1220**	**1231**	**1225**	**1214**	**1212**	**1206**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	70	72	73	72	72	71	72	72	71	71	70
Mechanical Engineering Associates	5	6	6	6	6	6	6	6	5	5	5
Surveying and Spatial Science Associates	8	8	8	8	8	8	8	8	8	8	8
Other Construction Associates	828	843	855	850	846	838	846	842	835	833	829
Total Design Cluster Associates	**912**	**928**	**942**	**936**	**932**	**923**	**932**	**927**	**919**	**917**	**913**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1090	1109	1126	1119	1113	1104	1114	1108	1099	1097	1091
Procurement Manager	26	26	27	26	26	26	26	26	26	26	26
Natural and Physical Science Professionals	306	311	316	313	312	309	312	311	308	307	306
Total Design Cluster, Other Skills Sectors	**1422**	**1446**	**1468**	**1458**	**1452**	**1439**	**1452**	**1445**	**1433**	**1430**	**1422**
Total Design Cluster Labour	**3539**	**3600**	**3655**	**3630**	**3614**	**3582**	**3616**	**3598**	**3567**	**3559**	**3541**
Job Type - Artisan Skills											
Tradepersons	812	826	839	833	830	822	830	826	819	817	813
Construction and Mining Labourers	1153	1173	1190	1182	1177	1167	1178	1172	1162	1159	1153
Mobile Plant Operators	915	931	945	939	935	926	935	930	922	920	916
Total Artisan Skills	**2880**	**2930**	**2974**	**2955**	**2941**	**2915**	**2943**	**2928**	**2903**	**2897**	**2882**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	743	756	768	763	759	752	759	756	749	748	744
Information and Organisation Professionals	349	355	361	358	357	354	357	355	352	351	350
Welfare Professionals	4	4	4	4	4	4	4	4	4	4	4
Social Professionals nec (inc. Transport Analysts)	46	47	48	47	47	47	47	47	46	46	46
ICT Professionals	268	273	277	275	274	271	274	272	270	269	268
Total Other Skills	**1411**	**1435**	**1457**	**1447**	**1441**	**1428**	**1442**	**1434**	**1422**	**1419**	**1412**
Total Labour (Design, Artisan and Other)	**7830**	**7966**	**8086**	**8033**	**7996**	**7926**	**8000**	**7961**	**7891**	**7875**	**7834**

Source: BIS Oxford Economics, ABS

Table B 29: Workforce Attrition by Occupation: Public Roads Sector, New Zealand

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	366	356	345	335	324	313	302	291	280	269	257
Civil Engineers	672	658	644	630	616	602	587	572	557	542	526
Mechanical Engineers	25	24	24	23	23	22	22	22	21	21	20
Surveyors and Spatial Scientists	92	89	86	83	80	77	74	71	69	66	63
Other Engineering Professionals	50	49	48	46	45	43	42	41	40	38	37
Total Design Cluster Professionals	**1205**	**1176**	**1147**	**1117**	**1088**	**1059**	**1028**	**997**	**966**	**935**	**904**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	70	68	66	63	61	59	56	54	52	50	48
Mechanical Engineering Associates	5	5	5	5	5	5	5	5	5	5	5
Surveying and Spatial Science Associates	8	8	7	7	7	6	6	6	5	5	5
Other Construction Associates	828	792	757	721	685	649	613	577	541	505	468
Total Design Cluster Associates	**912**	**874**	**835**	**796**	**758**	**719**	**680**	**641**	**603**	**564**	**525**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	1090	1057	1023	989	955	921	887	852	818	784	750
Procurement Manager	26	25	24	23	22	21	20	19	18	16	15
Natural and Physical Science Professionals	306	300	295	290	284	279	273	266	260	254	248
Total Design Cluster, Other Skills Sectors	**1422**	**1382**	**1341**	**1301**	**1261**	**1221**	**1179**	**1137**	**1096**	**1054**	**1013**
Total Design Cluster Labour	**3539**	**3431**	**3323**	**3215**	**3107**	**2998**	**2887**	**2776**	**2665**	**2554**	**2442**
Job Type - Artisan Skills											
Tradepersons	812	797	782	767	752	737	721	705	689	672	656
Construction and Mining Labourers	1153	1131	1110	1089	1067	1046	1023	1000	977	954	931
Mobile Plant Operators	915	898	881	864	848	831	812	794	776	757	739
Total Artisan Skills	**2880**	**2827**	**2774**	**2721**	**2667**	**2614**	**2557**	**2499**	**2442**	**2384**	**2326**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	743	726	709	692	674	657	638	619	601	582	563
Information and Organisation Professionals	349	339	329	319	309	299	289	278	268	257	246
Welfare Professionals	4	4	4	4	4	4	4	3	3	3	3
Social Professionals nec (inc. Transport Analysts)	46	45	44	43	42	41	40	39	38	37	36
ICT Professionals	268	262	257	251	246	240	233	226	218	211	204
Total Other Skills	**1411**	**1377**	**1343**	**1310**	**1276**	**1242**	**1204**	**1166**	**1128**	**1090**	**1052**
Total Labour (Design, Artisan and Other)	**7830**	**7635**	**7441**	**7245**	**7050**	**6853**	**6647**	**6441**	**6235**	**6028**	**5821**

Source: BIS Oxford Economics, ABS

Table B 30: Skills Gap^ by Occupation: Public Roads Sector, New Zealand

(Baseline scenario of 1.5% labour productivity growth, forecasts as at June)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	Estimate	Forecasts									
Job Type - Design Cluster Professionals (Degree Holders)											
Project Managers	0	17	33	41	50	58	72	82	89	100	109
Civil Engineers	0	25	50	59	70	78	99	111	120	134	146
Mechanical Engineers	0	1	2	2	2	2	3	3	4	4	4
Surveyors and Spatial Scientists	0	5	9	11	14	16	20	22	24	27	29
Other Engineering Professionals	0	2	4	5	6	7	9	10	11	12	13
Total Design Cluster Professionals	**0**	**50**	**98**	**119**	**143**	**161**	**203**	**228**	**248**	**277**	**301**
Job Type - Design Cluster Associates (Diploma/Certificate Holders)											
Civil Engineering Associates	0	4	7	9	11	13	16	17	19	21	23
Mechanical Engineering Associates	0	0	0	0	0	1	1	1	1	1	1
Surveying and Spatial Science Associates	0	0	1	1	2	2	2	3	3	3	4
Other Construction Associates	0	50	99	129	161	190	233	265	294	328	360
Total Design Cluster Associates	**0**	**54**	**107**	**139**	**174**	**205**	**252**	**286**	**317**	**353**	**387**
Job Type - Design Cluster, Other Skilled Sectors											
Contract, Program and Project Administrators	0	53	103	130	158	183	227	256	281	313	341
Procurement Manager	0	1	3	4	4	5	7	8	8	9	10
Natural and Physical Science Professionals	0	11	21	24	28	30	40	44	48	53	58
Total Design Cluster, Other Skills Sectors	**0**	**65**	**127**	**157**	**191**	**218**	**273**	**308**	**337**	**375**	**410**
Total Design Cluster Labour	**0**	**169**	**332**	**415**	**507**	**584**	**729**	**822**	**902**	**1005**	**1098**
Job Type - Artisan Skills											
Tradepersons	0	29	57	66	77	85	109	121	130	145	157
Construction and Mining Labourers	0	41	80	94	110	121	155	172	185	205	222
Mobile Plant Operators	0	33	64	74	87	96	123	136	147	163	177
Total Artisan Skills	**0**	**103**	**201**	**234**	**274**	**301**	**386**	**429**	**461**	**513**	**556**
Job Type - Other Skills (Informer and Technological)											
Urban and Regional Planners	0	30	59	71	85	95	121	136	148	166	181
Information and Organisation Professionals	0	16	31	39	47	54	68	77	85	94	103
Welfare Professionals	0	0	0	0	0	0	1	1	1	1	1
Social Professionals nec (inc. Transport Analysts)	0	2	3	4	5	5	7	8	9	10	10
ICT Professionals	0	10	20	24	28	31	41	47	52	58	64
Total Other Skills	**0**	**58**	**114**	**138**	**165**	**187**	**238**	**269**	**294**	**329**	**360**
Total Labour (Design, Artisan and Other)	**0**	**331**	**646**	**787**	**946**	**1072**	**1353**	**1519**	**1657**	**1847**	**2014**

Source: BIS Oxford Economics, ABS

^Workforce gap is calculated as labour demand less existing workforce. A positive number implies a shortage of labour, while numbers in brackets imply an excess supply as existing workforce after adjusting for retirements exceeds expected future labour demand.

Appendix C Industry and Roads Agency Survey

Figure C 1: Survey Introduction

Australia and New Zealand Roads Capability Analysis: 2016/17 to 2026/27 - BIS Oxford Economics

Information Gathering for the Research and Analysis Component (Part 1) of the Study

Introduction

BIS Oxford Economics has been engaged by Austroads to undertake a workforce capability analysis for member authorities. Specifically, BIS Oxford Economics has been asked to research and provide advice on the following capabilities:

1) The capability of the roads authorities to be able to deliver the services expected of it over the next 10 years and where gaps in workforce are likely to exist, and
2) The capability of the road construction workforce to be able to undertake the projects which are effectively locked-in (or forecast) for the next 5 to 10 years and where shortfalls are likely to be.

In addition, BIS Oxford Economics was asked by Austroads to highlight some of the longer term challenges that are likely to emerge for roads authorities and how the authorities should adapt to meet these challenges.

To provide solutions to the above research agenda, BIS Oxford Economics is seeking data and information from key participants in the roads industry. Hence, we would be grateful if you could please fill-in this questionnaire. The survey is in 10 parts with each section addressing the above research questions separately.

WE ASK THAT ROADS AGENCIES COMPLETE ALL PARTS OF THE SURVEY. PARTICIPANTS WHO ARE NOT ROADS AGENCIES SHOULD PROVIDE RESPONDENT INFORMATION IN PART 1, THEN COMPLETE PARTS 7-10 OF THE SURVEY

Respondent Information

A: Road Authority	
B: Respondent Name	
C: Academic Qualification	
C: Job Title and brief description of job role	
D: Contact Email	
E: Contact Phone Number	

Figure C 2: Survey Part 1

The questions below relate to the skills required to collate the information set to allow discussion and high level decision making at roads authorities.

We have identified four key functions of roads authorities including:

- *Adviser to the Minister*
- *Infrastructure Delivery*
- *Asset (Network) Management*
- *Communication (interaction with the general public)*

1: The information set upon which decisions are made at the Department or Authority level, we believe, has become more comprehensive over time. The methods used to pull together the information has also become more sophisticated over time. To help us track shifts in skill requirements and changes in occupation categories over time, can you please fill-in the following boxes. We are particularly interested in the in-house skills required.

	Think back to the last 10 years and suppose the Department had to advise the decision maker (who may be the Minister, a Board, senior official etc) on the best option of two competing roads projects. List the main skills typically required to collate the information in order to make an informed decision on the best option.	List the key skills presently needed to evaluate the best choice of two competing roads projects	Do you think new skills will be needed for project evaluation in the future. If so, please list them. If some skills will become redundant, please list those as well.
1A: Adviser to the Decision Maker	Example, Analysts and Economists to do cost benefit studies etc.		New Skills: Redundant Skills:
	List the traditional 'roads' skills required for delivery of roads projects	List the current skills required for delivery of roads projects	Do you think new skills will be needed for project delivery in the future. If so, please list them. If some skills will become redundant, please list those too.
1B: Delivery of Roads Projects	e.g. procurement skills		New Skills: Redundant Skills:
	Over the last 10 years, what were some of the essential skills required for management of the roads network.	List the key skills presently needed to manage the asset base	Do you think new skills will be needed for network management in the future. If so, please list them. If some skills will become redundant, please list those as well.
1C: Management of the Road Network			Network optimisation skills. List both head office skills and field services skills. New Skills: Redundant Skills:
	Please briefly describe the traditional methods of interacting with the general public and the skills required to disseminate information to the public	List the skills of current staff in the communications department	Do you think new skills will be needed for public engagement and dissemination of information in the future. If so, please list them. If some skills will become redundant, please list those as well.
1D: Communication			New Skills: Redundant Skills:
	Traditional skills	Current skills	Expected Future Skills
1E:Please list the traditional, current and expected future skill set required to perform any other important function of the roads authorities List core function here: 1) 2) 3)			

Please go to Part 2 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 3: Survey Part 2A

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 2 of survey (please enter details in white cells)

Where you see a downward arrow next to a box, please click on the downward arrow and choose response from the drop-down list

Metropolitan is defined as the Greater Capital City Statistical Area (GCCSA). Click on link below and see pages 7 to 11 for a map of Greater Capital City boundaries as defined by the ABS. Regional is total state employment less metropolitan staff. For New Zealand, Metropolitan refers to Auckland and other large cities.

http://www.abs.gov.au/websitedbs/d3310114.nsf/4a256353001af3ed4b2562bb00121564/6b6e07234c98365aca25792d0010d730/%24FILE/Greater%20Capital%20City%20Statistical%20Area%20-%20Fact%20Sheet.pdf

2. Please provide the size of the current skilled workforce by job cluster and by age group within your department and indicate the distribution of workforce by geography (i.e. the proportion based in metropolitan versus regional)

We are collecting data on four specific job clusters which are Designer, Informer, Technologist and Artisans clusters.
We have further broken down each job cluster into specific skills/occupations for which we will be undertaking gap analysis.
Hence data is sought for the number of employees in each job cluster by occupation by age profile.

2.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

	15-24	25-34	35-44	45-54	55-64	65+	Total	Number based in: Metropolitan	Regional	Total	Check (Col should be zero)
Design Professionals who are University trained											
Project Managers											
Construction Project Manager							0			0	0
Engineering Manager							0			0	0
Total Project Managers	0	0	0	0	0	0	0	0	0	0	0
Civil Engineers											
Civil Engineer							0			0	0
Geotechnical Engineer							0			0	0
Quantity Surveyor							0			0	0
Structural Engineer							0			0	0
Transport Engineer							0			0	0
Total Civil Engineers	0	0	0	0	0	0	0			0	0
Mechanical Engineers							0			0	0
Surveyors and Spatial Scientists											
Surveyor							0			0	0
Cartographer							0			0	0
Other Spatial Scientist							0			0	0
Total Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals							0			0	0
Total Engineers	0	0	0	0	0	0	0	0	0	0	0
Total (university trained) Design Cluster Professionals	0	0	0	0	0	0	0	0	0	0	0
Design Professionals who are not University trained											
Civil Engineering Associate Professionals											
Civil Engineering Draftsperson							0			0	0
Civil Engineering Technician							0			0	0
Total Civil Engineering Associate Professionals	0	0	0	0	0	0	0	0	0	0	0
Mechanical Engineering Associates							0			0	0
Surveying and Spatial Science Associates							0			0	0
Other Construction Associate Professionals							0			0	0
Total Associate Design Professionals	0	0	0	0	0	0	0	0	0	0	0
Other (tangential) jobs associated with the Design Cluster											
Contract, Program and Project Administrators							0			0	0
Procurement Manager							0			0	0
Natural and Physical Science Professionals							0			0	0
Total Other (design cluster) jobs	0	0	0	0	0	0	0	0	0	0	0

Figure C 4: Survey Part 2B

2.B. Job Cluster 2 - Informer Skills (Informers include professionals providing information, education or business services)

Urban and Regional Planners							0			0	0
Information and Organisation Professionals							0			0	0
Welfare Professionals							0			0	0
Transport Analysts							0			0	0
Total Informer Workforce	0	0	0	0	0	0	0	0	0	0	0

2.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)

ICT Professionals							0			0	0

2.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)

Tradepersons							0			0	0
Construction and Mining Labourers							0			0	0
Mobile Plant Operators							0			0	0
Total Artisan Skills	0	0	0	0	0	0	0	0	0	0	0
Total Defined Roads workforce	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

3. What is the distribution of your design cluster work force, by type of work performed? For example, 40% Construction, 40% Maintenance, and 20% Network/Operations

	Construction (%)	Maintenance (%)	Network (%)	
Project Managers				0
Civil Engineers				0
Mechanical Engineers				0
Surveyors and Spatial Scientists				0
Other Engineering Professionals				0
TAFE trained Associate Design Professionals				0

Please go to Part 3 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 5: Survey Part 3A

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 3 of survey (please enter details in white cells)

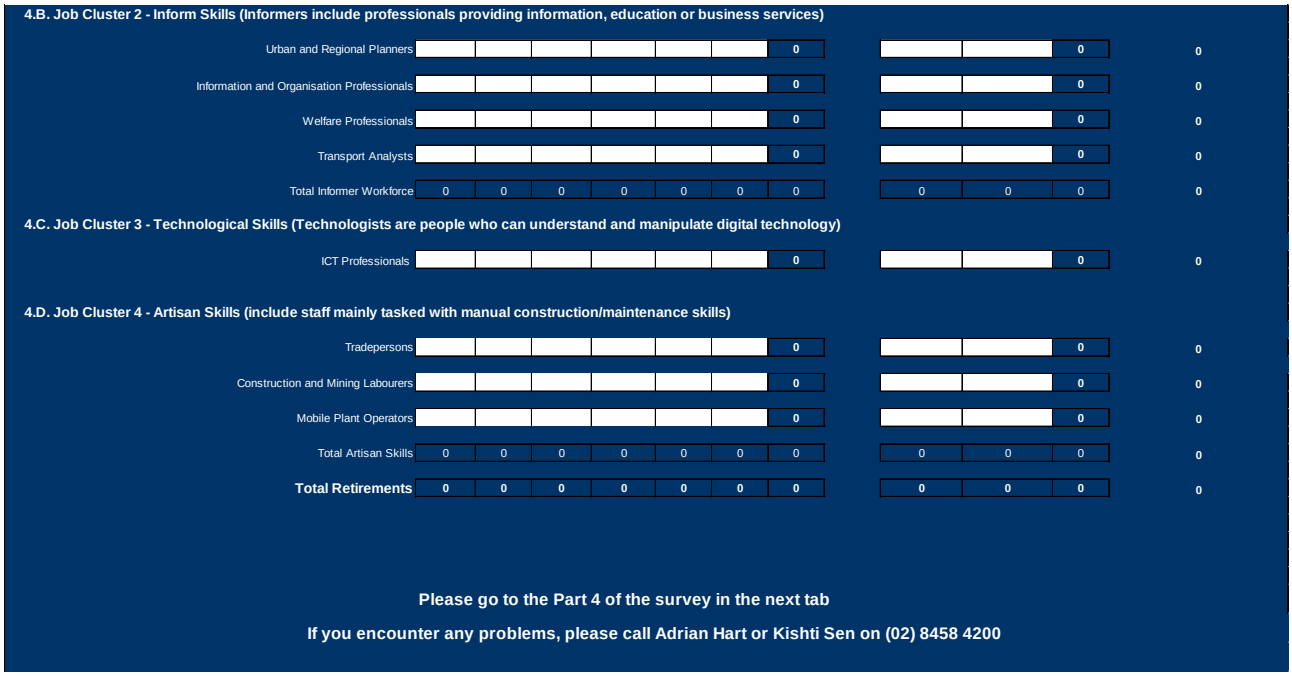
Where you see a downward arrow next to a box, please click on the downward arrow and choose response from the drop-down list

4. The total skilled roads workforce requirement to meet future capability will inevitably be increased by the attrition of the existing workforce through ageing effects, particularly through retirement. Please provide the average number of retirements (not exits) for occupations within a job cluster by age group per annum over the last three years (i.e. from 2014/15 to 2016/17):

4.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

	15-24	25-34	35-44	45-54	55-64	65+	Total	Number based in: Metropolitan	Regional	Total	Check (Col should be zero)
Design Professionals who are University trained											
Project Managers											
Construction Project Manager							0			0	0
Engineering Manager							0			0	0
Total Project Managers	0	0	0	0	0	0	0	0	0	0	0
Civil Engineers											
Civil Engineer							0			0	0
Geotechnical Engineer							0			0	0
Quantity Surveyor							0			0	0
Structural Engineer							0			0	0
Transport Engineer							0			0	0
Total Civil Engineers	0	0	0	0	0	0	0			0	0
Mechanical Engineers							0			0	0
Surveyors and Spatial Scientists											
Surveyor							0			0	0
Cartographer							0			0	0
Other Spatial Scientist							0			0	0
Total Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals							0			0	0
Total Engineers	0	0	0	0	0	0	0	0	0	0	0
Total (university trained) Design Cluster Professionals	0	0	0	0	0	0	0	0	0	0	0
Design Professionals who are TAFE trained											
Civil Engineering Associate Professionals											
Civil Engineering Draftsperson							0			0	0
Civil Engineering Technician							0			0	0
Total Civil Engineering Associate Professionals	0	0	0	0	0	0	0	0	0	0	0
Mechanical Engineering Associates							0			0	0
Surveying and Spatial Science Associates							0			0	0
Other Construction Associate Professionals							0			0	0
Total Associate Design Professionals	0	0	0	0	0	0	0	0	0	0	0
Other (tangential) jobs associated with the Design Cluster											
Contract, Program and Project Administrators							0			0	0
Procurement Manager							0			0	0
Natural and Physical Science Professionals							0			0	0
Total Other (design cluster) jobs	0	0	0	0	0	0	0	0	0	0	0

Figure C 6: Survey Part 3B



4.B. Job Cluster 2 - Inform Skills (Informers include professionals providing information, education or business services)

Urban and Regional Planners							0			0	0
Information and Organisation Professionals							0			0	0
Welfare Professionals							0			0	0
Transport Analysts							0			0	0
Total Informer Workforce	0	0	0	0	0	0	0	0	0	0	0

4.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)

ICT Professionals							0			0	0

4.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)

Tradepersons							0			0	0
Construction and Mining Labourers							0			0	0
Mobile Plant Operators							0			0	0
Total Artisan Skills	0	0	0	0	0	0	0	0	0	0	0
Total Retirements	0	0	0	0	0	0	0	0	0	0	0

Please go to the Part 4 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 7: Survey Part 4A

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 4 of survey (please enter details in white cells)

Where you see a downward arrow next to a box, please click on the downward arrow and choose response from the drop-down list

5. Please provide the average number of redundancies by occupation within a job cluster by age group per annum over the last three years (i.e. from 2014/15 to 2016/17):

5.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

Design Professionals who are University trained	15-24	25-34	35-44	45-54	55-64	65+	Total	Number based in: Metropolitan	Regional	Total	Check (Col should be zero)
Project Managers											
Construction Project Manager							0			0	0
Engineering Manager							0			0	0
Total Project Managers	0	0	0	0	0	0	0	0	0	0	0
Civil Engineers											
Civil Engineer							0			0	0
Geotechnical Engineer							0			0	0
Quantity Surveyor							0			0	0
Structural Engineer							0			0	0
Transport Engineer							0			0	0
Total Civil Engineers	0	0	0	0	0	0	0			0	0
Mechanical Engineers							0			0	0
Surveyors and Spatial Scientists											
Surveyor							0			0	0
Cartographer							0			0	0
Other Spatial Scientist							0			0	0
Total Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals							0			0	0
Total Engineers	0	0	0	0	0	0	0	0	0	0	0
Total (university trained) Design Cluster Professionals	0	0	0	0	0	0	0	0	0	0	0
Design Professionals who are TAFE trained											
Civil Engineering Associate Professionals											
Civil Engineering Draftsperson							0			0	0
Civil Engineering Technician							0			0	0
Total Civil Engineering Associate Professionals	0	0	0	0	0	0	0	0	0	0	0
Mechanical Engineering Associates							0			0	0
Surveying and Spatial Science Associates							0			0	0
Other Construction Associate Professionals							0			0	0
Total Associate Design Professionals	0	0	0	0	0	0	0	0	0	0	0

Figure C 8: Survey Part 4B

Other (tangential) jobs associated with the Design Cluster

Contract, Program and Project Administrators							0			0	0
Procurement Manager							0			0	0
Natural and Physical Science Professionals							0			0	0
Total Other (design cluster) jobs	0	0	0	0	0	0	0	0	0	0	0

5.B. Job Cluster 2 - Inform Skills (Informers include professionals providing information, education or business services)

Urban and Regional Planners							0			0	0
Information and Organisation Professionals							0			0	0
Welfare Professionals							0			0	0
Transport Analysts							0			0	0
Total Informer Workforce	0	0	0	0	0	0	0	0	0	0	0

5.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)

ICT Professionals							0			0	0

5.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)

Tradepersons							0			0	0
Construction and Mining Labourers							0			0	0
Mobile Plant Operators							0			0	0
Total Artisan Skills	0	0	0	0	0	0	0	0	0	0	0
Total Retirements	0	0	0	0	0	0	0	0	0	0	0

Please go to the Part 5 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 9: Survey Part 5A

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 5 of survey (please enter details in white cells)

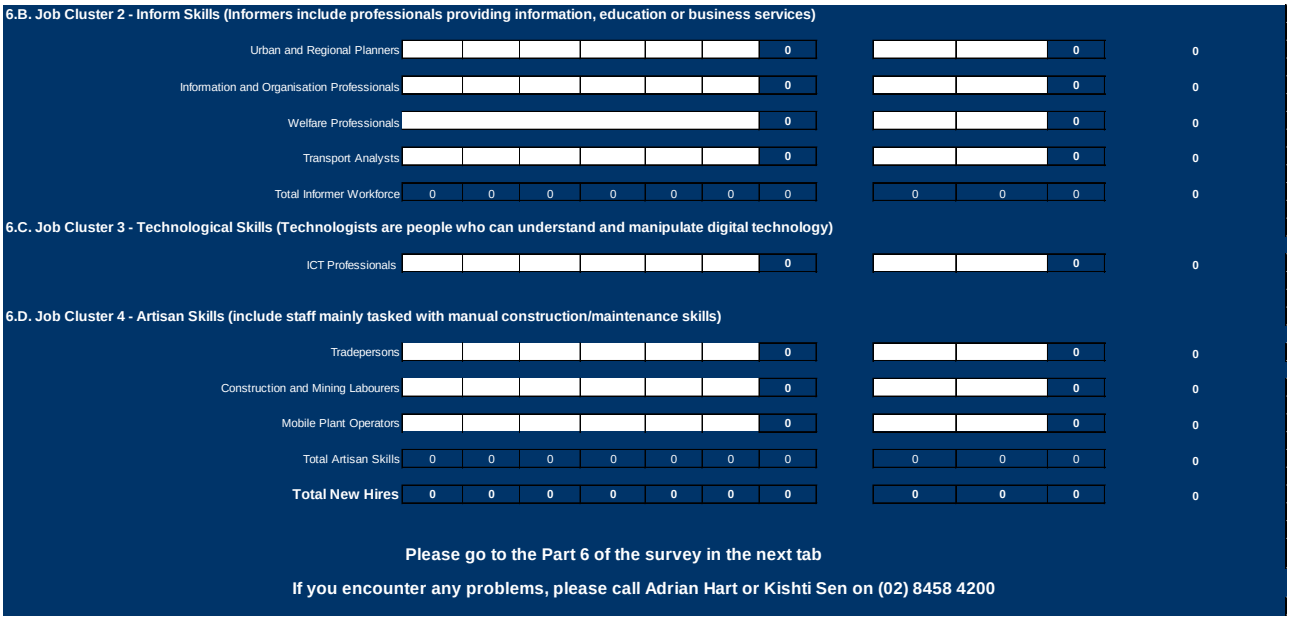
Where you see a downward arrow next to a box, please click on the downward arrow and choose response from the drop-down list

6. Please provide the average number of new hires by specialisation and by age group per annum over the last three years (i.e. from 2014/15 to 2016/17). New hires include replacements for staff lost through workforce attrition (i.e.) retirements and new recruits to meet increased workload. New hires does not include staff who were hired to replace employees who had exited the workforce to join other organisations including the private sector.

6.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

	15-24	25-34	35-44	45-54	55-64	65+	Total	Number based in: Metropolitan	Regional	Total	Check (Col should be zero)
Design Professionals who are University trained											
Project Managers											
Construction Project Manager							0			0	0
Engineering Manager							0			0	0
Total Project Managers	0	0	0	0	0	0	0	0	0	0	0
Civil Engineers											
Civil Engineer							0			0	0
Geotechnical Engineer							0			0	0
Quantity Surveyor							0			0	0
Structural Engineer							0			0	0
Transport Engineer							0			0	0
Total Civil Engineers	0	0	0	0	0	0	0			0	0
Mechanical Engineers							0			0	0
Surveyors and Spatial Scientists											
Surveyor							0			0	0
Cartographer							0			0	0
Other Spatial Scientist							0			0	0
Total Surveyors and Spatial Scientists	0	0	0	0	0	0	0	0	0	0	0
Other Engineering Professionals							0			0	0
Total Engineers	0	0	0	0	0	0	0	0	0	0	0
Total (university trained) Design Cluster Professionals	0	0	0	0	0	0	0	0	0	0	0
Design Professionals who are TAFE trained											
Civil Engineering Associate Professionals											
Civil Engineering Draftsperson							0			0	0
Civil Engineering Technician							0			0	0
Total Civil Engineering Associate Professionals	0	0	0	0	0	0	0	0	0	0	0
Mechanical Engineering Associates							0			0	0
Surveying and Spatial Science Associates							0			0	0
Other Construction Associate Professionals							0			0	0
Total Associate Design Professionals	0	0	0	0	0	0	0	0	0	0	0
Other (tangential) jobs associated with the Design Cluster											
Contract, Program and Project Administrators							0			0	0
Procurement Manager							0			0	0
Natural and Physical Science Professionals							0			0	0
Total Other (design cluster) jobs	0	0	0	0	0	0	0	0	0	0	0

Figure C 10: Survey Part 5B



6.B. Job Cluster 2 - Inform Skills (Informers include professionals providing information, education or business services)

Urban and Regional Planners							0			0	0
Information and Organisation Professionals							0			0	0
Welfare Professionals							0			0	0
Transport Analysts							0			0	0
Total Informer Workforce	0	0	0	0	0	0	0	0	0	0	0

6.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)

ICT Professionals							0			0	0

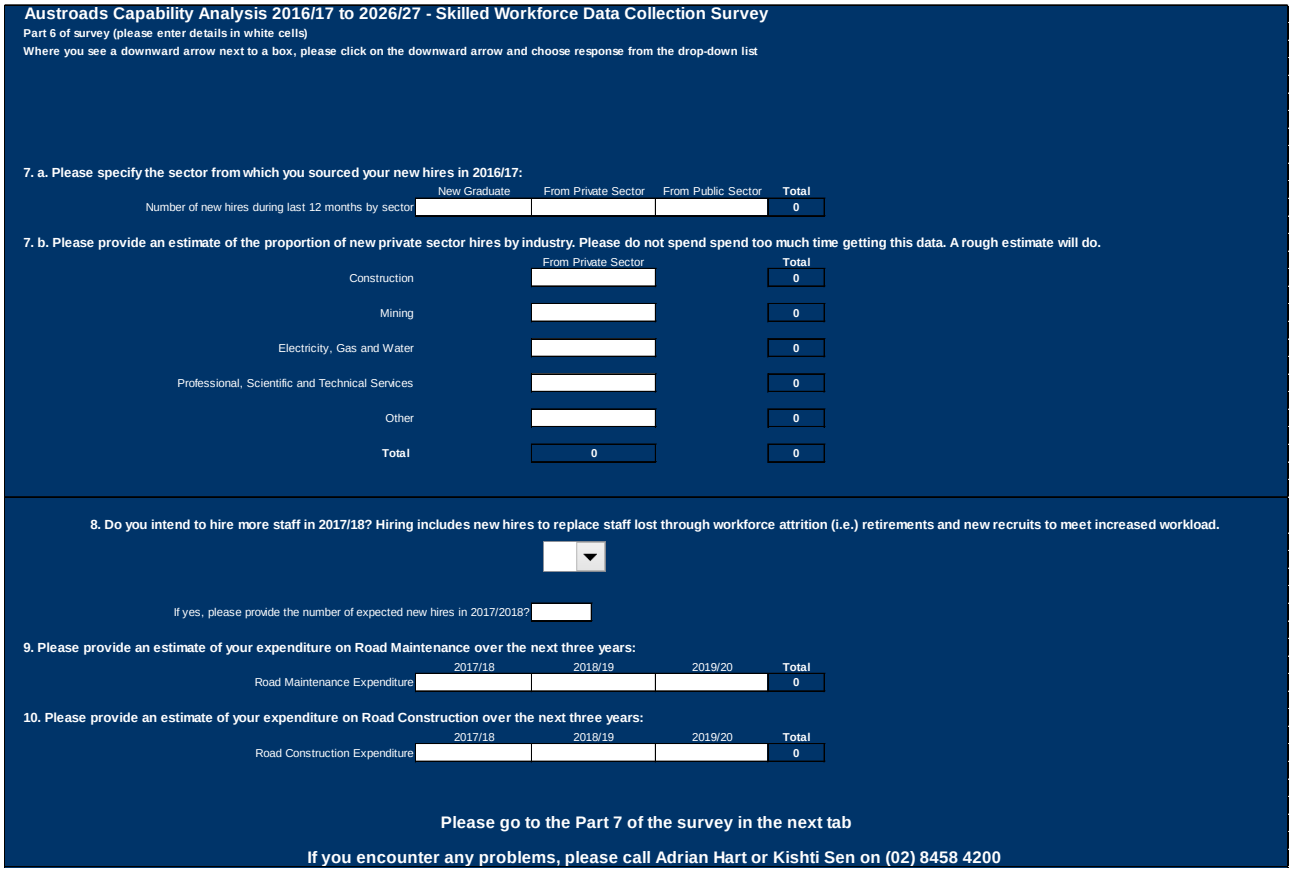
6.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)

Tradepersons							0			0	0
Construction and Mining Labourers							0			0	0
Mobile Plant Operators							0			0	0
Total Artisan Skills	0	0	0	0	0	0	0	0	0	0	0
Total New Hires	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Please go to the Part 6 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 11: Survey Part 6



Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 6 of survey (please enter details in white cells)

Where you see a downward arrow next to a box, please click on the downward arrow and choose response from the drop-down list

7. a. Please specify the sector from which you sourced your new hires in 2016/17:

	New Graduate	From Private Sector	From Public Sector	Total
Number of new hires during last 12 months by sector				0

7. b. Please provide an estimate of the proportion of new private sector hires by industry. Please do not spend spend too much time getting this data. A rough estimate will do.

	From Private Sector	Total
Construction		0
Mining		0
Electricity, Gas and Water		0
Professional, Scientific and Technical Services		0
Other		0
Total	0	0

8. Do you intend to hire more staff in 2017/18? Hiring includes new hires to replace staff lost through workforce attrition (i.e.) retirements and new recruits to meet increased workload.

If yes, please provide the number of expected new hires in 2017/2018?

9. Please provide an estimate of your expenditure on Road Maintenance over the next three years:

	2017/18	2018/19	2019/20	Total
Road Maintenance Expenditure				0

10. Please provide an estimate of your expenditure on Road Construction over the next three years:

	2017/18	2018/19	2019/20	Total
Road Construction Expenditure				0

Please go to the Part 7 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 12: Survey Part 7

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 7 of the survey seeks to identify skills which are in short supply right now and the severity of the shortage.

11. Please indicate the difficulty in recruiting staff by skill level

11.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

	5 Very difficult	4 Somewhat difficult	3 Neutral	2 Somewhat Easy	1 Easy	For very difficult positions, please say (by ticking the relevant box) if the recruiting difficulty arises because of: (1) Skills shortages in the talent market as evidenced by: Low number of applicants	Candidates do not have the needed work experience	Candidates do not have the right technical skills	or (2) Skills gap in the existing workforce due to: The local market is not producing enough work-ready/qualified job candidates	Competition from other employers	Salaries not being competitive for the market
Design Professionals who are University trained											
Project Managers											
Construction Project Manager											
Engineering Manager											
Civil Engineers											
Civil Engineer											
Geotechnical Engineer											
Quantity Surveyor											
Structural Engineer											
Transport Engineer											
Mechanical Engineers											
Surveyors and Spatial Scientists											
Surveyor											
Cartographer											
Other Spatial Scientist											
Other Engineering Professionals											
Design Professionals who are TAFE trained											
Civil Engineering Associate Professionals											
Civil Engineering Draftsperson											
Civil Engineering Technician											
Mechanical Engineering Associates											
Surveying and Spatial Science Associates											
Other Construction Associate Professionals											
Other (tangential) jobs associated with the Design Cluster											
Contract, Program and Project Administrators											
Procurement Manager											
Natural and Physical Science Professionals											
11.B. Job Cluster 2 - Inform Skills (Informers include professionals providing information, education or business services)											
Urban and Regional Planners											
Information and Organisation Professionals											
Welfare Professionals											
Transport Analysts											
11.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)											
ICT Professionals											
11.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)											
Tradespersons											
Construction and Mining Labourers											
Mobile Plant Operators											

Please go to Part 8 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 13: Survey Part 8

Austroads Capability Analysis 2016/17 to 2026/27 - Skilled Workforce Data Collection Survey

Part 8 of the survey seeks to identify skills which are likely to be in short supply in the medium to long term.

11. Please indicate which occupations are likeliest to experience shortages or capability constraints are likely to arise over (i) the next 10 years and (ii) beyond (10-20 years)

11.A. Job Cluster 1 - Design skills (Staff who mainly design and oversee the engineering/construction roads projects)

	Over the next 10 years (to 2026/27)					Over the next 10-20 years (2026/27 to 2036/37)				
	5 Extremely Likely	4 Likely	3 Neutral	2 Unlikely	1 Extremely Unlikely	5 Extremely Likely	4 Likely	3 Neutral	2 Unlikely	1 Extremely Unlikely
Design Professionals who are University trained										
Project Managers										
Construction Project Manager										
Engineering Manager										
Civil Engineers										
Civil Engineer										
Geotechnical Engineer										
Quantity Surveyor										
Structural Engineer										
Transport Engineer										
Mechanical Engineers										
Surveyors and Spatial Scientists										
Surveyor										
Cartographer										
Other Spatial Scientist										
Other Engineering Professionals										
Design Professionals who are TAFE trained										
Civil Engineering Associate Professionals										
Civil Engineering Draftsperson										
Civil Engineering Technician										
Mechanical Engineering Associates										
Surveying and Spatial Science Associates										
Other Construction Associate Professionals										
Other (tangential) jobs associated with the Design Cluster										
Contract, Program and Project Administrators										
Procurement Manager										
Natural and Physical Science Professionals										
11.B. Job Cluster 2 - Inform Skills (Informers include professionals providing information, education or business services)										
Urban and Regional Planners										
Information and Organisation Professionals										
Welfare Professionals										
Transport Analysts										
11.C. Job Cluster 3 - Technological Skills (Technologists are people who can understand and manipulate digital technology)										
ICT Professionals										
11.D. Job Cluster 4 - Artisan Skills (include staff mainly tasked with manual construction/maintenance skills)										
Tradespersons										
Construction and Mining Labourers										
Mobile Plant Operators										

Please go to Part 9 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 14: Survey Part 9

12: Roads Industry Workforce Capability - Part 9: Risks

In your view, what are the key risks to roads industry / agency workforce capability?

12A: Risk factors	Level of Impact (Check the most appropriate box) 5 Very High	4 High	3 Medium	2 Low	1 Very Low	Risk Horizon Next 5 Years Short Term	5-20 Years Long Term	Experience over past 5 years? Improved	Worsened	Unchanged
Loss of knowledge due to demographic impacts as experienced staff reach older age groups and retire										
Loss of capability in regional areas										
Low representation of women in the roads workforce										
Retaining skilled staff with 4-5 years experience from hire by other industries or departments										
Mismatches in skills supplied from education institutions										
Restrictions to hiring from overseas (e.g. visa restrictions, local employment policies)										
Difficulty in attracting new graduates										
Difficulty in attracting experienced staff										
Lack of effective and strategic workforce planning										
Volume of construction, maintenance and asset management work expected										
Insufficient level of internal (on the job) training to retain exisitng staff										
Insufficient level of job slots available for apprenticeships and cadetships										
Insufficient planning / understanding of the impact of new technologies										
Impact of changes to roads agency roles and functions										
Lack of funding for effective staffing										
Other (please specify)										
Other (please specify)										
Other (please specify)										

12B: Please elaborate on the reasons for your choices in Question 12A

12C: In your view, what initiatives are currently (or should be) undertaken to mitigate against workforce capability risks identified in Question 12A?

Please go to Part 10 of the survey in the next tab

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Figure C 15: Survey Part 10

13: Roads Industry Workforce Capability - Part 10: Impact of New Technologies

This question seeks to understand better the specific risks to workforce capability from technological change. In your view, what are the key risks to roads industry / agency workforces through changing technologies?

	Level of Impact (Check the most appropriate box)					Risk Horizon		Experience over past 5 years?		
	5	4	3	2	1	Next 5 Years	5-20 Years			
13A: Risk factors	Very High	High	Medium	Low	Very Low	Short Term	Long Term	Improved	Worsened	Unchanged
Insufficient data analysis / data scientist skills with new graduates										
Insufficient data analysis / data science skills with experienced hires										
Finding / attracting data analysts / data scientists into the roads industry										
Inability to effectively collect, store and mash data (i.e. establish data systems)										
Staff not having multidisciplinary skills across data and other capabilities (e.g. comms)										
Regulatory and safety skills to support new technologies (e.g. autonomous vehicles)										
Inability to train existing staff to work in new data-oriented roles										
Lack of appropriate engineering skills (e.g. process versus civil engineers)										
Insufficient behavioural/psychological skills to optimise management of the roads network										
Insufficient sharing of data within or between agencies to drive solutions										
Other (please specify)										
Other (please specify)										
Other (please specify)										

13B: Please elaborate on the reasons for your choices in Question 13A

13C: In your view, what initiatives are or should be undertaken to mitigate against workforce capability risks identified in Question 13A?

Thankyou for your participation in this industry survey

Please save the file on your computer and send the questionnaire as an attachment in an email to ahart@bisoxfordeconomics.com.au

If you encounter any problems, please call Adrian Hart or Kishti Sen on (02) 8458 4200

Austroads

Level 9, 287 Elizabeth Street
Sydney NSW 2000 Australia

Phone: +61 2 8265 3300

austroads@austroads.com.au
www.austroads.com.au