Economic impact of geospatial services in Australia

A report prepared for the Geospatial Council of Australia

30 October 2024

Foreword

This assessment of the value of geospatial information in Australia in 2023-24 and projections to 2033-34 was commissioned by the Geospatial Council of Australia. The Geospatial Council of Australia is the peak body representing the interests of organisations and individuals, including new and emerging professionals working in the vast range of occupations for surveying, downstream space and geospatial in the digital world.

We are extremely grateful to the organisations listed overleaf that have supported this work by contributing funding, and also through their participation via a steering committee, without which this work would not have been possible.

The study aims to highlight the critical role of geospatial information in enhancing national productivity, showcasing its significant direct economic impact on our national economy. Additionally, it seeks to explore opportunities for expanding its usage further. The study is not just an analysis of our current industry value – it's a forward-looking initiative projecting the potential impact of the geospatial industry on the Australian economy in 2034.

While there is a very strong focus on the economic and productivity benefits that geospatial data and technology deliver, we are also interested in capturing some of the broader benefits, including various societal benefits from the day-to-day use of geospatial information, such as finding our way around, knowing your kids are safe and when your bus is arriving.

From a strategic policy perspective, geospatial information and services are essential to tackling climate change, environmental management, sustainability and emissions reduction monitoring, resilience planning, emergency and national disaster response and management, along with defence and security.

By understanding where we stand today and envisioning our potential influence on the national economy over the next decade, we are aiming to use this report to shape the future policies that will not only foster further growth of Australia's economy but also position the geospatial sector at the heart of Australia's broader narrative and economic growth.

Kate Lundy
Chair
Geospatial Council of Australia

Acknowledgements

The Geospatial Council of Australia would like to thank to following organisations for their generous support, that has made this study possible.

Steering Committee

This work was overseen by a Steering Committee whose members are listed below.

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Abbreviations	Definitions
ABS	Australian Bureau of Statistics
AI	Artificial intelligence
ANZSIC	Australian and New Zealand Standard Industrial Classification
API	Application Program Interface
CEBR	Centre for Excellence for Biosecurity Risk Analysis
C-ITS	Cooperative Intelligent Transport Systems
CORS	Continuously Operating Reference Station
CTF	Controlled traffic farming (self-steering tractors)
EOS	Earth Observations from Space
FTE	Full Time Equivalent which equates to the standard hours that an employee has worked over a week. In this report, one FTE is equivalent to 40 hours.
GNAF	Geocoded National Address File
GNSS	Global Navigational Satellite Service
ICSM	Intergovernmental Committee on Surveying and Mapping
LIDAR	Light detection and ranging
Nec.	Not elsewhere classified
NMG	National Management Group for the Varroa Mite
NPIC	National Positioning Infrastructure Capability
NPV	Net present value
PV	Present value
RI	Real income which is the sum of income to Australians plus company profits
RTK	Real time kinematics (a technology for augmenting GNSS position)
SBAS	Satellite Based Augmentation Service
SLM	Serpentine Leaf Miner
SouthPAN	The Southern Positioning Augmentation Network
STES	State and Territory Emergency Services
VLM	Vegetable leaf miner
BoM	Bureau of Meteorology

Geospatial Council of Australia

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Summary Report

Executive Summary

This study

This study highlights the critical role of geospatial information in enhancing national productivity, showcasing its significant direct economic impact on our national economy.

It updates a study published in 2008 on the value of spatial information in Australia, commissioned at the time by the then CRC for Spatial Information and the Spatial Industries Business Association (ACIL Tasman, 2008). The study focusses on the accumulated economic impacts that geospatial data and technology are estimated to have delivered in 2023-24 and projected to deliver by 2033-34.

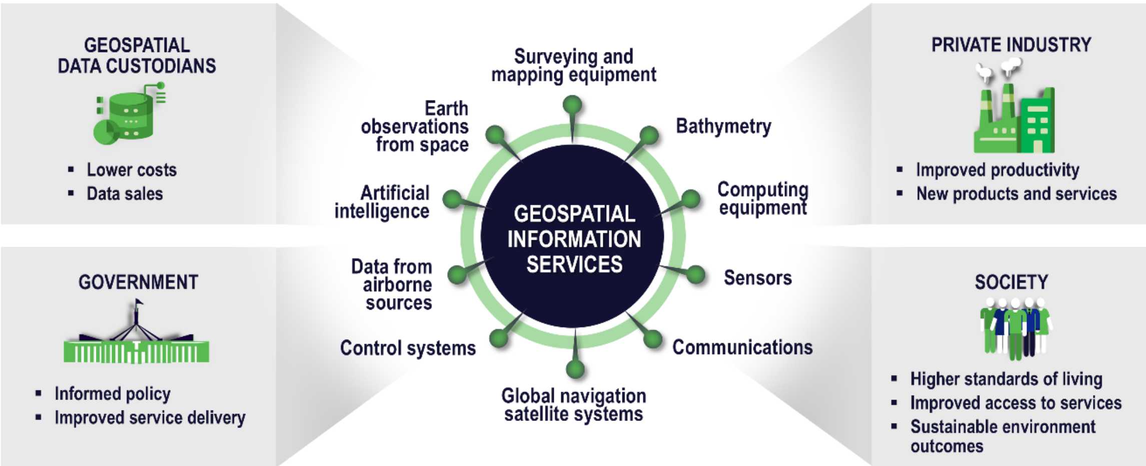
The geospatial information ecosystem

The geospatial ecosystem is critical to the nation's economy. Geospatial is referred to as an ecosystem rather than a sector or industry as the technologies within geospatial cut across almost every part of our economy and uplift all of our industry sectors. It now supports most areas of government, industry and society generally.

Geospatial technologies include geodesy, surveying and mapping, remote sensing, earth observations from space (EOS), aerial imagery and lidar data capture, topographic and hydrographic surveys, positioning, navigation and timing (PNT), geospatial information systems (GIS), GIS analysis, sensors and control systems, machine learning (ML) and artificial intelligence (AI).

With the rapid spread of geospatially supported systems and technologies, there are few areas of government, industry or society that do not benefit from geospatial information and services.

Figure ES 1 Benefits derived from geospatial enabled products and services



Source: ACIL Allen

Beneficiaries of geospatial information services

Government

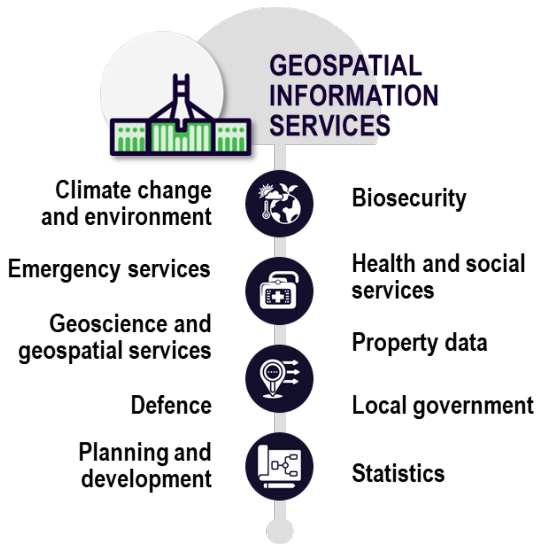
Geospatial information services are embedded in many government processes supporting evidence-based policy formulation, and a range of government activities at the national, state/territory and local government levels.

Some of the highest levels of adoption are in emergency services, supporting the transition to net zero emissions, climate change resilience, monitoring emissions and ground cover, planning and development, land management, property data, meteorology, biosecurity, fisheries management, geoscience, bathymetry, resources and energy, public transport, and asset management. Defence is a major user of geospatial information. Local government relies on geospatial information for land management, planning and other local government services.

The development of spatial digital twin infrastructure by some state and local governments is underway and has the potential for significant savings for planning and development, infrastructure and asset management.

Other areas, where the use of geospatial information services is important, include general administration, finance, health and social services. However, use is growing in these areas. Development of platforms and services such as the Digital Atlas of Australia led by Geoscience Australia and the Australian Bureau of Statistics, and geocoding data held by the Australian Bureau of Statistics, point to a future marked by an increase in the use of geospatial information services for a range of activities in government, including policy analysis, and demographic and regional economic analysis.

Figure ES 2 Geospatial services supporting government



Protection of critical infrastructure is a priority for government and society. Critical infrastructure includes space infrastructure, energy, water and sewerage, communications, defence and transport. Geospatial information systems and services are embedded in these areas.

Industry

Geospatial information systems and technologies play a critical role in most industries. They are deeply embedded in agriculture, forestry and fisheries, construction, mining, all modes of transport and logistics, resources and energy and aspects of finance and insurance.

Geospatial information services are important supporting technologies for the transition to net zero emissions by 2050. For example, they are critical to the development of electric autonomous vehicles, which have the potential to reduce emissions in the mining, agriculture and transport sectors.

There has been less penetration in other areas such as healthcare, retail and wholesale trade, arts and recreation and administrative services. However, with the growing availability of devices and geospatial data, geospatial applications are growing in online purchasing and delivery, ride share, rental hire, real estate, and marketing.

Figure ES 3 Geospatial services supporting industry

Mining

Mining is one of the most geospatially enabled industries in Australia. Geospatial information services are embedded in exploration, development, production, processing, supply chain and environmental management throughout the mining cycle.

Critical minerals are important to Australia's transition to net zero by 2050. Geoscience and space technologies have the potential to enhance and accelerate exploration for critical minerals.

Robotics and autonomous vehicles are delivering increased productivity and safety in mining operations. Geospatial information services and technologies provide critical support to these operations.

Design, construction and property

The level of adoption in design, construction and property development is high in most areas. Geospatial information services are critical to surveying, route selection and construction, building design, set out, compliance monitoring and asset maintenance.

The emergence of spatial digital twin concepts offers the prospect of further productivity growth through better coordination of design and construction of buildings, transport and infrastructure. Increasing productivity in these sectors is critical to the housing supply and delivery of infrastructure.

Transport

Geospatial information services underpin many areas of transport. Global Navigation Satellite Systems (GNSS) solutions provide support for navigation in road, maritime and air transport. Geospatial systems support route optimisation, logistics, fleet management and autonomous vehicles.

The emerging area of Cooperative Autonomous Vehicles and Cooperative Intelligent Transport services will contribute to improving the efficiency of road transport and improving safety.

Geospatial information services and technologies are also supporting logistics and warehousing for tracking and monitoring of goods and deliveries.

Agriculture

Agriculture has been one of the earliest adopters of technologies and systems supported by geospatial technologies. The case for the use of precise satellite positioning in broadacre cropping has been established for many years. Productivity is crucial to maintaining Australian agriculture's competitiveness in global markets. Precise positioning services support technologies such as remote sensing, auto-steer and yield monitoring systems that deliver productivity benefits to many agriculture enterprises.

Biosecurity

Geospatial information systems play an important role in protecting Australia's biosecurity. They support risk assessment, data sharing between governments, industry and research organisations, detection of incursions of pests and disease, optimising resource allocation at the response stage and creating visualisations to communicate biosecurity risks to stakeholders, policy makers and the public.

Other areas

Geospatial information is also fundamental to other areas of the private sector including professional services such as surveying, engineering and architecture, communications, finance and insurance, wholesale and retail trade, accommodation and food services. The level of adoption in professional services and insurance is high. Its role in manufacturing through technologies such as additive engineering, robotics and supply chain management is expected to grow in the future.

Consumers

Geospatial technologies offer a broad range of benefits to consumers, so much so that their use is now ubiquitous in everyday life. On the inventory of apps on a smartphone, there are many applications that rely on geospatial information.

From finding the nearest and nicest café to navigating unfamiliar streets, consumers rely heavily on navigation apps which leverage geospatial data to provide real-time directions. Consumers also benefit from delivery tracking when ordering products online and from location services for public transport, taxis and ride share.

Weather applications and services, such as the Bureau of Meteorology (BoM) radar, use geospatial data to provide local forecasts and warnings of storms, heavy rain, or extreme temperatures. This information helps plan activities accordingly, whether adjusting travel plans, or ensuring the safety of outdoor activities.

There are also numerous health benefits for consumers. Through the use of mobile apps and wearable devices, consumers can monitor their physical activity and track health metrics with the support of geospatial information services.

Figure ES 4 Geospatial services supporting consumers

Aggregate economic impact

Estimates of the productivity impacts on 26 sectors of the Australian economy were employed as inputs into ACIL Allen's Computable General Equilibrium (CGE) model to estimate their impact on output, incomes and employment.

Two scenarios were established: a business-as-usual scenario (BAU) and a favourable environment scenario. The difference between these two scenarios is driven by assumptions about progress in development, implementation and adoption of geospatial information systems by government and industry. Considerations include development of the science and technologies that underpin geospatial information (including geodesy and the Foundation Spatial Data Framework), progress in storing and sharing data (including ownership, access security), progress in developing spatial digital twin frameworks, and establishing geospatial data infrastructure as a fundamental component of critical infrastructure. A further consideration is the availability of workforce in the geospatial sector.

The BAU scenario assumes that progress on these issues will be slower over the next 10 years.

The favourable operating scenario assumes an acceleration of progress over this period.

Impact on the economy

The results of the CGE modelling are summarised in Table ES 1. The results of the modelling reflect the direct impacts of the productivity gains in each sector plus economy- wide impacts as the direct impacts work their way through the economy.

Table ES 1 Impact of geospatial information services on GDP, Income and Employment

	2023-24	2033-34 BAU	2033-34 Favourable operating environment
	$million	**$million**	**$million**
Gross Domestic Product	38,568	62,394	89,514
Real income	29,290	55,895	76,880
Employment	12,114	21,674	31,849

Source: ACIL Allen

Impact on GDP

The modelling results show:

— The impact of modern geospatial information services on GDP in 2023-24 is estimated to be **$38,568** higher than it would have otherwise been.
  — This represents a Compound Average Annual Growth Rate (CAGR) of around **9%** over the 17 years from 2006-07 to 2023-24.
— The impact of geospatial information services on GDP in 2033-34 is projected to be
  — **$62,394 million** higher in 2033-34 under the BAU scenario.
    - This represents a CAGR of **5%** between 2023-24 and 2033-34.
  — **$89,514 million** higher than it would otherwise be in 2033-34 under the favourable operating environment.
    - This represents a CAGR of around **9%** between 2023-24 and 2033-34.

Impact on income

Measures of real income are an indication of the welfare of Australians. The impact on income is:

— an additional **$29.3 billion** in 2023-24
— an additional **$55.9 billion** under the BAU case in 2033-34
— an additional **$76.9 billion** under the favourable operating environment.

Impact on employment

The impact on employment is:

— an additional **12,114 FTE** jobs in 2023-24
— an additional **21,674 FTEs** in 2033-34 under the BAU scenario
— an additional **31,849 FTEs** under the favourable operating environment scenario.

Value to Consumers

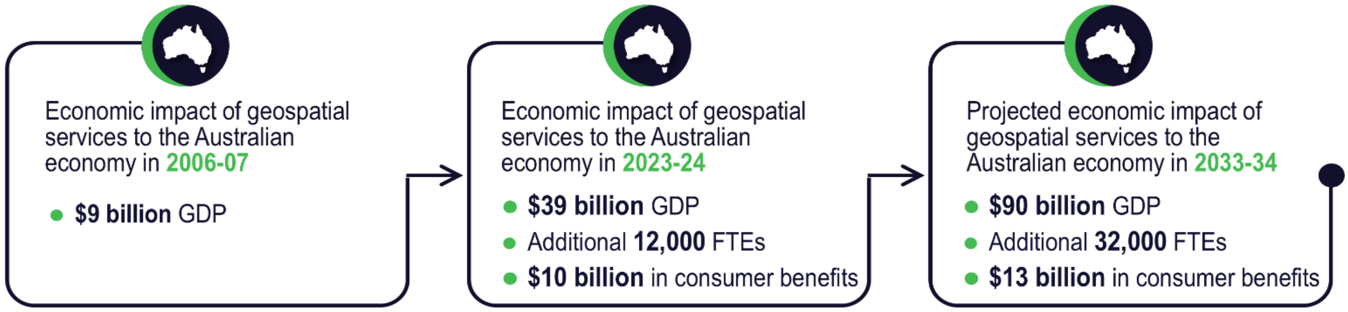
Consumers also benefit from time saved in commuting, researching, online shopping and in the future safer and more efficient transport. Estimates of the collective benefits are:

— **$10.5 billion** in value to consumers in 2023-24
— **$12.2 billion** in 2033-34 under the BAU scenario
— **$13.0 billion** under the favourable operating scenario.

Summary of the aggregate impacts

A summary of the aggregate impacts is provided in Figure ES 5.

Figure ES 5 Summary of impact under the favourable scenario



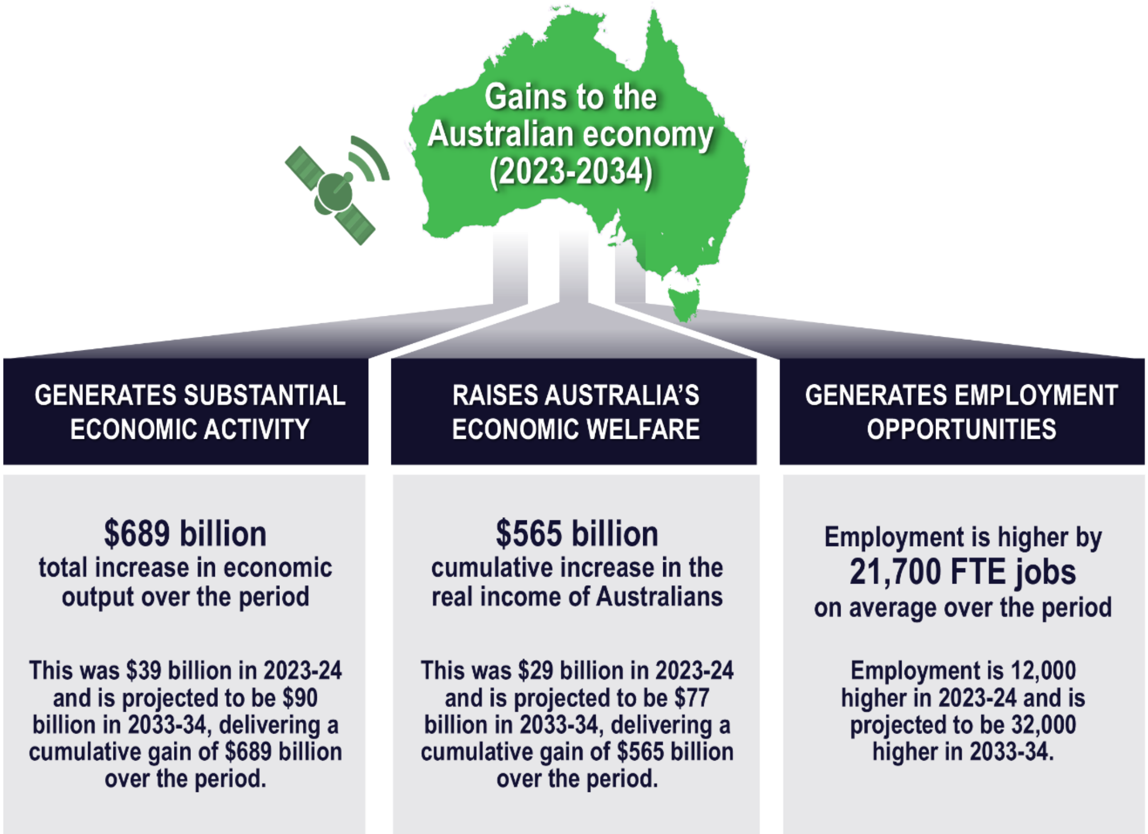
Source: ACIL Allen

Impact over the period 2023-24 to 2033-34

Over the next decade, the economic impacts in terms of economic activity, economic welfare and the employment opportunities generated are significant (Figure ES 6).

The undiscounted impact on economic output is projected to be $689 billion over the period and the impact on real income is projected to be $565 billion over the same period. Employment is projected to be higher by 21,700 FTE jobs on average over the period.

Figure ES 6 Impact over 10 years



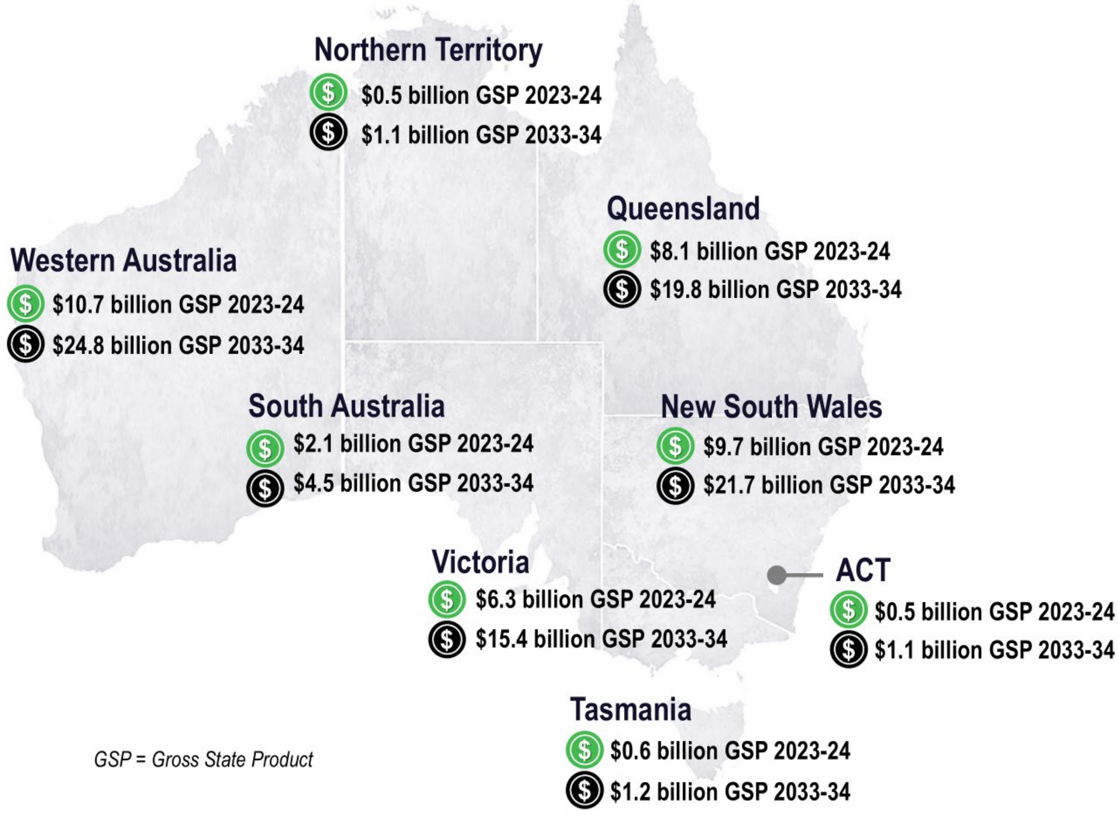
Source: ACIL Allen

Note: The figures quoted are undiscounted $(2023-24)

Impact on the States and Territories

The states and territories also benefit. Western Australia has the highest impact on gross state product in 2033-34 under the most favourable case of 24.8 billion. The impact on Gross State Product in New South Wales, Queensland and Victoria is $21.7 million, $19.8 billion and $15.4 billion respectively.

Figure ES 7 Impact by State and Territory



Source: ACIL Allen

Impact on sectors

The total impact on output for selected sectors over the 2023-24 to 2033-34 period is summarised in Figure ES 8. The largest impact over the period occurs in the mining sector where output is projected to be $161 billion higher that it would have otherwise been without modern geospatial data services. Over the same period, the increase is $72 billion for government, $55 billion for construction, $42 billion for financial services and insurance and $41 billion for agriculture, fisheries and forestry.

Figure ES 8 Impact on industries

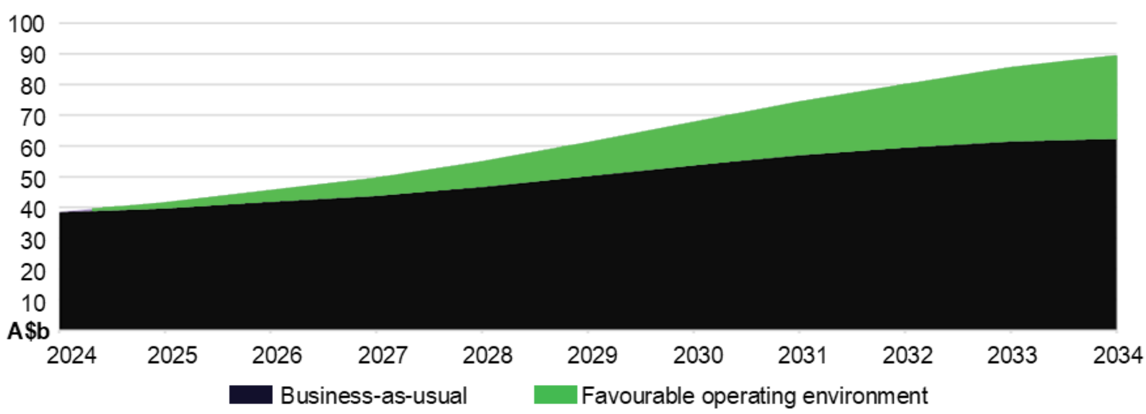
	Under the business-as-usual scenario increases GDP by 2023-24	Under the favourable operating environment scenario increases GDP by 2033-34
Mining	$126.8 billion	$160.7 billion
Government services	$63.2 billion	$72.4 billion
Construction	$43.7 billion	$54.7 billion
Manufacturing	$31.3 billion	$36.9 billion
Financial services & insurance	$32.5 billion	$42.2 billion
Agriculture, forestry and fishing	$30.0 billion	$47.9 billion
Transport	$23.2 billion	$26.7 billion
Utilities	$22.8 billion	$27.2 billion

What would shift the dial to the higher outcome

There is a large difference between the 2 scenarios assessed in this study. The lower outcome represents a decline in the rate of growth in impact of geospatial information services on output. The higher outcome represents a growth rate consistent with the previous 17 years.

These projections are a best estimate of a BAU and a favourable operating environment scenario. It is possible that the BAU scenario could be lower, and the favourable operating environment could be higher depending on the future operating environment.

Figure ES 9 Impact on GDP of the 2 scenarios



Source: ACIL Allen

Which path is realised depends on a number of factors including:

Digital and data frameworks inclusive of geospatial

— mechanisms and policies for sharing geospatial data including ownership, access and security, in the course of progressing the digital transformation agenda

Strengthening linkages with adjacent parts of the economic ecosystem

— consolidating the relationship between geospatial information, digital engineering and critical infrastructure

— progress on spatial digital twins by State/Territory, local government and the private sector with strong overlap of digital twins and digital engineering

Enhance essential enabling technologies and systems

— the level of investment in geodesy, the Foundation Spatial Data Framework and bathymetry

— secure access to space-based systems and services including Earth observations from space, Position Navigation and Timing, and satellite communications, through system redundancy or sovereign alternatives.

— progress in adoption of automated technologies such as applied AI and PNT to support greater application of autonomous machinery, vehicles, vessels and aircraft.

Innovation for economic and social impact

— research and development to build knowledge and innovation to empower Australia's geospatial sector to better enable key industries and professions as well as governments and public programs

Build professional communities

— workforce availability in the geospatial field at both professional and technical levels with accelerated education and training availability

There are risks in some areas. For example, the United Nations – Global Geodetic Centre of Excellence reported on concerns over the global geodesy supply chain and the linkages to critical infrastructure (UN-GGCE, 2024). The report estimated that outages of just 48 hours on PNT services would have an impact exceeding $2 billion. There are also concerns over workforce availability in the geospatial sector in Australia. These are examples of factors that are likely to influence future outcomes.

Realising the full potential of geospatial information services will depend on progress on the above factors.

Main Report

1 Introduction

This report was commissioned by the Geospatial Council of Australia with support from industry and government. It assesses the socio-economic economic impact of geospatial information in Australia as at 2023-24 and looking forward to 2033-34.

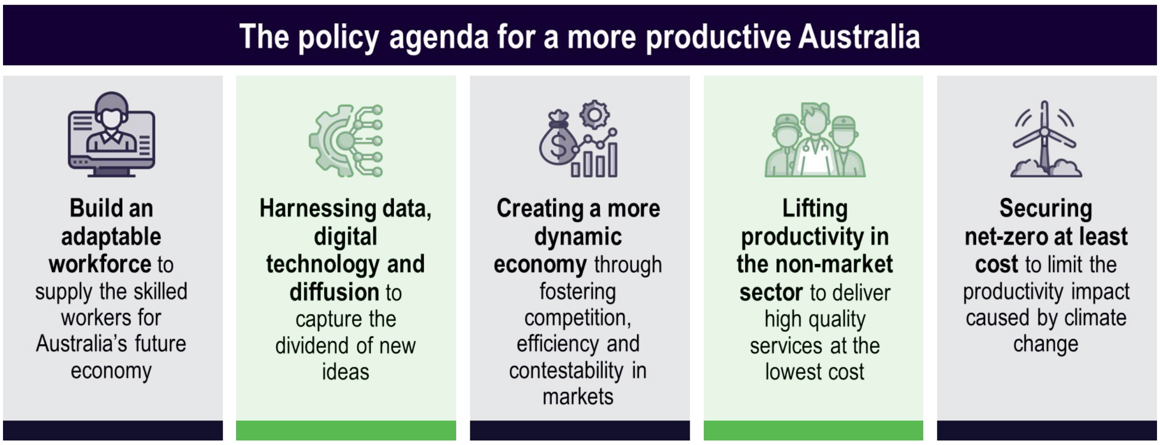
1.1 Context

The 2023 Intergenerational report notes that Australia's future path of economic growth and development faces many challenges. This includes digitalisation and adoption of new technologies, shifts in Australia's industrial base, the energy transformation, demographic change and geopolitical uncertainty (Commonwealth Treasury, 2023).

One of the issues in meeting these challenges is an outlook of lower long-run productivity growth. Australia's productivity growth has slowed since the mid-2000s. The productivity growth assumption in the 2023 Intergenerational Report is 1.2% per annum, consistent with the 20-year average. This compares with the 1.5% assumed in the 2021 Intergenerational Report consistent with the 30-year average at that time.

The Productivity Commission's 2023 report on raising productivity also highlighted the lower rate of growth in productivity over the past 20 years (Productivity Commission, 2023). The Commission identified building a skilled workforce and harnessing data and digitisation as one of the key challenges to be met in improving this position.

Figure 1.1 Productivity Commission agenda for a more productive Australia



Source: (Productivity Commission, 2023)

Government policy is focused on national prosperity and economic progress more broadly of which enhancing Australia's productivity performance is a key priority. A key challenge is how to maximise opportunities and address challenges associated with the major forces, trends and transitions that can be expected to impact the Australian economy over coming decades (The Hon Dr Jim Chalmers MP, 2023).

Geospatially supported technologies have an important role to play in meeting these challenges. Maps and location data have been a part of human endeavour for millennia. However, the power and pace of growth of these technologies has accelerated over the past 25 years. There are very few areas of the Australian economy or society that do not use geospatial information in one form or another. Geospatial technologies offer potential productivity improvements in many areas of government and industry. They are also part of the digital transition that Treasurer Chalmers identifies.

1.2 This study

This study aims to highlight the critical role of geospatial information in enhancing national productivity, showcasing its significant direct economic impact on our national economy. Additionally, it seeks to explore opportunities for expanding its usage further.

The study focusses on the accumulated economic and productivity benefits that geospatial data, and technology is estimated to deliver in 2023-24 and projected to 2033-34. It also explores other benefits (non-financial) including various societal benefits from the day-to-day use of geospatial information, such as tackling climate change, environmental management, sustainability and emissions reduction monitoring, resilience planning, emergency and national disaster response and management, along with defence and security.

1.3 Methodology

ACIL Allen undertook an evaluation of the value of geospatial information for the then Cooperative Research Centre for Spatial Information in 2007-08. There has been no Australia wide assessment since that time. However there have been several reports completed on different aspects of Earth Observations from Space (EOS), Position Navigation and Timing, Bathymetry/Seabed Mapping, and general assessments of the value of mapping data that provide case studies and examples of impacts that were drawn upon for this report.

In addition, the Geospatial Council (GCA) issued a call for case studies of applications from industry and government. Over 167 case studies were assembled. They provided data on the extent of additional adoption and application since 2007-08 that supported ACIL Allen's assessment of the impact of geospatial information. A list of the 167 case studies is provided at Appendix B. Sixty-five of these case studies are listed in this report. Further details of these case studies are provided in the companion document to this report (GCA - ACIL Allen, 2024).

Finally, the GCA launched a survey of industry users seeking data on the extent of productivity impacts. A total of 39 responses to the survey were received. The survey provided additional data for the assessment. A summary of the findings of the survey is provided at Appendix A.

Overall, a balance of evidence was adopted in updating our 2007-08 assessment of the economic, social and environmental impact of geospatial information in Australia.

1.3.1 Evaluation process

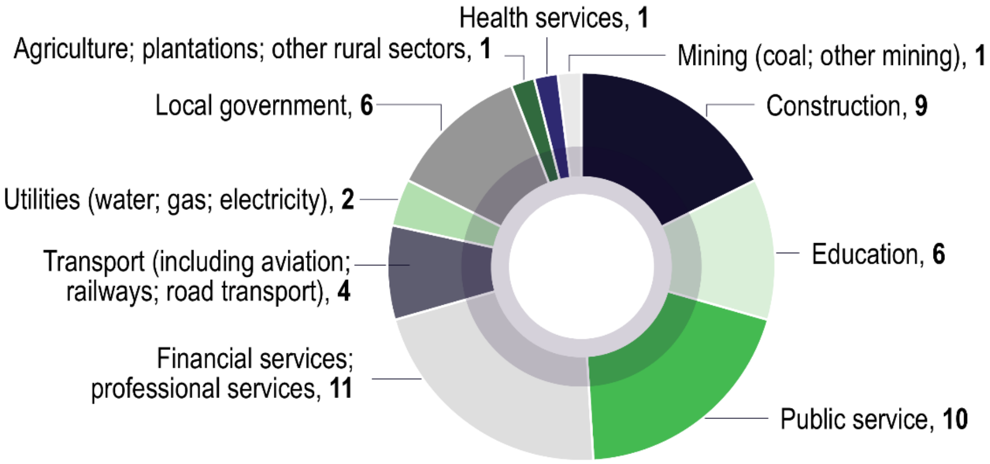
Initial research

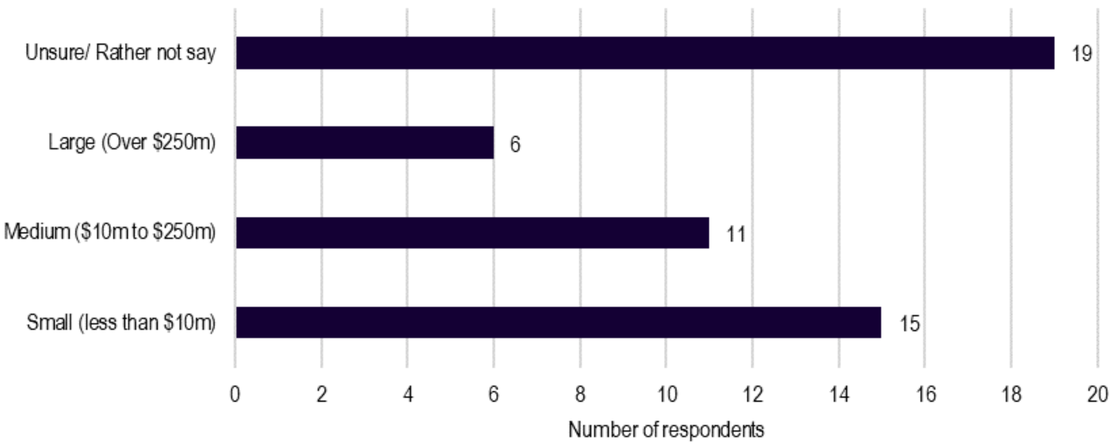
The initial research phase will review relevant reports published globally on estimates of the value and economic contribution of geospatial information. ACIL Allen has undertaken a major literature review of evaluation methodologies and has collated reports and papers from around the word on the value of geospatial information.

An online survey was conducted and promoted by the Geospatial Council of Australia. At total of 51 responses were received. The largest number of responses came from financial and professional services (11), the public sector (14) and construction (9).

Of the total responses, 15 were from smaller organisations with annual turnover of less than $10 million, 11 were from medium sized organisations with annual turnover between $10 million and $250 million and 6 were from large organisations with annual turnover in excess of $250 million. Nineteen respondents did not give a turnover figure.

Figure 1.2 Breakdown of respondents' industry and organisation size





Source: ACIL Allen

Some respondents only completed parts of the survey. The results of those that did respond were analysed and used to support estimates of productivity impacts for this study.

Case studies

Case studies were drawn from existing reports and from a call for case studies issued by GCA. A total of 180 case studies were assembled from those received from government, industry and researchers. Some were stand-alone case studies, while others were included in existing reports.

These case studies provided further evidence of how geospatial information and services were being used by industry, government and society in 2023-24. Many of the reports and case studies were forward-looking and provided insights into future technologies and services that are projected to use geospatial information services in the future.

The full list of case studies is provided in a separate document that accompanies this report.

Assessing the impact of geospatial information.

In this report we are assessing the impact of geospatial information which is measured by the difference in output of the economy with geospatial information compared to a counterfactual scenario without geospatial information. To be practical we focused on modern geospatial information technologies that have been developed since the year 2000. This ignores some technologies that existed prior to the advent of modern geospatial information technology such as traditional surveying and mapping, photogrammetry, unaugmented global satellite positioning systems, older forms of seabed mapping and earlier versions of Earth observations from space.

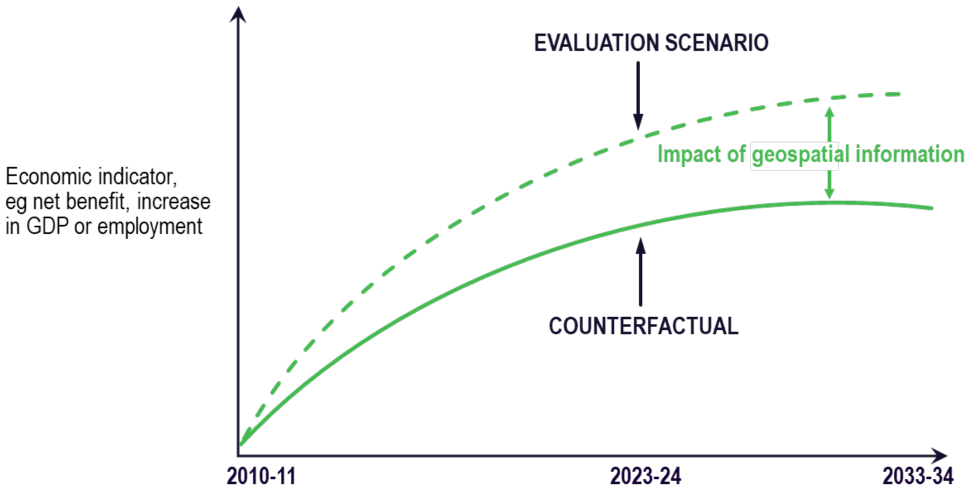
To estimate the impact of geospatial information, 2 scenarios were formulated:

— the accumulated impact of geospatial information as at 2023-24
— the forecast productivity impact by 2033-34 with a high but feasible level of adoption
— the forecast productivity impact by 2033-34 with a lower level of adoption

The assumptions behind these 2 scenarios are set out in Section 4.1 in this report.

The difference between the scenarios being evaluated and the counterfactual scenario represents the economic impact (Figure 1.3).

Figure 1.3 Comparing the evaluation scenario and the counterfactual



Source: ACIL Allen

Productivity impact by sector

Productivity impacts were estimated for 23 sectors of the economy based on Australian and New Zealand Standard Industry Classification 2006 (ANZSIC). These sectors include both the private sector, Commonwealth, State and Local Governments, non-government organisations and research and education institutions.

Data from the research and case studies was used to estimate:

— productivity impacts from applications by sector
— level of adoption of each application by sector.

The productivity impact for each sector is then estimated from the productivity impact of each application and the level of adoption in that sector.

$$Productivity\ impact\ of\ an\ application\ for\ a\ sector$$
$$=$$
$$productivity\ created\ by\ the\ application\ \times\ the\ level\ of\ adoption\ across\ the\ sector$$

The concept of value add

Value add is an important concept in economic impact assessment. For a firm it is the difference between revenue and the cost of inputs:

$$Value\ add = revenue - cost\ of\ inputs$$

From an accounting perspective value add is broadly equivalent to Earnings Before Interest and Taxes (EBIT) plus wages and salaries. Value add is important because it is the main component of Gross Domestic Product which is a well-recognised measure of the total output of an economy.[1]

Economic modelling

To estimate the impact of geospatial information systems 2 scenarios and a counterfactual were formulated for the two scenarios outlined above.:

To be practical we focused on modern geospatial information technologies that have been developed since the year 2000. This ignores some technologies that existed prior to the advent of modern geospatial information technology such as traditional surveying and mapping, photogrammetry, unaugmented global satellite positioning services (GNSS), older forms of seabed mapping and earlier versions of earth observations from space (EOS).

The difference between the scenarios being evaluated and the counterfactual scenario represents the economic impact (Figure 1.3).

[1] Gross Domestic Product = Gross Value Add + taxes -subsidies

Macroeconomic modelling

ACIL Allen used its Computable General Equilibrium (CGE) model of the Australian economy, Tasman Global, to calculate the economic impacts for the 3 scenarios we have analysed. The model draws on the sector productivity impacts discussed above. These productivity impacts produce new outcomes for the economy. The differences between each scenario evaluated and the counterfactual scenario produces the economic and employment impact.

Details of Tasman Global are provided in Appendix C. The model is a global model that is based on the GTAP data base produced by Purdue University. ACIL Allen adapts the model to suit the situation being modelled. The model produced the economic impacts in terms of macroeconomic aggregates as follows:

— Gross Domestic Product (GDP)
— Real Income (RI)
— economic contribution by Sector
— economic contribution by state
— employment.

Consumer benefits

Consumer benefits were estimated from research from existing reports, consultations with selected consumer orientated organisations and ACIL Allen's internal research. We drew on past studies, plus the outputs from the initial research, survey and consultations to provide estimates of benefits to consumers. The main areas of benefit to consumers and society relate to time saved and improved information available to consumers to guide them in online shopping and in the use of ride share and navigation services.

Where the consumer benefits relate to private and personal activities, consumer benefits are additive to the economic impact calculated above. Where they relate to consumers engagement in economic activity, such as travelling to work or working from home, they are likely to be included in the economic impact.

2 What is the geospatial information sector?

Geospatial information is made up of a suite of geocoded data spanning a vast array of location-based technologies. There are few areas of human endeavour or activity that do not use it these days and its use by government, industry and society is growing every day.

This chapter describes the technologies and techniques that make up the geospatial industry from foundation spatial data to advanced applications of remote sensing, position navigation and timing (PNT), geospatial information systems, control systems and artificial intelligence (AI).

It concludes by noting the vast array of geospatial information that is now available for inclusion in Geospatial Information Systems (GIS) that can offer productivity benefits to government and industry, consumer benefits and sustainable environmental outcomes.

2.1 The geospatial sector

The geospatial sector describes the organisations and professionals that acquire, integrate, manage, analyse, map, distribute, and use geographic, temporal, and geospatial information and knowledge. The industry includes consulting knowledge professionals, fundamental and applied researchers, technology developers, educators, and the applications developed and used to address the planning, decision-making, and operational needs of people and organisations of all types. Many of these activities are carried out by members of the wider geospatial information 'sector', which includes numerous government or semi-public agencies, universities, and other not-for-profit institutions, as well as private sector actors.

The geospatial sector is critical to the economy. Few, if any, industry sectors are not using geospatial technologies in their operations. Government is one of the biggest users of geospatial products, supporting critical activities including biosecurity and emergency management; defence; environmental and natural resource management; planning and property development approvals; all forms of primary industry; space, air, sea, and land transport; aspects of the retail sector; finance and insurance; many forms of health, education, and community services; and virtually all aspects of public administration. Geospatial information is at the heart of big data, and it is considered that about 80% of the world's information can be depicted and or analysed spatially.

By knowing where things are, geospatial information enables us to make sense of the world and is a fundamental and important element of everyday life.

There is limited statistical evidence of the size of the geospatial sector.

Given its enabling benefits to most parts of the economy it is perhaps better described as an ecosystem. General estimates come to around $17 billion in terms of value added to the Australian economy of which surveying and mapping comprise around $4.4 billion (IBIS World, 2023) and the remainder comprises Earth Observations from Space, Position Navigation and Timing, geospatial analysis and consumer services.[2]

[2] Personal communication with industry experts.

2.2 The foundations of the geospatial sector

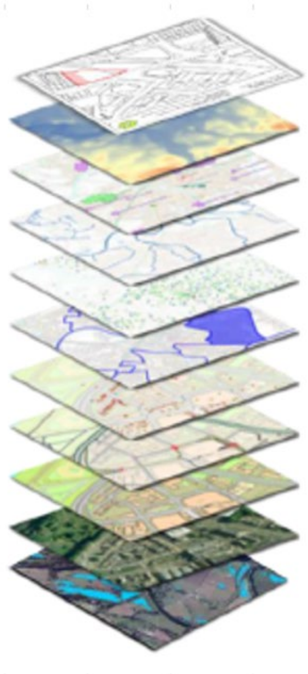
Geodesy, surveying and mapping provide the foundation on which all geospatial data is based. As the world moves to applications that require greater accuracy, these activities become increasingly important.

Geodesy is the science of the size, shape of the Earth, its gravity field, the determination of the exact position of geographical points on the earth (latitude, longitude, and elevation), and how these change over time. It is the foundation on which Australia's spatial data (co-ordinates, property boundaries, elevation etc) are based. It is the platform on which foundation spatial data infrastructure is created.

Geodesy is the framework on which many areas of evidence-based policy development and program delivery are based. It is relied upon every day in the fields of civil engineering, industrial automation, agriculture, mining, construction, financial transactions, intelligent transport systems, disaster response and emergency response and environmental studies.

The Foundation Spatial Data Framework (FSDF) is a change program on Australia's "common asset" of location information. The FSDF is a collaborative exercise between the Commonwealth, State, and Territory Governments, given jurisdictional data is often the foundation of national information, that includes 14 fundamental geospatial data themes. [3] These data themes include administrative boundaries, topography, water, transport and positioning plus a number of other important geospatial data themes.

Figure 2.1 FSDF Themes



Source: https://link.fsdf.org.au/

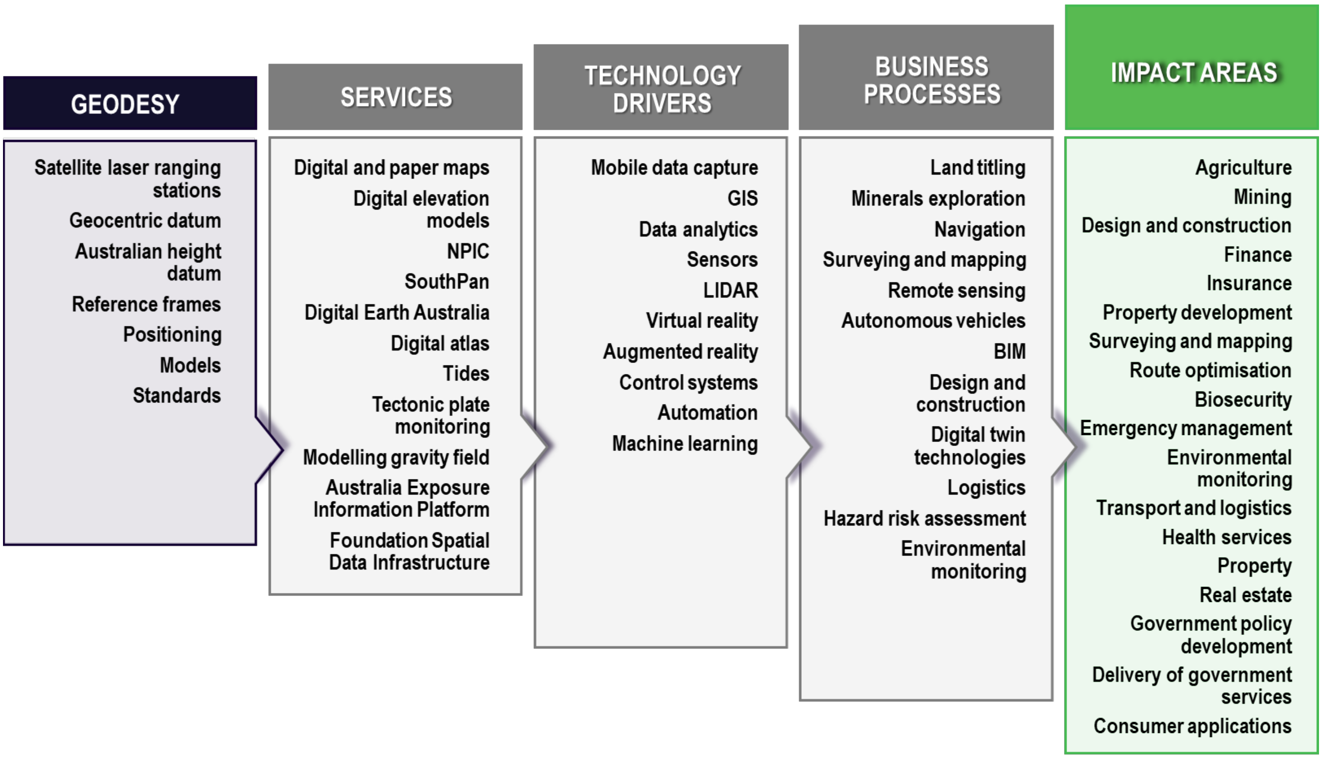
The FSDF data themes group data with similar characteristics in order to improve the efficiency and effectiveness of information management processes. Some data may naturally fit within more than one theme, for example a road is both transport infrastructure and also used to delineate some administrative boundaries. This situation is resolved within the logic of the theme structure.

With the increased use of more accurate Global Navigational Satellite Systems (GNSS), it has been necessary for adjustments to be made to mapping and cadastral data in recognition of the impact of movement in tectonic plates that has seen Australia move 1.8 metres northeast since 1994. This has been overseen by the Intergovernmental Committee on Surveying and Mapping (ICSM).

This foundation data provides the basis for value-added services and impact areas that now support government, industry and society in general. Figure 2.2 provides an illustration of how the foundation of geodesy and foundation spatial data supports technology and services that ultimately enable business processes in almost every area of the Australian economy.

[3] Four of these data sets (buildings and settlements, geology and soils, physical infrastructure and population distribution) are still in the development stage

Figure 2.2 Geodesy and positioning supporting services, technology, and business processes.



Source: GA and ACIL Allen

2.3 Remote sensing technologies

2.3.1 Earth observations from space (EOS)

Earth observations from space provide valuable insights into our planet's health, changes, and interconnected systems. Scientists continue to leverage these observations to address global challenges and enhance our knowledge of Earth's complex systems.

EOS involves capture of the condition of a georeferenced object such as a parcel of land, the extent of land cover, a water resource, the condition of a crop, the temperature of the sea or the extent of human development. It uses sensors mounted on satellites to provide this data. Some data streams are captured in imagery with various degrees of accuracy and spectral bands depending on the sensor, allowing such things as analysis of water quality, soil health and crop yield prediction. Others use radar (synthetic aperture radar or SAR) to penetrate cloud and record physical features, while others use infrared sensors and radiometers to identify heat sources and temperature.

Well known EOS services include Landsat, operated by the US National Aeronautics and Space Administration (NASA) and United States Geological Survey; Sentinel operated by the European Commission, along with satellite services provided by other governments and the private sector.

The availability of data from EOS has increased rapidly over the past 15 years with the emergence of Low Earth Orbit (LEO) satellites that offer lower cost and frequent services with more precise imagery and radar satellites that can provide accuracy to half a metre and less in some circumstances.

Government and industry are active players in EOS. Geoscience Australia (GA) provides EOS services, expert advice and information for decision makers in government and industry. It participates in cooperative arrangements with international bodies and is Australia's principal representative on the intergovernmental Group on Earth Observation (GEO). It also operates ground stations in the Northern Territory and Western Australia to downlink data from Landsat, NOAAA, TERRA, AQUA and some NPP satellites.

GA also collaborates with the National Computational Infrastructure, CSIRO and research organisations such as Frontier SI and SmartSAT CRC for development of the next generation of EOS products.

Digital Earth Australia, a GA program, provides information on areas of high temperature that is used by fire authorities for early warnings of forest fire hotspots.

State and Territory Governments also are involved in coordinating access to EOS data. For example, the Victorian Department of environment, Energy and Climate Change operates a whole of government geospatial data and analytics panel that has allowed procurement of satellite data across Victoria for forest fire management.

There are also private operators that provide important EOS services. Currently the companies operating Earth observation satellites on a commercial basis are all foreign entities. This includes the Canadian company MDA that supports the Radarsat program; US-based Maxar that operates a small constellation of medium-large satellites with the highest available resolution outside of restricted military satellites; Planet, that operates a large constellation of small satellites capturing high resolution imagery; US-based Spire Global that operates small Cubesats capturing atmospheric and ocean information; Blacksky Global that provides both high-resolution imagery offering very rapid acquisition and SAR; and ICEYE, a Finnish company that focuses on SAR technology providing all-weather imaging capabilities.

There are also Australian companies that are engaged in providing EOS (e.g. Nova Systems) and other satellite related services in the IoT market (e.g. Fleet Space Technologies). The recent launch in July 2024 of the Kanyini Mission, led by the South Australian Government and Smartsat CRC with its private sector partners, is a micro satellite on a relatively small budget ($6.5Million) carrying dual IoT and imagery. payloads which will deliver critical space data that will be used for research in the areas of emergency services, the environment, water quality monitoring, mining and bushfire mitigation. It also has the aim of developing local capability in the small-satellite supply chain and pave the way for external investment and future growth in Australia and abroad.

A report prepared by Deloitte Access Economics for Geoscience Australia in 2021 estimated that the value of the economic benefits attributable to EOS were of the order of $2.5 billion in 2020. This was based on benefits generated for weather forecasting, wildlife conservation, agriculture, resource management, natural disaster response, climate science, infrastructure, urban planning and financial services (Deloitte Access Economics, 2021).

2.3.2 Airborne imagery and LIDAR

Airborne imagery involves the capture of high-resolution images of the Earth surface and related features from airborne platforms such as fixed-wing aircraft, helicopters and drones. The sensor technology includes very high-resolution imagery, multispectral and hyperspectral sensors, thermal infrared cameras and laser imaging, detection and ranging (LIDAR).

Digital cameras are used for mapping and land cover classification. Multispectral sensors provide data beyond visible light such as the near infra-red spectrum while hyperspectral sensors deliver finer spectral resolution. Thermal infrared cameras detect heat emissions that can be used to locate fire hot spots or monitor vegetation health.

LIDAR sensors record precise distances and are used to generate very high-resolution 3D digital elevation models (or digital surfaces) used for terrain modelling for applications such as flooding exposure, landform analysis, infrastructure planning and asset maintenance analysis.

Airborne LIDAR can also be used in building 3D digital models of the built environment, currently provided by private companies, for example Aerometrex, Woolpert, Geoscape, Nearmap and others in Australia.

2.3.3 Terrestrial data capture

Imagery and LIDAR, sensors can also be mounted on vehicles or carried manually to record 3D imagery of the built and natural environment as well as the interior and exterior of buildings.

These terrestrial systems are being used for many applications such as analysing maintenance needs for highways and bridges. They provide an efficient way of capturing large amounts of asset condition data. Automated feature extraction and isolating areas for further investigation are improvements being supported by AI.

2.4 Positioning navigation and timing

Global Navigation Satellite Systems (GNSS) are a space-based system of satellites that provide position, navigation and timing services on a global scale. GNSS uses constellations of satellites to transmit signals that can be interpreted by receivers to determine their location anywhere on the planet.

Examples of GNSS services include the US Global Positioning Service (GPS), the European Union's Galileo, China's BeiDou and the Russian Federation's GLONASS constellations.

Most open positioning services are accurate to around 5 to 10 metres. However, there is no guarantee on the reliability or integrity of the position provided. To obtain precise positions, observations from navigation satellite systems must be corrected for a range of errors introduced by the atmosphere and the dynamic nature of the satellites. These corrections are derived from networks of ground-based positioning infrastructure with precisely known coordinates.

There are several approaches to augmenting or correcting GNSS signals. These approaches differ in accuracy, reliability, coverage, time to fix, cost, and delivery mechanism (e.g. satellite, internet). Common techniques are real-time kinematic (RTK), precise point positioning (PPP) and Satellite-Based Augmentation Systems (SBAS).

Several private firms provide augmentation services to users. These include Omnistar, and Aptella's AllDayRTK service in Australia. Some state governments also provide positioning augmentation services.

The Australian Government also provides augmentation services via SouthPAN (Southern Positioning Augmentation Network) under the Positioning Australia Program in Geoscience Australia.

National Positioning Infrastructure Capability (NPIC)

Through the National Positioning Infrastructure Capability (NPIC), Geoscience Australia is unifying the management of Australia's positioning infrastructure. This ensures that consistent, fit-for-purpose positioning data and services are available to government, industry, and academia. GA collects GNSS data streams from selected government and commercially operated reference stations, validates the data streams, and then makes them openly accessible. Positioning service providers integrate these open data streams into value-added services which are sold to users across several market sectors to enable centimetre-level positioning services.

In a report prepared for Geoscience Australia in 2022, ACIL Allen estimated that the NPIC program delivered a net economic benefit of $545 million over 20 years in present value terms. This was an economy- wide estimate based on benefits generated from impacts in the surveying and mapping, construction, mining and agriculture sectors (ACIL Allen, 2022).

Southern Positioning Augmentation Network (SouthPAN)

SouthPAN is a Satellite-Based Augmentation System (SBAS) comprised of reference stations, telecommunications infrastructure, computing centres, signal generators, and satellites that provide improved positioning and navigation services in Australia, New Zealand, and its maritime region. GA is working with Toitū Te Whenua Land Information New Zealand on the deployment of SouthPAN

SouthPAN provides augmented and corrected satellite navigation signals directly from the satellite rather than through a mobile phone. This allows as little as 10-centimetre level accuracy to be available everywhere, overcoming gaps in mobile, internet and radio communications. SouthPAN will be particularly suitable for the aviation sector as it works towards SBAS providing improved integrity and precision for aviation navigation.

In a report prepared for Geoscience Australia in 2021, EY estimated that the present value of benefits from an SBAS service were anticipated to be $7.6 billion over a 30-year period. These benefits were estimated over agriculture, resources, construction, aviation, consumer, maritime, rail, roads, spatial and utilities (EY, 2019).

2.5 Seabed mapping

Seabed mapping is important to Australia’s marine and maritime operations. Seabed mapping involves “collection, collation, compilation, analysis and interpretation of information on (and below) the ocean floor and includes bathymetry, acoustic backscatter, sediment samples, sub-bottom profiles, and sea floor imagery; and extends to derived interpreted products and information, such as maps of seabed geomorphology, hardness and habitat.” (Deloitte Access Economics, 2021).

Currently around 25% of the seafloor within the Australian Exclusive Economic Zone has been mapped to sufficient resolution to inform on its sustainable management and use. Seabed mapping data is used by many industries including commercial fishing and aquaculture, oil and gas operations, search and rescue, defence, shipping and tourism operations.

The Hydroscheme Industry Partnership Program (HIPP), a seabed mapping program, is an example of a fundamental area of government expenditure to support the nation’s priorities in shipping, fisheries, aquaculture, offshore renewable energy, marine tourism and recreational boating. The $1billion program over a decade is expected to obtain full, high quality bathymetric coverage of Australia's Exclusive Economic Zone by 2050.

2.6 Geospatial information systems and services

Geospatial information systems and services are tools used to store, manipulate, analyse and manage geographic data. They play a central role in understanding the geospatial relationships between physical attributes of the natural and built environment to support decision making, policy, planning and resource management.

Geospatial information systems and services comprise data, hardware and software, data-base management systems, applications, analytical tools, and presentation tools to support decision making and analysis by government, industry and society. The power of these services is the ability to layer features such as property boundaries, topography, demographic, economic, and social data within a three-dimensional digital data base. All of the data is geocoded which enables extensive spatial analysis and visualisation of the results of analysis.

Geospatial information systems can be found in many areas. The most common is in the mapping data contained in mobile phones and devices. It is not always recognised by users that the mapping and location data is drawing on most of the above technologies including EOS, remote sensing and positioning data.

Most modern building design is now done with Computer Aided Design (CAD) systems. The emergence of Digital Twins can locate the CAD models in time and space relative to other infrastructure such as property boundaries, transport systems and utilities.

The Foundation Spatial Data Framework is embedded in GIS systems and shared with all users through portals and services provided by governments. As the digital transition proceeds, more data will be held in 3D digital format which is creating more and more options for users to share, analyse and present data for improved productivity and decision making to support policy development across government, industry and society.

2.7 Sensors, control systems, automation, and artificial intelligence

The capability available from integrating geolocated data with control systems creates opportunities for autonomous systems such as autonomous mining and agricultural machinery, autonomous driving systems and other applications that automate activities that previously required continued human intervention.

Autonomous machines are now well established in the mining and agricultural sectors freeing up human resources, improving productivity and providing a safer working environment. Control systems also support remote control of vehicles such as drones and other machinery. The ability to remotely control such systems is useful for capture of data and monitoring of the condition of assets such as roads and bridges and other infrastructure assets.

An emerging development is the application of machine learning and artificial intelligence to geospatial data to sort through the geocoded data and shorten the time for analysis. For example, AI is now being used to analyse geospatial data captured from LIDAR surveys and highlight critical areas for maintenance attention. Such applications are in the early stages of adoption but would seem to have significant potential for productivity improvement.

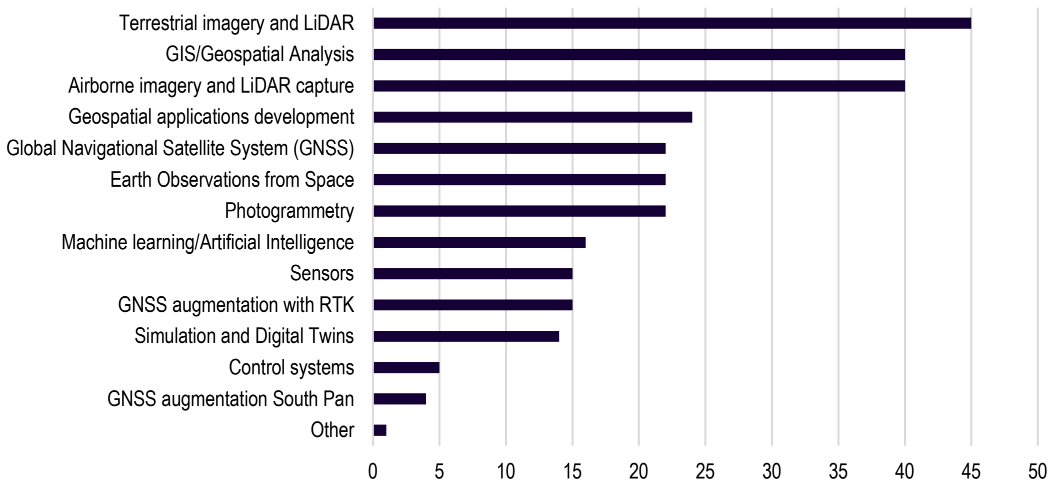
2.8 Use by respondents to the survey

The survey discussed in Section 1.3.1 above included a question on what technologies were used be respondents. While only 51 organisations responded the distribution of technologies shown in Figure 2.3 below provides some insight into the current use of geospatial information services in Australia.

The results show the current dominance of terrestrial imagery and LIDAR, GIS and geospatial analysis airborne imagery and LIDAR, geospatial applications development, GNSS, EOS, photogrammetry and machine learning and AI. It is interesting to note the level of use of machine learning and artificial intelligence.

Other areas, such as application of digital twins and SouthPAN are low because the technologies and applications are only in the early stages of introduction.

Figure 2.3 Geospatial information services reported by respondents to the survey



Source: ACIL Allen

Finding 1

This chapter described the vast array of geospatial solutions that are now available to governments, industry and consumers in support of a wide range of human endeavours from supporting the delivery of government policy and services, providing productivity benefits to industry and delivering consumer benefits. There are few areas of government and industry that are not drawing on geospatial information for service delivery. By far the majority of Australian consumers are using geospatial information every day when they shop, navigate or search for services.

The growth in the availability of accurate geospatial data is growing rapidly and the potential to combine, share and analyse these data is facilitated through GIS and other systems supported by analytical tools and increasingly machine learning and AI to provided better services to government, industry, and society.

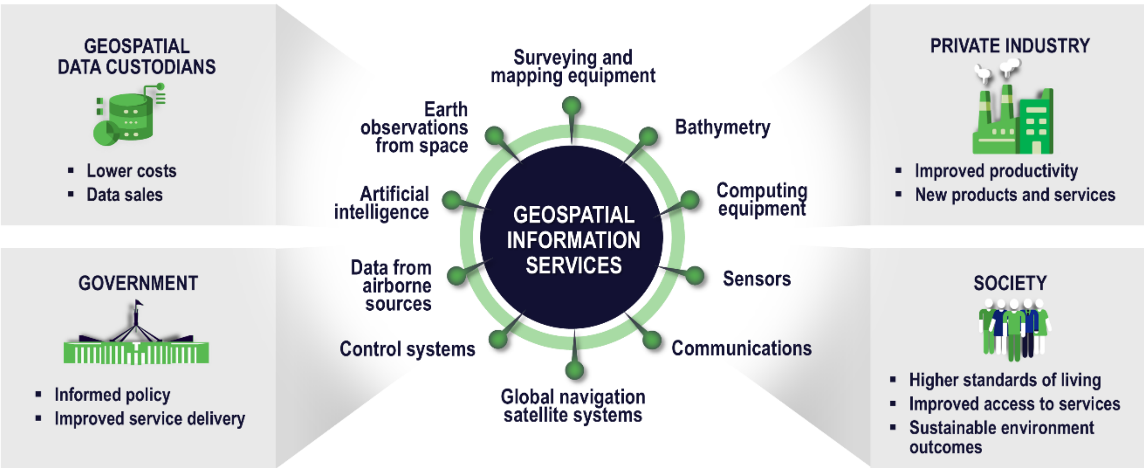
3 What are the benefits of geospatial information and services?

Chapter 3 discusses the benefits that are derived from geospatially supported products and services in government, industry, consumers and society. The estimates of adoption and impact are based on the findings of the survey, and a review of reports released over the past 25 years

3.1 Introduction

With the rapid spread of geospatially supported systems and technologies, there are few areas of government, industry or society that do not depend on geospatial information and services. The economic impact of these services can now be found in almost every sector of the economy and society.

Figure 3.1 Benefits derived from geospatial enabled products and services.



Source: ACIL Allen

3.2 Geospatial information systems in government

The government sector is primarily reflected in the Australian and New Zealand Standard Industrial Classification (ANZSIC) for Public Administration and Safety. This includes policy and program areas in the Commonwealth and State and Territory Governments and local government. There are elements of government activities in other classification areas including Education and Training, Health Care and Social Assistance and Arts and Recreation Services, and Utilities

Government is a significant user of geospatial information. The survey of 16 responders from government indicated that all areas of geospatial information are actively sourced including EOS, GIS, GNSS, RTK, SouthPan, airborne and terrestrial imagery and LIDAR, GIS, machine learning and AI, geospatial analytics and visualisation of spatial digital twins.

The responses indicated levels of adoption ranging from 11% in areas such as in geocoding data, to as high as 50% in areas such as land and property management and mapping. Localised productivity impacts were reported to lie between 11% in areas such as coastal and maritime activities and place-based decision making to 50% in areas such as cadastral, topographic and geodetic data management, data capture and land and resources management and mapping.

The case studies for public administration and safety identified benefits across emergency services, surveying and mapping, environmental monitoring and climate change, coastal zone management, resource identification, biosecurity, maritime activities, demographics, water resource management, geoscience, meteorology, land and property management integrated online planning services, e-planning, asset management and facilities maintenance, smart transport systems, telecommunications and utilities infrastructure, and local government services.

The following paragraphs outline a selection of 36 case studies in public administration and safety. Full details of the case studies are included in the companion document “Detailed Case Studies” issued with this report.

3.2.1 Emergency services

Australia has long experienced the impacts of natural disasters. The total value of claims for building and content losses from other natural hazards in Australia was $5.3 billion in 2021-22, climbing steadily in recent years (Productivity Commission, 2023). When considering both financial and social impacts, the total impact of natural disasters in Australia was estimated to be $38 billion in 2021 (Deloitte Access Economics, 2022)

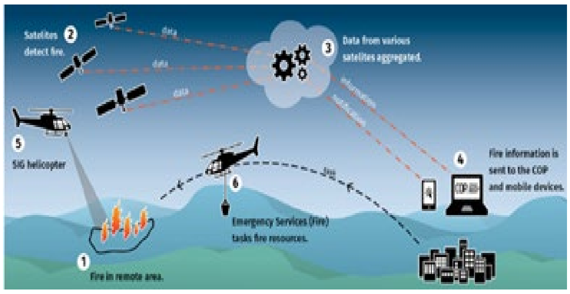
Geospatial information is a fundamental enabling capability that supports response and recovery from natural disaster events. It also supports ongoing mitigation activities by government, the insurance industry and society to reduce the future exposure of the community to natural disaster experiences.

The 4 case studies outline below illustrate the critical importance of geospatial information and services to the preparation response and recovery phases of managing damages and costs. The beneficiaries of these services include governments, businesses, emergency services organisations and policy formulation groups. Ultimately, it is the community that benefits though better management of extreme events and reduced personal and financial costs of natural disaster events.

Digital Earth Hotspots

Digital Earth Australia (DEA) Hotspots is a national bushfire monitoring system that provides timely information about hotspots to emergency service managers and critical infrastructure providers across Australia. Updated with new information every 10 minutes, the mapping system uses satellite sensors to detect areas producing high levels of infrared radiation (called Hotspots) to allow users to identify potential fire locations with a possible risk to communities and property.

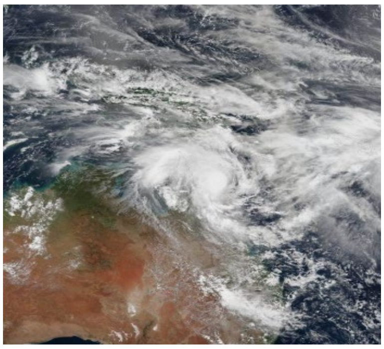
Early warning fire services in Tasmania



The Tasmanian State Emergency Service utilises real-time satellite-based bushfire detection and notification for their Common Operating Platform (COP). The introduction of the early warning system means that new fire starts are detected in near real-time by a growing constellation of satellites. Automated alerts are sent out within minutes, rather than hours (or in some cases days).

Within 10 minutes of receiving the alert, the fire start locations are shown in Land Information System Tasmania's COP. The COP combines these alerts with contextual mapping layers to give the fire agencies, emergency services and police full situational awareness, enabling them to decide where and when to deploy their available resources and equipment and coordinate responses.

Planning for severe weather events



Severe weather events can create significant damage to properties, creating additional insurance costs and, in some cases, threaten lives. A project undertaken by Queensland Fire and Emergency Services in conjunction with the Insurance Council of Australia, Geoscience Australia, the University of Queensland and James Cook University, IAG, Suncorp and Core Logic examined Southeast Queensland's vulnerability to severe winds. The project produced critical information to mitigate damage caused by future winds.

The project will guide retrofit improvements to certain home types to reduce potential damage by severe winds. It includes a determination of regions and house types that would be most cost effective to retrofit. Geospatial information and systems are a critical support for this work.

The National Exposure Information System (NEXIS) and the Australian Exposure Information Platform (AEIP).

Easy access to nationally consistent exposure information gives emergency managers the ability to quickly prepare an exposure report to identify what is potentially at risk

The National Exposure Information System (NEXIS) contains a collection of foundation geospatial and exposure datasets stored, maintained and managed within GA from both openly available and restricted datasets. The key data types include buildings, institutions, infrastructure, businesses, agriculture areas (including value of commodities produced) and places of environmental importance (such as world heritage areas and Ramsar wetlands)).

The Australian Exposure Information Platform (AEIP) is the delivery platform that allows that exposure information to be available to users at all times. AEIP makes it possible for decision makers to perform critical pre-planning or carry out real time assessments of different scenarios to see what is potentially exposed by a hazard event, anywhere across Australia.

Western Australia and New South Wales Emergency Services draw on NEXIS.

The benefits delivered by NEXIS and AIEP are estimated to be around $30 million per year with a net present value of around $300 million calculated over 15 years at a discount rate of 7%.

Full list of case studies relevant to emergency services

The full list of 9 case studies supporting this report, including the above 4 case studies, are summarised in Table 3.1.

Table 3.1 Emergency services

	Case study + [beneficiaries]	Description	Impacts
1	National Exposure Information System (NEXIS) and the Australian Exposure Information Platform (AIEP) [Emergency Services Organisations]	NEXIS contains a collection of exposure datasets stored, maintained and managed within Geoscience Australia from a variety of both openly available and restricted datasets used to create nationally consistent exposure information.	The benefits delivered by NEXIS and AIEP are estimated to be around $30 million per year with a net present value of around $300 million calculated over 15 years at a discount rate of 7%.
2	Satellite imagery to manage control burn operations. [Emergency services organisations, society and businesses.]	Digital Twin Victoria provides satellite imagery to support planning, execution and evaluation of planned burns through the procurement of satellite data across Victoria.	DTV's Satellite Tasking Service opens up a range of satellites to procure data from a data delivery timeframe of between 2-12 hours making it a service for emergency management when natural disasters occur.
3	National Joint Common Operating Picture (NJCOP) [Emergency services, businesses and the community exposed to natural disasters]	The NJCOP overlays key infrastructure with information such as road closures, the location of landmark buildings, as well as documenting biosecurity alerts and relevant space events.	The NCOP System is used by the National Emergency Management Agency to rapidly obtain an overview of an emergency situation to inform the deployment of Commonwealth Government support and assets.
4	NSW Emergency Coordination Unit [Emergency services, government, individuals and businesses impacted by disasters]	The EICU ensures the emergency management sector has the best intelligence and spatial data available to deal with emergencies, such as terrorism, natural disasters, and major events.	The EICU delivers a $97.2m benefit to NSW Government in data processing overhead. This number would be significantly higher if software and hardware fees, licensing, and other ICT costs that have been streamlined were included.
5	Digital Earth Australia (DEA) Hotspots [Emergency Services and first responders]	Using rapid access to international satellite data streams Geoscience Australia provides a visualised information frame to help emergency services and responders understand and analyse the risks.	It has been estimated that earth observation data delivers benefits in terms of avoided costs of bushfires of $16.5 million per year.
6	Common Operating Platform for early warning of fires in Tasmania [Emergency services, first responders, industries and communities]	The Tasmanian Emergency Service Organisations use a Common Operating Platform (COP) that provides emergency services organisations with a single authoritative mapped view of shared information for use in emergency planning and response activities.	The COP includes real-time satellite-based bushfire detection and notification data and real time geospatial data feeds from a Specialist Intelligence Gathering (SIG) helicopter. The 2018-19 bushfire season cost $60 million to bring under control and incurred at least $100 million in insured losses.

	Case study + [beneficiaries]	Description	Impacts
7	Foundation spatial data supporting the recovery phase in NSW [Emergency services, government support programs, communities affected by natural disaster events]	In the summer of 2019-20 around 50,000 square km of bushfire affected areas across NSW were captured by Spatial services to update the FSDF imagery. The data provided information for emergency services mapping tools to locate affected customers and infrastructure.	This application ensures that the social cost to affected communities is minimised. It ensures that damage assessments are well informed and emergency management mapping tools are updated.
8	Geocoded National Address File (GNAF) use in emergencies [Emergency Services, businesses, government responders and government assistance programs]	GNAF was used in the 2019-20 Black Summer Bush Fires to provide address data with other geospatial data to identify businesses that were most significantly impacted by the fires. GNAF is also used by Australian Bureau of Statistics, Australia Post, Australian Electoral Commission, banks, insurance companies and property industry.	A calculation by Lateral Economics (2022) of net benefits estimates that the G-NAF has a current value of $1.36 billion in NPV terms, and $1.64 billion in NPV terms in a scenario in which G-NAF provides improved offerings.
9	Assessment of severe wind hazard in South-East Queensland [Policy makers, researchers and people who live in high wind risk areas of Southeast Queensland.]	The project modelled different scenarios to provide insight into which residential homes would best be suited to retrofit improvements.	The project identified retrofit improvements to certain home types that would reduce the potential damage in severe winds and identified regions and house types that would be most cost effective to retrofit.

Source: Case Study Document accompanying this report

Note: The sources of benefit estimates are provided in the Case Study Document accompanying this report.

3.2.2 Climate change

As scientific understanding of climate change increases, there is recognition of its complexity and urgency. The impacts of climate change are becoming more evident and severe, affecting communities, economies, and ecosystems worldwide.

The potential economic damages from climate change to Australia at current global emission levels are quantified as $584.5 billion in 2030, $762 billion in 2050 and more than $5 trillion in cumulative damages from now until 2100 (Kompas, 2019).

Geospatial information can play a key role in providing vital information in the response to climate change and environmental protection. Geospatial information enables a greater understanding of the temporal and spatial dimensions of climate change and the environment. It's crucial in understanding the dynamic nature of environmental shifts.

The following 4 case studies illustrate the benefits and beneficiaries of the use of geospatial information services.

National Greenhouse Reporting Scheme

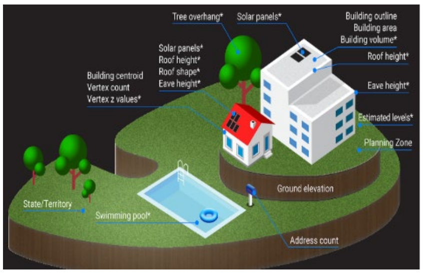
The National Greenhouse and Energy Reporting (NGER) Scheme is a unified national framework for reporting company information relating to greenhouse gas emissions, energy production and energy consumption. The greenhouse gas emissions data reported by the NGER Scheme serve as important inputs to the preparation of the National Greenhouse Accounts used by government in policy formulation and program management for climate change issues.

Climate change adaptation project

The Victorian Department of Planning is developing an evidence-based critical asset adaptation planning approach to enable the assessment of climate change adaptation risks at metropolitan train and tram locations and critical assets.

This project will enable better asset risk assessment and enhance the resilience of the transport system by addressing climate risks. Ultimately the beneficiaries will be commuters on metropolitan train transport in Melbourne.

Leveraging building intelligence for a net-zero future



The journey to global net-zero carbon emissions requires structured and reliable data to support planning for the transition to net zero emissions. Improving the energy efficiency of buildings is part of this journey, as it leads to lower energy costs, improved health for occupants, and reduced carbon emissions. Combining data on energy use, building design, construction materials, building conditions and location is important to accurately measure emissions from commercial buildings.

The Department of Climate Change, Energy, the Environment and Water undertook an update of the commercial Building Baseline Study in 2022 to report on energy consumption and greenhouse gas emissions in commercial buildings. This work was supported by a geospatial management system "Geoscape Buildings" that comprises over 16 million buildings derived from satellite and aerial imagery and continually updated. Geoscape Buildings is a critically important data source supporting ongoing research and analysis for planners, policy makers and the property industry in the coming years.

Coastline monitoring

Understanding the impact of climate change necessitates knowledge of coastal dynamics and rising sea levels. Digital Earth Australia (DEA) Coastlines integrates satellite data with tidal modelling to chart the evolving contours of Australia's coastline since 1988. The resulting annual shoreline plots and detailed rates of change illustrate the dynamic processes at play: beaches expanding, sandspits shifting, river mouths altering, and tidal flats transforming over time.

The City of Gold Coast Council and Griffith University used DEA Coastlines tools and notebooks on the DEA Sandbox to quantify and describe the effects of coastal management actions at South Stradbroke Island. In 1986, the migrating and dynamic entrance to the Nerang River was stabilised with training walls and an artificial sand-bypassing system was established to maintain the natural flow of sand to South Stradbroke Island.

DEA Coastlines information empowers scientists, managers, and policymakers to assess the impacts of various drivers affecting our coastlines and aids in planning and forecasting future scenarios.

Full list of case studies relevant to climate change

A full list of 11 case studies relevant to climate change, including the above 4 case studies, is provided in Table 3.2 below.

Table 3.2 Climate change and the environment

	Case study + [beneficiaries]	Description	Impacts
10	National Greenhouse Energy Reporting Scheme [Policy formulation, governments, industry, the community]	The National Greenhouse and Energy Reporting (NGER) Scheme is a unified national framework for reporting company information relating to greenhouse gas emissions, energy production and energy consumption. Geospatial information is crucial to the NGER Scheme as it enables mapping of emission sources, monitoring and compliance, risk assessment and response, as well as tracking spatial trends and patterns.	The NGER scheme allows for a unified approach to emission and energy use reporting, reducing the costs and complications of accurate reporting. Geospatial systems and analysis support mapping and reporting for policy makers and program managers.
11	Monitoring commercial buildings with the support of Geoscape [Policy makers, planners, building owners and society in general]	The Department of Climate Change, Energy, the Environment and Water undertook an update of the commercial Building Baseline Study in 2022 to report on energy consumption and greenhouse gas emissions in commercial buildings. Geoscape Buildings provides statistics on the built environment of Australia at any level of aggregation, from a single address to the whole nation.	The transition to net zero by 2050 will require authoritative information on energy use and emissions from buildings. Geoscape is a critically important data source supporting ongoing research and analysis for planners, policy makers and the property industry in the coming years.
12	Digital Earth Coastlines [Gold Coast City Council, coastal planners and policy makers, residents of coastal areas, coastal environment]	The City of Gold Coast Council and Griffith University used DEA Coastlines tools and notebooks on the DEA Sandbox to quantify and describe the effects of coastal management actions at South Stradbroke Island.	The study highlights how DEA Coastlines can be used to inform future coastal management interventions planned for the region in 2023 and beyond. It shows how coastal engineering, artificial walls and sand-bypassing can have the desired effect of stabilising coastal land against erosion while maintaining natural water flows.
13	Coastal climate change impact assessment [Coastal planners and coastal communities]	Geospatial analysis was undertaken of erosion variability of the Victorian Coastline for the Victorian Government to create impact profiles for key assets potentially vulnerable to coastal inundation resulting from climate change	This work provided insight into the coastal areas and assets in Victoria that are at risk from climate change. These results aim to bolster the planning and execution of adaptation and mitigation efforts, create specific monitoring initiatives, and pinpoint areas for comprehensive local coastal hazard assessments.

	Case study + [beneficiaries]	Description	Impacts
14	Climate risk map [Australian homeowners, local government, policy makers]	This is a user-friendly web service which enables the general public to determine the risk of fires, floods and extreme winds in their suburb, local government area or electorate. The service is sponsored by the Climate Council.	The Climate Risk Map assists Australian homeowners and the residential building industry to understand, and plan for the likely effects of climate change, particularly as these factors impact home insurability.
15	Climate change adaptation project [Victorian commuters, metropolitan rail operators]	The Victorian Digital Twin project is assisting the Victorian Department of Transport and Planning to detail current and projected climate impacts at specific high-risk metropolitan rail public transport in 20 locations and their effects on critical asset performance.	The current and projected climate impacts on rail will enable better asset risk assessment and enhance the resilience of public transport in Victoria.
16	Monitoring mangrove location change in the face of storm events and climate change. [Government environmental policy makers]	The Digital Earth Australia (DEA) program used a newly developed satellite data classification technique to create a series of maps that show how mangrove locations have changed over time in response to storm events and a changing climate.	These maps inform mangrove management for entities such as the Queensland Department of Environment and Science.
17	eReef forecasting and modelling program [Great Barrier Reef Marine Park Authority, reef researchers, natural resource managers]	eReef is the world's largest reef forecasting and modelling program that was developed by CSIRO in partnership with the Great Barrier Reef Foundation, the Australian Institute of Marine Science, the Bureau of Meteorology and the Queensland Government.	eReef provides near real-time information and innovative tools, while promoting sustainable practices and informed decision-making. In 2017, ACIL Allen estimated that the value of spatially enabled monitoring programs could be of the order of $150 million to $200 million to the communities that live contiguous to the reef.
18	Machine learned data to augment geospatial analysis of fire threats [Government environmental agencies, rural fire management]	Land Use Victoria's Data Science team has developed a repeatable Geo-AI approach using high-resolution aerial imagery to accurately locate silage production sites, identify individual waste tyres and detect large tyre storages. This program utilised machine learning and satellite imagery to identify more than one million tyres across Victorian agricultural land, demonstrating the efficiency of the method for government and regulatory agencies. The data has been shared with other government agencies to inform environmental compliance activities and emergency services for bushfire activities.	This program accurately locates silage production sites, identifies individual waste tires, and detects large tire storages across Victorian agricultural land. This approach not only enhances efficiency for government and regulators but also contributes to mitigating environmental risks associated with improper waste tire storage and fire hazards.
19	Shared Environmental Analytics Facility (SEAF)	The Western Australian Biodiversity Science Institute (WABSI) and the Western Australian Marine Science Institution (WAMSI), alongside other partners, are leading efforts to establish a Shared Environmental Analytics Facility (SEAF) in Western Australia. A five-year pilot program has been proposed in Western Australia. The SEAF would be underpinned by a single central geospatially enabled hub and initially feature 2 regional spokes, one in the Pilbara and another in Cockburn Sound.	The Pilbara regional spoke is expected to deliver $1.4 billion NPV in quantified direct regional benefits over 10 years. The Cockburn Sound regional spoke is expected to deliver $227 million NPV in quantified direct regional benefits over 10 years. These benefits arise from enhanced data, efficiencies for proponents and operators, reduced risks and a holistic view of the environment.

	Case study + [beneficiaries]	Description	Impacts
20	Open-Source Geospatial Foundation (OsGeo) [Policy makers, communities in Pacific Island States]	GeoServer' is an OSGeo project which disseminates critical data related to natural resources, climate patterns, and environmental changes. This data benefits environmental awareness, decision-making, and disaster response efforts in Australia and abroad.	The birth of OSGeo reflects the maturity of various open-source communities, recognising the need to synergise geospatial software development for enhanced interoperability. Simultaneously, the evolving internet landscape introduced new requirements and expanded the role of geospatial data and applications beyond their niche status.

Source: Case Study Document accompanying this report

3.2.3 Planning, development and government services

Australia faces challenges over the next decade to provide housing, buildings and infrastructure for a growing population.

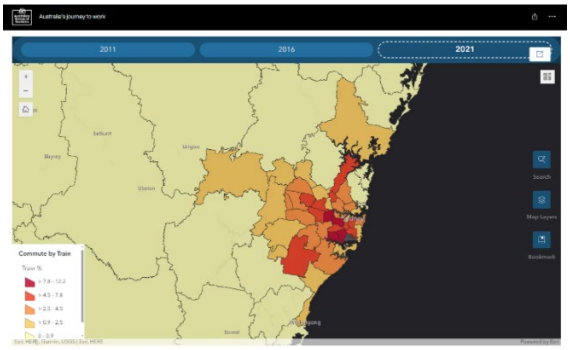
The property market and infrastructure underpin the financial welfare of many Australians. Housing affordability, energy and transport infrastructure are priority issues, presenting challenges for government policy over the next decade.

Geospatial information services have a major contribution to improving productivity in the construction and infrastructure value chain. This includes planning and design, development approvals and compliance, construction activities and asset management.

The following 6 case studies illustrate the importance and value of geospatial information systems for government.

Australian Census

Sound public policy depends on reliable data on the nation's population to inform decision makers at all levels for policy analysis, planning of public services and resource allocation. ABS's census findings inform all areas of Australian society, government policy, funding allocation, and planning for public services, ensuring that resources are directed where they are needed most, and that communities' needs are accurately represented.



A key component of the Census is the categorisation and collection of data according to the Australian Statistical Geography Standard (ASGS), which is the classification of Australian geography into areas by population size, urban centres and localities, remoteness and more (ABS, Jul2021-Jun2026). The ASGS is a social geography, developed by the ABS every 5 years to reflect the location of people and communities. It is used for the publication and analysis of Australia's official statistics and a wide range of other data.

ABS Census data are released in geospatially native formats on the geographic boundaries defined through the Australian Statistical Geography Standard, allowing governments and communities to interact with statistics from the neighbourhood to the national level. It was estimated that the Census generated $6 for every $1 spent on its activities (Lateral Economics, 2019). The report, Valuing the Australian Census, concludes that Census data plays a critical role in improving Australia's economic and social infrastructure.

Digital Atlas

In May 2024, Geoscience Australia launched the Digital Atlas of Australia, the Australian Government's new geospatial platform. The Digital Atlas is transforming how we access and use data by providing hundreds of curated national datasets in a central platform.

Using location as the connecting thread, the Digital Atlas brings together data on Australia's geography, people, economy and the environment from trusted sources across government and increasingly industry and academia.

Powered by a digital ecosystem, the Digital Atlas seamlessly connects data across borders, systems and technology. It is moving us away from data silos, enabling seamless integration, sharing, and analysis of location data to foster collaboration, efficiency and innovation across government, businesses and communities.

An example of this collaboration is the partnership between Geoscience Australia, the Australian Bureau of Statistics and the Department of Social Services that is improving the availability, transparency and use of place-based socio-economic data. This partnership has made income support recipient data available in the Digital Atlas, integrating it with demographic and socio-economic information in interactive applications. The applications allow users to explore patterns of income support at a local level, providing policymakers and stakeholders with the necessary insights to inform tailored policy interventions.

By bringing together hundreds of curated, trusted national datasets in a single location, the Digital Atlas is enabling users to explore, analyse and visualise data on Australia's geography, people, economy and the environment by location.

Improving planning processes for government and the public

This example shows how development of a single geospatially enabled digital data system is being used to improve the efficiency and effectiveness of planning processes in South Australia and enabled better engagement between the public and planners in the process.

PlanSA is South Australia's online planning and development system, administered by the South Australian Department for Trade and Investment. The digitalisation of PlanSA involved the transfer of countless processes and information systems into a single, 100% digital system, enabled by geospatial technology.

The planning portal provides the opportunity for South Australians to shape their community and have a say on development applications occurring in their local government area. The platform utilises geospatially enabled tools for developers and the public to monitor developments and define zoning boundaries and conditions more effectively, allowing for timelier, evidence-based decision making.

The Geocoded National Address File (GNAF)

Authoritative address data is vital to governments, the private sector including the insurance industry and activities such as responding to natural disaster events, locating properties for rating and insurance purposes, electoral services and delivery services. The publishing of the Geocoded National Address file is a cooperative program between all levels of government.

GNAF provides an authoritative and nationally consistent record of Australian addresses and location data to support government, business and the community. It is constructed utilising data sourced from local governments, state, and territory government land administration agencies, as well as the Australian Electoral Commission (AEC), and other confidential commercial providers.

GNAF is managed by Geoscape. which is the trading name of PSMA Australia Limited, a public company owned by Australia's governments.

A calculation by Lateral Economics (2022) of net benefits estimates that GNAF has a current value of $1.4 billion in NPV terms. There are numerous social benefits such as improved trust in the integrity and fairness of the system as well as the reduction of effort needed to build national address files (Lateral Economics, 2022).

Digital twin developments

The emergence of spatial digital twin models is opening up options for applications in many areas of government services. The following examples demonstrate how spatial digital twin models are supporting improved asset management in schools in NSW and how the Western Australia Government is proceeding with the development of the WA digital twin and its benefits.

NSW spatial digital twin for managing school infrastructure

School Infrastructure NSW (SINSW) is responsible for management and delivery of infrastructure for 2,200 schools in NSW. SINSW develops around 80 business cases each year for construction and maintenance of school infrastructure. Combined with other technologies, the Live NSW Spatial Digital Twin (SDT) program will support the digitisation and automation of the business case process.

SINSW estimates that this will lead to a 45% reduction in time to deliver a strategic business case. Estimated savings are $202 million over 10 years in avoided business case costs.

Western Australian Advanced Spatial Digital Twin

Western Australia is investing in an Advanced Spatial Digital Twin (ASDT) branded as Spatial WA, with the objectives of improving the State Government's ability to "plan, design, test, and collaborate using a highly accurate virtual environment. The ASDT, which will be delivered alongside a Next Generation Spatial Cadastre (NGSC), will reduce information silos by serving as a centralised location for datasets and create new spaces for secure collaboration.

Planners, developers, surveyors, the construction and utilities sectors and communities in Western Australia, as well as Emergency Services will also benefit.

Full list of case studies relevant to planning, development and government services

A full list of 15 case studies relevant to planning, development and government services, including the above 6 case studies, is provided in Table 3.3 below.

Table 3.3 Planning and development

	Case study and users	Description	Impacts
21	Australian Census [Governments, industry, researchers, society]	The Australia Bureau of Statistics census informs government policy, funding allocation, and planning for public services, ensuring that resources are directed where they are needed most, and that communities' needs are accurately represented. A key component of the census is the categorisation and collection of data according to the Australian Statistical Geography Standard (ASGS), which is the classification of Australian geography into areas by population size, urban centres and localities, remoteness and more.	ABS Census data are released in geospatially native formats on the geographic boundaries defined through the Australian Statistical Geography Standard, allowing governments and communities to interact with statistics from the neighborhood to the national level. It was estimated that the Census generated $6 for every $1 spent on its activities (Lateral Economics, 2019). The report, Valuing the Australian Census, concludes that Census data plays a critical role in improving Australia's economic and social infrastructure.
22	The Australian Census and its use of the Geocoded National Address File (GNAF) [Governments, industry, researchers, society]	The ABS required an address autocomplete service to be integrated into several Census self-service transactions. Geoscape employed its predictive Application Program Interface (API) to assist with the autocompletion of the address field in the online form. This ensured the address data sorted in the system was structured and verified against official sources using Geoscape's Geocoded National Address File (GNAF).	The online self-service, supported by the Address API from Geoscape, contributed to a significant reduction in load on the Census Contact Centre and call wait times, delivering a much smoother experience for the public.
23	Digital Atlas of Australia [Governments, industry, researchers, society]	The Digital Atlas of Australia brings together trusted national data with easy access for anyone to explore, analyse, and visualise data on Australia's geography, people, economy and environment.	The Digital Atlas of Australia brings together trusted national data with easy access for anyone to explore, analyse, and visualise data on Australia's geography, people, economy and environment.

	Case study and users	Description	Impacts
24	Foundation Spatial Data Framework in NSW [Governments, industry, property owners, developers]	The FSDF is the source of authoritative data on which governments, industry and society depend for the conduct of government and private business, property transactions and management and almost any activity that society undertakes. It is a strategic national asset that delivers significant value to people, organisations, and the wider Australian society.	The cadastral and land registration systems allow people, businesses, and governments to leverage and manage property assets. At the national level the authoritative and consistent data provided by the cadastre creates confidence and improved decision making for land management and development. At the state and territory level it increases productivity by reducing transaction costs and eliminating duplication across the land and utility sectors.
25	Victoria 's Digital Cadastre Modernisation (DCM) and Digital Transformation Program [Utility, construction and asset managers, property and land developers]	Victoria's DCM program is modernizing the Victorian cadastre. in 4 stages: digitalisation; adjustment; integration; and automation. The project employed industry-leading software in survey adjustment in conjunction with a highly capable team to adjust 4.2 million land parcels over 3 years.	This work benefited property and land development, and also assisted in the utility, construction infrastructure and asset management sectors. There were also many social and economic benefits such as better and more integrated planning of land use and better foundations for 3D and 4D geospatial usages. The value of such actions if applied across Australia is estimated to be around $2 to 3 billion per year.
26	The Geocoded National Address File (G-NAF) [Land and property owners, businesses, government, general public]	G-NAF is a solution that helps open access to address data. It is constructed utilising data sourced from local governments, state, and territory government land administration agencies, as well as the Australian Electoral Commission (AEC), and other confidential commercial providers.	A calculation by Lateral Economics (2022) of net benefits estimates that the G-NAF has a current value of $1.4 billion in NPV terms. There are numerous social benefits such as improved trust in the integrity and fairness of the system as well as the reduction of effort needed to build national address files.
27	Implementing the Addressing strategy 2035 [Land and property owners, businesses, government, general public]	The Intergovernmental Committee on Surveying and Mapping (ICSM) is responsible for the assignment, storage and exchange of addresses from a local to federal level across Australia and New Zealand. It is creating the Addressing 2035 Strategy to create a single point of reference for All Australian and New Zealand locations and addresses.	The benefits from the ICSM project are associated with administrative savings that come from improved address data. The Addressing 2035 Strategy will ensure that the value of GNAF will continue, and the effectiveness and efficiency of its operations are improved through a streamlined data flow and more logistical efficiency within government and society at large.
28	NSW Point [General public, government]	The team at Geoscape created an address tool called 'NSW Point' for the NSW state government and its agencies to use. It solves the challenge of inconsistent address data by allowing its users to find an accurate physical or mailing address in an online form. A critical part of this tool is the Geoscape, Predictive API and Addresses API.	The benefits of work by NSW Spatial Services in developing NSW Point have been more efficient access to government processes and reductions in cost and effort associated with web applications that rely on address data.

	Case study and users	Description	Impacts
29	Plan South Australia [General public, property owners and developers, government]	PlanSA is South Australia's online planning and development system, administered by South Australian Department for Trade and Investment. The digitalisation of PlanSA involved the transfer of countless processes and information systems into a single, 100% digital system, enabled by geospatial technology. The single, digital approach taken has allowed South Australia to become the first state to operate "a single, comprehensive planning scheme".	PlanSA has utilised geospatial information in the creation of a unified development and land use 'one-stop shop' platform. The platform utilises geospatially enabled tools for developers and the public to monitor developments and define zoning boundaries and conditions more effectively, allowing for timelier, evidence-based decision making.
30	Great Ocean Road Survey [Government, emergency services, policy makers, asset managers]	In October 2020, the Department of Land, Water, and Planning employed cutting-edge mobile laser scanning technology (LIDAR), to conduct a comprehensive survey along the entirety of the road. The survey aided the ongoing efforts by government to adapt the land management system to innovative technologies that deliver major productivity gains.	The survey creates positioning technology-based mapping that benefits fire prevention, biodiversity conservation, road management, planning and development, urban development and research and community engagement.
31	Transport for NSW - Smart places accelerator program – envisioning in 3D [Council staff, developers and the community]	The NSW Department of Customer Service is developing a 3D model of three town centres across Camden Council in South West Sydney, after a successful 3D model pilot program of a town within the council.	The key benefits include improved collaborative planning, reduced holding costs for business, reduced transaction time, improved visual impact and shadow impact assessment, data driven planning, risk minimisation and cost optimisation.
32	Western Australia Digital Twin Program [Government administration and services, developers and the community]	In early 2024 the Government announced a 10-year program, Spatial WA, to deliver a Next Generation Spatial Cadastre (NGSC) and Advanced Spatial Digital Twin (ASDT). The objectives of the program are to improve the Government's ability to "plan, design, test, and collaborate using a highly accurate virtual environment".	The Spatial WA program is illustrative of the potential benefits for government, developers and the community for improvements in delivery of government services and for planning and development and coordination of infrastructure.
33	Bathurst integrated health project [Local residents, councils and developers]	The NSW Department of Customer Service has developed a digital twin for Bathurst. This model fits within a larger spatial digital twin of Bathurst, which includes various points of data of interest to the community, such as public transit information, accessibility information such as disabled parking spaces, fuel and housing prices, leisure activities, and EV charging facilities.	This case study demonstrates the power of Spatial Digital Twin Models as a tool for consultation with the community on major developments in metropolitan and regional areas where community consultation is a critical part of the planning and development process.
34	NSW School Infrastructure [Governments, schools, educators and students]	Combined with other technologies, the Live NSW Spatial Digital Twin (SDT) created a standardised approach to due diligence which was piloted with NSW School Infrastructure on 473 sites in just 4 weeks.	SINSW estimates savings of $202 million over 10 years, in avoided strategic business case costs. This benefit will be generated by the SDT and realised by SINSW. From the pilot alone, the productivity benefits and avoided costs are an estimated $4.4 million.

	Case study and users	Description	Impacts
35	Hobart City Council Digital Twin [Local residents and businesses, tourists and government]	The City of Hobart is developing a Digital Twin, which is a virtual representation of the city that integrates a range of data sources. The Digital Twin will give government, industry, and the public a more integrated and insightful understanding of the current and planned environment.	Economic benefits of the Digital Twin are estimated to be several hundred million dollars over the next decade. These benefits arise from the efficiencies and economic development enabled by the Digital Twin.

Source: Case Study Document accompanying this report

Note: The sources of benefit estimates are provided in the Case Study Document accompanying this report.

3.2.4 Defence

Australia's geospatial sector is in the midst of rapid technological change, increasing the utility of geospatial intelligence (GEOINT) as a critical enabler for Australian Defence Force (ADF) operations. The Government's 2024 National Defence Strategy directs the ADF to shift to an integrated, focused force designed to address the nation's most significant strategic risks. The strategy requires this force to be more capable of the impactful projection of military power.

GEOINT and geospatial data underpins every ADF capability. It is essential to ADF planning, exercises and operations. Additionally commercial imagery and data support situational awareness, international partnerships, disaster response and Defence estate management. The Australian Geospatial-Intelligence Organisation (AGO), as the Defence GEOINT lead, has been partnering with Australian and international geospatial sector members for many years to enable Defence and national security efforts.

Recognising the nexus between a maturing Australian commercial geospatial sector and increasing ADF requirements for timely GEOINT and data, AGO is increasing its engagement with imagery, data and service providers to identify partnership opportunities as a capability multiplier.

More information is available at Defence Intelligence Group | About | Defence or questions can be directed to AGO's Industry Engagement Team at ago.industryengagement@resources.defence.gov.au.

Defence Estate as the nation's largest landholder draws on geospatial information services to manage its various construction sites and projects.

An example of an application in the Defence estate portfolio is provided in Table 3.4 below.

Table 3.4 Defence estate

	Case study	Description	Impacts
36	Defence Estate [Government, Department of Defence]	OpenSpace utilises a portable camera which can be used by a project manager to capture photos of a construction site. Images are automatically stitched together and overlaid upon the plan, creating a 3D environment that users can virtually walk through.	The use of virtual walkthroughs is 20 times faster and more complete than manual solutions and has been proved to save on travel time, cost and generate carbon emission savings as a result.

Overall assessment for government

Taking the survey and the case studies into account, plus consultations with industry experts and users, ACIL Allen has drawn up an estimate of the levels of adoption across sectors of activity in the public administration and safety sector. This is summarised in Table 3.5 Use of geospatial information in public administration and safety

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Geological survey	Geoscience Mapping Minerals and energy resources exploration	High in all cases	Level of adoption will remain high and increase in some areas as technologies advance.
Surveying and mapping	Foundation spatial data Property boundaries and cadastre Remote sensing Position, navigation and timing Topography Digital elevation models	High in all cases	High levels of adoption expected to continue as demand for georeferenced digital data increase.
Planning and development	Planning Development approvals and compliance	Low to medium in planning. Medium in development activities.	Geospatial information services are expected to continue to grow with progress in planning, compliance and development approvals. Adoption could increase to 75% in some areas.
Property services	Land administration Land valuation	Low to medium%	Adoption expected to increase to as high as 80% as digitisation of land development and land administration continues.
Spatial digital twin	3D and 4D digital models of the built and natural environment	High	Adoption will continue at 100% as the use of spatial digital twins grows.
Meteorology	Atmospheric monitoring Monitoring the marine environment Weather forecasting and warnings	Medium to high with adoption rates between 50% to 80%	Adoption levels expected to increase to between 75% to 100% with ongoing integration of geospatial data into forecasting and weather warnings.
Environment and climate change	Ground cover and land monitoring Emissions monitoring Coastal zone management	Medium to High in atmospheric and marine monitoring Medium in coastal zone management	Adoption levels expected to increase to the higher end of the scale to meet demands for sustainable resource management and the transition to net zero.
Natural resources	Water quality and water resources monitoring Soil conservation and management	Low to medium up to 50%	Adoption in water resource management expected to increase to meet sustainable water resource management. Adoption in soil conservation likely to increase slightly
Managing natural disasters	Emergency services to mitigate and manage fires, flooding, extreme weather and tidal surge Hazard Mapping	Medium to high in both cases	Use in emergency services for mitigation, response and recovery will maintain adoption levels at close to 100%

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Biosecurity	Managing incursions of pests and disease	Medium to high	Adoption in managing and responding to biosecurity risks likely to be at the higher end of this range as applications are developed.
Fisheries management	Regulation Sustainable management of fisheries	Low to medium on both cases	Current levels of adoption likely to be sustained or increased slightly.
National statistics and social indicators	Geocoded demographics and statistics	Low to medium	Use of geospatial data in national statistics and demographic analysis likely to increase adoption levels to up to 50%
Public administration and electoral services	Electoral boundaries Digital transformation	Medium to high Low to medium	Applications in public administration is projected to continue to grow as the digital transformation of government services progresses. Adoption levels of up to 75% possible.
Public transport	Location and timetable services Ticketing systems Services planning	Low to medium	Adoption in public transport for management of services, timetable services and ticketing is growing and potentially will increase to as high as 75%.
Road transport	Traffic management Road maintenance Route selection	Low to medium	Use in traffic management to increase with implantation of intelligent transport systems. Applications in road maintenance are likely to increase with increased data capture and analysis including the use of AI. Adoption levels of 80% possible.
Rail transport	Signaling/location services, control systems, Advanced train management systems	Low in operations Medium in advanced train management systems	Adoption levels likely to increase to as high as 50% to support operations, maintenance and passenger interaction.
Air transport	Navigation services GNSS augmentation services	Medium to high in navigation services Low in augmented GNSS	Expanded use of augmentation of GNSS in navigation services and regulation is likely to see adoption levels increase to around 90% to 100%.
Sea transport and maritime activities	Navigation aides Search and rescue Automatic identification systems Managing oil pollution	Low to medium – some areas as high as 50%	Adoption of geospatial information and GNSS in navigation expected to continue to increase potentially to 75%. Current levels of adoption in AIS and oil pollution monitoring and management to be maintained.
Law enforcement	Location services for policing	Low %	Adoption expected to increase with use of geospatial information services in crime prevention as well as in response.
Asset management	Location services to monitor and maintain assets	Low to medium	Considerable growth in adoption expected as technologies merge and spatial digital twin models expand.

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Public health and social services	Ambulance services Planning primary health care Epidemiology Family and social services	Medium to high in ambulance services Low in the other areas	Applications in health and social services expected to grow to as high as 50% in some areas as digital services expand in delivery of government supported health and social service programs to meet the increasing demands the sector.
Defence and national security	Defence Intelligence Australian Defence Force Requirements	High	The use of geospatial information services is expected to continue at a high level consistent with its GEOINT program and support for defence operations.
Public finance	Regional impacts of budget appropriations Location based economic analysis	Low	Adoption in areas such as budget analysis and program management likely to grow with adoption levels as high as 25% possible.

Source: ACIL Allen

In this table, the level of adoption means the extent to which an activity draws on geospatially enabled products and services. For example, an estimate of 80% of atmospheric monitoring means that 80% of the activities involved in atmospheric monitoring rely on geospatial information in one form or another.

The table addresses activities at the Commonwealth, State and Territory and Local Government Levels. Many areas of government are fully dependent on geospatial information and services. For example, geoscience and meteorology as almost totally driven by geospatial information services. Environmental monitoring, climate change and emergency services are similarly dependent on geospatial information. The table below provides an overview of the levels of adoption and future possibilities.

Table 3.5 Use of geospatial information in public administration and safety

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Geological survey	Geoscience Mapping Minerals and energy resources exploration	High in all cases	Level of adoption will remain high and increase in some areas as technologies advance.
Surveying and mapping	Foundation spatial data Property boundaries and cadastre Remote sensing Position, navigation and timing Topography Digital elevation models	High in all cases	High levels of adoption expected to continue as demand for georeferenced digital data increase.
Planning and development	Planning Development approvals and compliance	Low to medium in planning. Medium in development activities.	Geospatial information services are expected to continue to grow with progress in planning, compliance and development approvals. Adoption could increase to 75% in some areas.
Property services	Land administration Land valuation	Low to medium%	Adoption expected to increase to as high as 80% as digitisation of land development and land administration continues.
Spatial digital twin	3D and 4D digital models of the built and natural environment	High	Adoption will continue at 100% as the use of spatial digital twins grows.

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Meteorology	Atmospheric monitoring Monitoring the marine environment Weather forecasting and warnings	Medium to high with adoption rates between 50% to 80%	Adoption levels expected to increase to between 75% to 100% with ongoing integration of geospatial data into forecasting and weather warnings.
Environment and climate change	Ground cover and land monitoring Emissions monitoring Coastal zone management	Medium to High in atmospheric and marine monitoring Medium in coastal zone management	Adoption levels expected to increase to the higher end of the scale to meet demands for sustainable resource management and the transition to net zero.
Natural resources	Water quality and water resources monitoring Soil conservation and management	Low to medium up to 50%	Adoption in water resource management expected to increase to meet sustainable water resource management. Adoption in soil conservation likely to increase slightly
Managing natural disasters	Emergency services to mitigate and manage fires, flooding, extreme weather and tidal surge Hazard Mapping	Medium to high in both cases	Use in emergency services for mitigation, response and recovery will maintain adoption levels at close to 100%
Biosecurity	Managing incursions of pests and disease	Medium to high	Adoption in managing and responding to biosecurity risks likely to be at the higher end of this range as applications are developed.
Fisheries management	Regulation Sustainable management of fisheries	Low to medium on both cases	Current levels of adoption likely to be sustained or increased slightly.
National statistics and social indicators	Geocoded demographics and statistics	Low to medium	Use of geospatial data in national statistics and demographic analysis likely to increase adoption levels to up to 50%
Public administration and electoral services	Electoral boundaries Digital transformation	Medium to high Low to medium	Applications in public administration is projected to continue to grow as the digital transformation of government services progresses. Adoption levels of up to 75% possible.
Public transport	Location and timetable services Ticketing systems Services planning	Low to medium	Adoption in public transport for management of services, timetable services and ticketing is growing and potentially will increase to as high as 75%.
Road transport	Traffic management Road maintenance Route selection	Low to medium	Use in traffic management to increase with implantation of intelligent transport systems. Applications in road maintenance are likely to increase with increased data capture and analysis including the use of AI. Adoption levels of 80% possible.
Rail transport	Signaling/location services, control systems, Advanced train management systems	Low in operations Medium in advanced train management systems	Adoption levels likely to increase to as high as 50% to support operations, maintenance and passenger interaction.

Area	Activity	Estimated adoption 2023-24	Future possibilities to 2033-34
Air transport	Navigation services GNSS augmentation services	Medium to high in navigation services Low in augmented GNSS	Expanded use of augmentation of GNSS in navigation services and regulation is likely to see adoption levels increase to around 90% to 100%.
Sea transport and maritime activities	Navigation aides Search and rescue Automatic identification systems Managing oil pollution	Low to medium – some areas as high as 50%	Adoption of geospatial information and GNSS in navigation expected to continue to increase potentially to 75%. Current levels of adoption in AIS and oil pollution monitoring and management to be maintained.
Law enforcement	Location services for policing	Low %	Adoption expected to increase with use of geospatial information services in crime prevention as well as in response.
Asset management	Location services to monitor and maintain assets	Low to medium	Considerable growth in adoption expected as technologies merge and spatial digital twin models expand.
Public health and social services	Ambulance services Planning primary health care Epidemiology Family and social services	Medium to high in ambulance services Low in the other areas	Applications in health and social services expected to grow to as high as 50% in some areas as digital services expand in delivery of government supported health and social service programs to meet the increasing demands the sector.
Defence and national security	Defence Intelligence Australian Defence Force Requirements	High	The use of geospatial information services is expected to continue at a high level consistent with its GEOINT program and support for defence operations.
Public finance	Regional impacts of budget appropriations Location based economic analysis	Low	Adoption in areas such as budget analysis and program management likely to grow with adoption levels as high as 25% possible.

Source: ACIL Allen

The table shows a wide range of adoption levels across public administration and safety. High levels of adoption are observed in geoscience, meteorology, planning and land administration, environmental and climate change management and emergency management, defence and certain areas of transport. It is also growing in local government

Adoption is lower in other areas such as health and human services, public finance, and law enforcement.

The development of spatial digital twin models by some State Governments is likely to accelerate the adoption of geospatially supported systems more widely in government.

Finding 2

Government adoption of geospatially supported services and products is high in planning, development, emergency management, environment and climate change, geoscience, meteorology, defence and certain areas of transport. Adoption is lower in other areas of government such as health and human services, public finance and general policy and programs.

The emergence of investment in spatial digital twins by State Governments is projected to increase the use of geospatial services across all areas of government including health and social services, asset management, demographic and public finance and program analysis.

3.3 Geospatial information systems in the private sector

Geospatial information systems and geospatially supported technologies play a critical role in most industries. It is deeply embedded in agriculture, forestry and fisheries, construction, mining, all modes of transport and logistics, resources and energy and aspects of finance and insurance. Many organisations in these areas have been early adopters of geospatial information technologies.

It has shown less penetration in other areas such as healthcare, retail and wholesale trade, arts and recreation and administrative services. However, with the growing availability of geospatial devices and data, it is finding applications in online purchasing and delivery, ride share, rental, real estate, and marketing for retail outlets.

Respondents to the survey from industry included representatives from agriculture (1), construction (9), education (6), professional services (10), health (1), mining (1), transport (4), and utilities (2). The sectors with the highest levels of adoption were construction, professional services, utilities, mining and transport.

The survey response was limited by the relatively small number of responses. However, it indicated a number of useful observations:

— Levels of adoption of geospatial supported products and services were as high as 50% in asset management in construction, education, utilities and transport. Productivity impacts were reported to be between 11% and 50% of the cost of operations.
— Professional services included support for surveying, mapping and development and management of critical infrastructure. Levels of adoption and productivity impacts were reported to be as high as 50% in some applications in 2023-24.
— Geospatial support for the mining response included use of EOS aerial imagery and LIDAR, and positioning services. It also involved machine learning and artificial intelligence applied to mining operations.

A total of 27 case studies relevant to private sector activities were identified from case studies submitted and from published reports. The case studies revealed high levels of adoption of geospatially enabled products and services in surveying and mapping, design and construction, agriculture, mining, transport and maritime operations.

Other reports mentioned applications in other areas that drew on geospatial information including financial services, wholesale and retail activities, health and social services and administrative support. In general, the level of adoption in these areas was lower but in most cases was increasing. For example, adoption in the insurance sector is significant and rising.

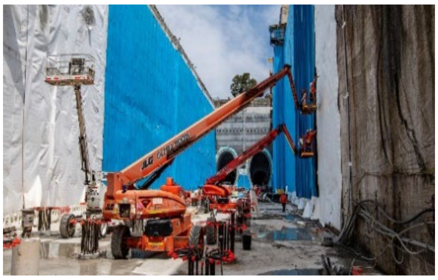
Sections 3.3.1 to3.3.3 list case studies that illustrate the impact and importance of geospatial information to industry.

3.3.1 Design, construction, property and transport

The following 5 case studies illustrate the importance of geospatial information systems to property development, design, construction and transport.

Waterloo Station integrated development

The case studies demonstrate the savings in time and productivity in the property development and design and construction sectors from the emerging use of 3D digital models of the built environment that are increasingly being captured under the term spatial digital twins.



This is illustrated in the integrated development of the Waterloo metro station being constructed in Sydney. The contractor used an innovative 3D scanning technology to capture 3D geospatial data within the station box. The solution allows for a complete account of the pre-existing characteristics of the site, and exact records of the changes made during construction. Not only does this ensure that the assets used for the construction are well organised, but that assets and utilities can be located with certainty in the event of future infrastructure projects, delivering benefits for decades to come. The geospatially enabled approach has delivered cost savings, as well as providing an increased degree of clarity, reducing programme risk.

Archistar eComply

eComply is a geospatially enabled tool developed by Archistar for builders, designers, and architects to pre-check 3D building designs against the Small Lot Housing Code. The tool provides feedback on more than 90 complex checks in around 90 seconds. This means house designers can rapidly make changes before sending their plans to a building surveyor for final assessment, reducing the approval process.

Industry testers self-reported that the new tool could save up to 4 weeks off the approval process. They also noted the benefit of the iterative design and compliance test methodology which is helpful for the off-site modular housing sector.

The eComply pilot is already demonstrating the value that Digital Twin technology can deliver to cut regulatory red tape by taking weeks off current building approval times.

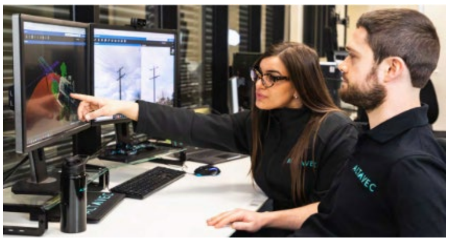
Movement detection system

Billions of dollars in damage, loss of life and irreversible damage to the environment are caused each year as a result of land movements, landslides and structural displacement. Traditional surveying has always been constrained by the time, risk and cost involved. Developed by Kurloo Technology, the Queensland University of Technology and the CRC for Advanced Manufacturing, Kurloo a movement detection system is now manufactured in Australia.

Kurloo employs cutting edge technology, cloud computing, accurate three-dimensional displacement, fully automated processing and online access to results. It draws on low-medium Global Navigational Satellite sensors with low pow wide area networks. It is a fully integrated devise supported by cloud processing and data analytics. The product gathers critical data while the project team is offsite providing a safe data gathering and processing system with unlimited online access. It is a fast, precise and reliable technology to provide accessible, rapid, accurate, reliable and sustainable early warning system for monitoring displacement.

It has been applied by Queensland Rail to monitor the risk to their network of long-term slope stability in order to put in place maintenance and disaster response programs to ensure that the train network continues to operate safely. It has been employed by the Port of Brisbane to optimes the design and development through a critical understanding of settlement during and after construction.

Virtual asset management



Spatial digital twins also deliver productivity benefits for infrastructure and asset managers. The case study on virtual asset assessment demonstrates how asset owners can realise productivity gains through virtual asset assessment.

This case study identified significant savings of 50% in asset management programs, a 90% reduction in data management effort and 60% savings in time for inspection teams. The authors of this case study estimated that savings of up to $500 million per year could be achieved if applied across Australia. This is consistent with earlier estimates based on survey of the design and engineering industry on the savings from such concepts (ACIL Allen, 2017).

Under Keel Clearance in Port Hedland

Under Keel Clearance (UKC) is the distance between the seabed and a ship's keel. The measure can be used to ascertain the likelihood of a ship grounding (impacting the seabed). UKC requirements are determined and enforced by ports or regulatory authorities.

Port Hedland is one of three major iron ore ports in the Pilbara, Western Australia, and the largest bulk export port in the world (Pilbara Ports, n.d.). The Pilbara Ports Authority developed a Hydroid, or Lowest Astronomical Tide Model, which is a model to better understand sea levels and depths of a particular area

The Port Hedland port estimates that the technology delivers around $240 million per annum in savings from increased ship movements in the Port.

Trade through Australian Ports is valued at around $650 billion annually. The Australian Port Industry generated a total Gross State Product of $264 billion in 2024-24. Geospatial information systems supporting navigation in port activities and bathymetry is a critical support for sustaining Australia's trade.

Before You Dig Australia

Currently estimated at approximately 15,000 strikes per annum, third party damages to Australia's utility infrastructure are driving significant cost to community in regard to repairs, disruption, and risk of injury.

BYDA provides free plans across Australia to allow all scales of development, from a DIY project to full-scale construction site to proceed without risking a utility strike. Their services, which are now offered digitally, utilise geospatial technology to fulfill 2.2 million plan requests per year – with each plan delivered promptly avoiding a potential utility strike.

The efficient delivery and easy use of the platform ensures users are more likely to employ diligent and responsible practices, and also reap the benefits of reduced stand-by time, and reduced cost of damage to utilities.

Increased application of GIS mapping in BYDA's platform has potential to increase the effectiveness and value of BYDA. Ongoing digitisation of land, property and infrastructure data including through digital twin programs will therefore deliver increased benefits to BYDA services.

Full list of case studies relevant to design, construction, property and transport

A full list of 8 case studies relevant to planning, development and government services, including the above 6 case studies, is provided in Table **3.6** below.

Table 3.6 Design, construction proport and transport

	Case study	Description	Impacts
37	Waterloo Integrated Station Development [Planning, development and construction]	Veris utilised an innovative 3D scanning technology to capture data within the station box, which was then georeferenced. The solution allows for a complete accounting of the pre-existing characteristics of the site, and exact records of the changes made during construction.	The value of such a geospatially enabled approach, if applied across all construction activities could deliver productivity benefits of 1 to 2%. If applied at 1% over the construction sector this would amount to savings for the construction industry of the order of $250 million per year.
38	eComply [Planning, construction, design and government]	Archistar eComply minimises the challenges of ensuring design changes are compliant with codes and regulations. The tool provides feedback on more than 90 complex checks in around 90 seconds. This means house designers can rapidly make changes before sending their plans to a building surveyor for final assessment, cutting up to 4 weeks off the approval process.	Industry testers self-reported that the new tool could save up to 4 weeks off the approval process. The eComply pilot is already demonstrating the value that Digital Twin technology can deliver to cut regulatory red tape by taking weeks off current building approval times and deliver over AU$ 30 million in benefits.

	Case study	Description	Impacts
39	Kurloo movement detection [Geotechnical engineers, surveyors, dam engineers, structural engineers, asset managers.]	Developed by Kurloo Technology, the Queensland University of Technology and the CRC for Advanced Manufacturing, Kurloo a movement detection system is now manufactured in Australia. Kurloo employs cutting edge technology, cloud computing, accurate three-dimensional displacement, fully automated processing and online access to results. It draws on low-medium Global Navigational Satellite sensors with low pow wide area networks. It is a fully integrated devise supported by cloud processing and data analytics.	The technology has been applied by Queensland Rail to monitor the risk to their network of long-term slope stability in order to put in place maintenance and disaster response programs to ensure that the train network continues to operate safely. Users report that Kurloo provides a cost effective, adaptable and highly accurate solution to enable control of high-risk locations and better plan development on site. The technology saves costs and increases on site safety
40	Virtual Asset Assessment [Asset owners in government and industry]	Altavec and an Australian energy company implemented a cloud-based Virtual Asset Assessment solution. This system uses images from aircraft, drones, or field inspections to identify and audit asset defects within 24 hours. It reduces the need for ground inspections, lowering costs and risks. The platform also enhances data utilisation and communication through secure APIs.	An energy company reported significant productivity benefits including a 40% increase in number of asset inspections, a 50% saving in asset maintenance programs', a 90% reduction in data management effort, and a 60% saving in time for inspection teams.
41	Before You Dig Australia [Building, construction and infrastructure industries]	Before You Dig Australia (BYDA) is an organisation that facilitates the provision of asset plans and information to anyone working in and around infrastructure assets directly from owners of utility services. Considering the extraordinarily high costs of utility strikes, BYDA's utilisation of geospatial infrastructure provides an essential service to individuals and organisations requiring critical information on the locations and characteristics of underground utilities.	BYDA estimates that the cost of repairing utility strikes in Australia is over $4 billion per annum, when considering labour, administration and material costs. The benefits of BYDA include reduced time, effort and cost in design, as well as improved accuracy. It can also aid Utility Providers or BYDA in producing better informed projects in early stages, reducing damage during investigations, and improving the safety of those digging. BYDA will benefit from ongoing development of authoritative digital records of property and infrastructure assets through concepts such as spatial digital twins.
42	National Flood Insurance Data Base [Insurance industry, property owners]	In partnership with state and territory governments, the general insurance industry has developed and licensed the National Flood Information Database (NFID) for use by insurers in determining the flood risk to individual properties. NFID is an address database containing 13.7 million property addresses, overlayed with the known flood risk according to government flood mapping.	The average annual damage from flooding in Australia was estimated to be around $8.8 billion in 2017(Deloitte Access Economics, 2017). An efficient and effective framework for assessing flood risk is fundamental to managing financial risk faced by property owners. Geospatial information and analysis underpin flood risk assessment by the insurance industry and increases access to flood insurance for property owners.

	Case study	Description	Impacts
43	Ship clearance in Port Headland [Resource industries involved in shipping from Port Hedland]	Port Hedland is one of 3 major iron ore ports in the Pilbara, Western Australia, and the largest bulk export port in the world. The Pilbara Ports Authority developed a Hydroid, or Lowest Astronomical Tide Model, which is a model to better understand sea levels and depths of a particular area.	The Port estimates that the technology delivers around $240 million per annum in savings from increased ship movements in the Port.
44	Heavy Vehicle Access Management System (HVAMS) Heavy vehicle operators, transport departments	The Tasmanian Department of State Growth introduced the geospatially enabled Heavy Vehicle Access Management System (HVAMS) to provide heavy vehicle operators with a self-service system to check which roads and bridges can be accessed without a permit and under conditions relating to specific vehicle and load type.	The HVAMS has improved road access for the heavy vehicle industry and reduced red tape for the industry. As a result, 80% of Over Size Over Mass vehicle movements and 90% of special purpose vehicle movements are now undertaken permit free. This has led to reductions in waiting times and a reduction in road manager resources required to administer permits.

Source: Case Study Document accompanying this report

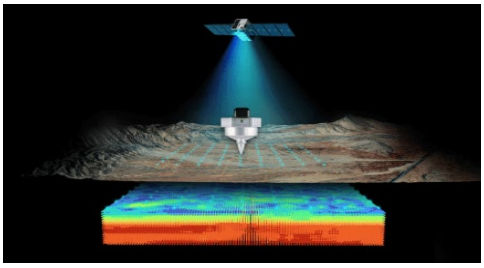
Mining

Mining is one of the most geospatially enabled industries in Australia. Geospatial information services are embedded in exploration, development, production, processing, supply chain and environmental management throughout the mining cycle.

Critical minerals are important to Australia's transition to net zero by 2050 and the world as lithium, copper, cobalt, nickel, chromium, zinc, platinum and rare earth minerals are important to renewable energy technologies including battery technology, catalytic converters, clean energy technologies, efficient energy conversion and lightweight batteries.

The following 4 case studies illustrate the importance and value of geospatial information systems for government.

Exosphere accelerates exploration

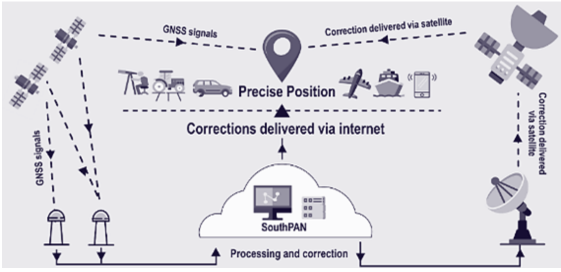


The Exosphere case study based on Fleet Space Technologies work is an indication of new and innovative ways of conducting minerals exploration. The mining industry, including Rio Tinto, Barrack Gode and Core Lithium, are using this technology to better target exploration effort.

Fleet Space's ExoSphere combines satellites, smart seismic sensors and AI to accelerate mineral discovery while also reducing environmental impact. Smart seismic sensors (Geodes) gather 3D seismic data which is then transmitted to satellites in low Earth orbit and processed by an AI engine to deliver real-time 3D subsurface insights up to depths of 2.5km with near-zero environmental impact. The technology aims to accelerate mineral discovery while at the same time reducing the cost and environmental impact of exploration programs.

Precise satellite positioning supports mine safety

A further case study of the Satellite Based Augmentation System **SouthPAN**, shows how accurate positioning can improve mining operations and safety through its use in Safety Fleet Management Systems to alert operators of warnings through more accurate and reliable positioning. An economic benefit analysis of this application estimated an economic value of $7.6 billion over 30 years for Australia and New Zealand.



Mining also benefits from 3 cm precision positioning provided by RTK systems and the CORS network. The **National Positioning Infrastructure Capability program** provides 3cm accuracy satellite positioning that is of value to the mining sector for activities such as monitoring tailings dams and precise positioning in a range of activities including management of mining operations to protect environmentally and culturally sensitive areas, management of stockpiles and rehabilitation activities.

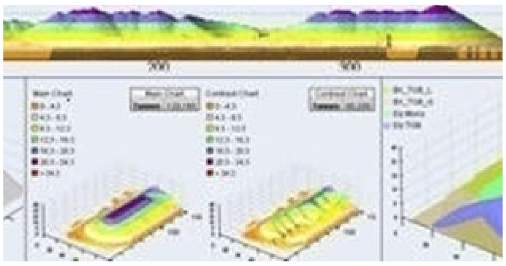
Autonomous operations in mining

Safe AI is an international company involved in transitioning heavy industry to connected and autonomous vehicles. The company has partnered with Aptella to retrofit a large fleet of haulage trucks operated by MACA, an international mining and construction contracting group.

The Safe AI Autonomous Framework case study from Aptella demonstrates how autonomous vehicle technology can lower operating costs of mining by up to 30%, reducing fuel consumption and emissions by 10 to 15%. BHP for example have noted a reduction in haul accidents by over 90% through the use of autonomous machines.

QMaster Mine Management System

QMASTOR is a supply chain management system using positioning technologies to track the tonnage, quality and value of commodities in real-time. It was designed in the early 2000's to address the need for automated, real-time supply management systems.



The system provides for efficient transport and storage of commodities by providing the information that is essential to inventory management, mine planning and logistics scheduling. Satellite positioning is a key supporting technology to this system.

Full list of case studies relevant to mining

A full list of 9 case studies relevant to mining, including the above 4 case studies, is provided in Table 3.7 below.

Table 3.7 Mining

	Case study	Description	Impacts
45	Fleet Space Technologies [Mining industry, customers for critical minerals]	Launched in 2022, Fleet's ExoSphere is the first to utilise satellites to gather data from their seismic sensors on the ground to assess the presence of minerals in a survey area. Fleet's non-invasive Ambient Noise Tomography (ANT) method allows their Geodes (seismic sensors) to gather data	Fleet's ExoSphere technology allows for fast-tracked, lower cost, and lower environmental impact exploration to inform real-time decision making.
46	Satellite technology for mineral mapping [Industry, researchers, government]	CSIRO, utilising Japan's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite data created the first continent-wide mineral map. The formation of this expansive mineral map required CSIRO to combine over 3,500 images containing reflectance and emissivity data captured from the satellite. This marked the first ever continent-wide set of mineral maps upon its release in 2012.	CSIRO's innovation in the applications of satellite data for mineral mapping inform the industry's understanding of Australia's mineral composition and distribution and has played an important role in advancing the understanding of what can be achieved with satellite imagery.
47	AusAEM [Resource managers]	The AusAEM project utilises a non-invasive testing technique known as airborne electromagnetic (AEM) surveying. This enables the measurement of ground conductivity variations to depths of several hundred meters.	AusAEM is unlocking Australia's hidden natural assets, supporting communities, and shaping a sustainable future.
48	Hydrogen Economic Fairways Tool [Policy makers, industry, researchers]	The Hydrogen Economic Fairways Tool (HEFT) is a key tool of the AusH2 portal, established to support the 2019 National Hydrogen Strategy and Geoscience Australia's report on Prospective Hydrogen Production Regions of Australia. The project focusses on the development and application of new resource economic modelling algorithms for mineral, energy and groundwater systems.	Deloitte estimated that the tool saves between $30,000-$50,000 per prospective project. These savings are due to reduction in time and due diligence required to investigate the eligibility of hydrogen projects. Cost savings could reach up to $100,000 per project in large or complex cases.
49	Satellite-Based Augmentation System (SBAS) by Southern Positioning Augmentation Network (SouthPAN) [Mining industry and mining workforce]	The project brought together experts from industry and academia to trial the SouthPAN signal and gain a greater understanding of how widely it could be used in the sector. Fitted on fleet vehicles at a Middlemount mine site in Queensland, SouthPAN receivers tested proximity awareness using the approximate display of the Safety Fleet Management System.	An economic benefit analysis of SouthPAN was conducted and found that SouthPAN has an expected value of $7.6 billion over 30 years for Australia and New Zealand based on tested applications, with $1.58 billion of this figure accruing to the resources industry. This includes an estimated PV$577m saving on fuel and labour costs for haul trucks.

	Case study	Description	Impacts
50	SafeAI - Autonomous Heavy Equipment [Mining industry, mining operations and mining workforce]	SafeAI have partnered with Aptella to retrofit a large fleet of haulage trucks operated by MACA, an international mining and construction contracting group. The SafeAI Autonomous Framework (SAF) is an ASIL-D safety certified operating system that supports safer, more productive worksites. It is an interactive and customisable operating system that provides users with the ability to create and deploy autonomous applications in mining and construction.	Autonomous vehicle technology can lower operating costs by up to 30%, reducing fuel consumptions and emissions by 10-15% and extending equipment lifespan by 50%. Productivity can be increased by 15-30% by reducing downtime, human error, and inefficiencies. BHP have noted a reduction in haul accidents by over 90%.
51	Autonomous Road Trains [Mining companies, mining workforce]	Hexagon and mining services company Mineral Resources Limited (MinRes) are equipping a fleet of 120 road trains (triple-trailer vehicles) with a drive-by-wire autonomous driving system to enable road trains to travel from mine-to-port more efficiently and safely.	Hexagon estimate that a fleet of 100 road trains could save MinRes up to US$236 million per annum or 50% of current trucking costs using their autonomous platooning system.
52	NGIS and Skyline's common operating picture [Mining industry]	Perth-based geospatial company NGIS have partnered with Skyline, a 3D technology company, to deliver an intelligent digital platform for the Australian mining industry. It allows the user to integrate unmanned aerial vehicle (UAV) data for dynamic terrain modelling with outputs from geological modelling and engineering designs, enabling a self-service approach to monitoring mine site production and compliance that drives operational awareness and efficiencies.	Geospatially enabled common operating picture advances planning, decision making, and day-to-day operations of a mine site.
53	QMaster Mine Management Systems [Industry]	QMASTOR is a supply chain management system using positioning technologies to track the tonnage, quality and value of commodities in real-time. It was designed in the early 2000's to address the need for automated, real-time supply management systems. The system is used to optimise operations from "pit to port" in areas such as inventory management, mine planning and logistics scheduling.	QMASTOR allows for efficient transport and storage of commodities by providing the information that is essential to inventory management, mine planning and logistics scheduling.
54	K2fly Natural Resource Governance [Mining industry, government, the environment]	K2fly provides enterprise Software-as-a-Service (SaaS) solutions for technical assurance, resource and mineral governance. K2fly's cloud-based platform assists environmental rehabilitation activities. The platform helps community, geotechnical, and management teams improve compliance.	1-2 mm precision detection of land surface deformation over time using EO data allows for highly accurate monitoring and management of mine site rehabilitation.

Source: Case Study Document accompanying this report

Note: The sources of benefit estimates are provided in the Case Study Document accompanying this report.

3.3.2 Agriculture

Australian agriculture plays a crucial role in the country's economy and national food security. In terms of economic value, Australian agriculture is a significant contributor to the country's GDP. The gross value of agricultural production in Australia was $84 billion in 2023-24. Agriculture plays a crucial role in rural communities, providing employment and supporting local economies. According to ABARES, the agriculture, forestry, and fishing industries employed around 266,300 people in 2022-23, representing around 2% of Australia's total employment. [4]

Productivity is extremely important to agricultural production in Australia. As farms produce more output per unit of land, the overall supply of food rises. By improving resource efficiency, such as water and fertiliser use, productivity increases can also reduce the environmental impact of agriculture,

One avenue for productivity increases is through technology adoption of which geospatial information systems play a key role. The combination of Earth observation from space and precise positioning is known as precision farming leading to improved efficiencies with respect to fertilising, by knowing where and when to apply fertiliser together with positioning for control traffic farming.

The following 4 case studies illustrate the importance and value of geospatial information systems for government.

Precise positioning supporting broad acre cropping

Agriculture has been one of the earliest adopters of technologies and systems supported by geospatial technologies. The case study on the use of precise satellite positioning in broad acre cropping illustrates this point. Productivity is crucial to maintaining Australian agriculture's competitiveness in global markets. In agriculture, precise positioning services support technologies such as remote sensing, auto-steer and yield monitoring systems which deliver productivity benefits for agriculture enterprises.

Control traffic farming (CTF) is an important support for precision agriculture. CTF aims to achieve spaced permanent 'traffic lanes' for use in sowing and harvesting to minimise soil compaction and overlap of tyre tracks. CTF requires good guidance systems and relies heavily on precise positioning technologies. It delivers enhanced crop productivity leading to greater cropping frequency and reliability and it improves resource use efficiency including pesticides, fertilisers and optimises nutrient and water usage.

Examples of the benefits include increased benefits of wheat prosecuting by $5 to $50 per acre from reduced chemical use and reduced emissions by 30 to 50% (Tullberg, 2018). Space based augmentation systems were estimated to deliver a total benefit to broad acre agriculture of (90 million in present value terms over a 30-year period (EY, 2019).

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[4] (ABARES, 2034)

Robotics delivering savings on farm

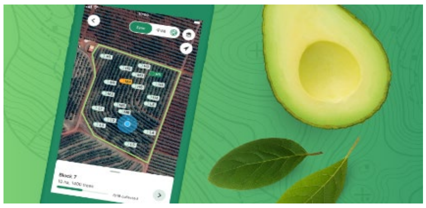
The use of robotics in agriculture is demonstrated in the case study of **SwarmFarm Robotics.** SwarmFarm is an autonomous farming platform that uses precision positioning (real-time kinematic (RTK)) to guide robotic fleets whose functions are customisable by users and can be controlled remotely via any iOS device. Numerous lightweight and modular robots can operate on the same farm in unison with each other, acting as a ‘swarm’ to undertake large and complicated tasks autonomously.

Through the application of positioning technologies, SwarmFarm Robotics provides economic benefits and improved capabilities to farmers. Savings of up to 80% in reduced chemical use have been reported using robotics.

Precision agriculture in avocado production

The avocado industry has increased production significantly over the past 15 years. Accurate yield forecasts assist the industry to make informed decisions around forward selling and market access. At the orchard level, understanding crop loads allows growers to better plan harvesting logistics. Spatial mapping of yield at the block level can support decisions around variable rate application of inputs such as water, fertilizer, pesticides and improved response to plant disease such as Phytophthora.

The Applied Agricultural Remote Sensing Centre (AARSC) team developed a mobile application called Crop Count which utilises high-resolution satellite imagery to support avocado growers and enable them to forecast yields, map tree health, and mitigate the damage of natural disasters. Since 2020, this methodology has been evaluated in Australia, South Africa and New Zealand and has led to its adoption to now expand across 7 countries as well as additional commodities such as mango, citrus, tea tree and macadamia.



Crop Count is a world-first yield forecasting technology that offers avocado growers 93% accuracy. Benefits of this innovation include cost and time savings, the ability to forward sell crops, and better plan for labour and storage requirements.

Australian Citrus Orchards National Citrus Map

In 2022, Citrus Australia partnered with Agriculture Victoria and the Applied Agricultural Remote Sensing Centre (AARSC) to map Australian citrus orchards. Prior to this map, Citrus Australia recorded data from citrus orchards with the Citrus Tree Census, which recorded data in tabular format only. The map supports improvements in in protecting the provenance, biosecurity status, and export markets of the industry's 1,150 orchards, satisfying export traceability and certification requirements for high-value global markets, It also helps with planning and recovery from bushfires, floods, and the effects of climate change, provides industry data for carbon tracking, water usage, and avoidance of food wastage, enables rapid responses to outbreaks such as citrus canker, varroa mite, and HLB and a richer course of live data for business decisions about further plantings and varietal changes.

The benefits of this map include improvements to traceability, biosecurity, exports, emergency response, sustainability and business planning.

Full list of case studies relevant to agriculture

A full list of 6 case studies relevant to agriculture, including the above 4 case studies, is provided in Table 3.8 below.

Table 3.8 Agriculture

	Case study	Description	Impacts
55	Australian Citrus Orchards [Citrus farmers and broader industry]	The National Citrus Map has now provided an additional spatial information set, assisting the industry to make more powerful and informed decisions across industry challenges and opportunities. It includes orchard level information such as tree age, variety, and management.	Benefits of this map include improvements to traceability, biosecurity, exports, emergency response, sustainability and business planning.
56	Precision agriculture technologies in avocado production systems [Avocado farmers and broader industry]	The Applied Agricultural Remote Sensing Centre (AARSC) team developed a mobile application called Crop Count which utilises high-resolution satellite imagery to support avocado growers and enable them to forecast yields, map tree health, and mitigate the damage of natural disasters.	Crop Count is a world-first yield forecasting technology that offers avocado growers 93% accuracy. Benefits of this innovation include cost and time savings, the ability to forward sell crops, and better plan for labour and storage requirements.
57	Benefits of Satellite-Based Augmentation Systems (SBAS) [Broad acre agriculture]	Analysis was completed into the economic benefits of Satellite-Based Augmentation Systems (SBAS), including benefits to the broadacre sector. It incorporated data from two projects which surveyed farmers and conducted empirical research to estimate the benefits of implementing SBAS signals	This analysis estimated the total benefit of SBAS to the broadacre sector of $990 million over a 30-year period including a 35% reduction in yield loss from tyre tracking.
58	SwarmFarm Robotics [Farmers]	SwarmFarm is an autonomous farming platform that uses precision positioning (real-time kinematic (RTK)) to guide robotic fleets whose functions are customisable by users and can be controlled remotely via any iOS device. Numerous lightweight and modular robots can operate on the same farm in unison with each other, acting as a 'swarm' to undertake large and complicated tasks autonomously.	Individual weed treatment is cost-effective and significantly reduces herbicide use, in addition to reducing the likelihood of herbicide resistance. In 2021, a client of SwarmFarm Robotics reported a chemical use reduction of 80%.
59	Benefits of the precise positioning to grain growers [Grain farmers]	Control traffic farming (CTF) is an important support for precision agriculture. CTF aims to achieve spaced permanent 'traffic lanes' for use in sowing and harvesting to minimise soil compaction and overlap of tyre tracks. CTF requires good guidance systems and relies heavily on precise positioning technologies.	Variable rate fertiliser application increased the economic benefits of wheat production by $5-50/hectare due to cost savings of reduced agrochemical use. CTF generated increased profits of $46.8/hectare due to avoiding unnecessary use of agrochemicals from reduced overlap, and labour reduced labour costs. CTF might decrease the global warming potential of soil emissions by 30-50%.

	Case study	Description	Impacts
60	Rural Intelligence Platform [Agribusiness community]	CSIRO have partnered with a rural technology startup Digital Agriculture Services (DAS) in the development of a platform that combines artificial intelligence, machine learning and cloud-based geospatial technology to deliver reliable, independent and robust farm data and analytics.	Rural Intelligence Platform empowers farmers and land managers by providing actionable insights based on authoritative and robust data. The platform enhances productivity, sustainability, and informed decision-making across rural Australia.
61	Horticulture industry maps [Horticultural farmers]	Industry bodies collaborated with the University of New England's AARSC to map all commercial orchards over one hectare in Australia. This was achieved using digitised industry data, high-resolution satellite and airborne imagery, web searches, and field validation.	These maps enhance decision-making, support traceability, and empower growers and biosecurity agencies to focus their efforts more effectively.

Source: Case Study Document accompanying this report

Note: The sources of benefit estimates are provided in the Case Study Document accompanying this report.

3.3.3 Biosecurity

Australia operates a complex biosecurity system with many different stakeholders. It has been estimated that damages from pests and diseases over the next 50 years would decline by approximately $325.26 billion due to the operation of Australia's biosecurity system, at a cost of $10.45 billion (Dodd, 2020).

Early detection of, and a rapid, effective response to biosecurity incursions can have a large impact on limiting their damage. Implementing effective and efficient surveillance and response programs is becoming increasingly difficult as exposure to biosecurity threats increases.

Geospatial information systems play an important role in protecting Australia's biosecurity. They support risk assessment, data sharing between governments, industry and research organisations, detection of incursions of pests and disease, it optimises resource allocation at the response stage and creates visualisations to communicate biosecurity risks to stakeholders, policy makers and the public.

The following 2 case studies illustrate the importance and value of geospatial information systems for government biosecurity effort.

Management of red imported fire ants

Red imported fire ant (RIFA) was first detected in Brisbane in 2001. In 2017, a cost-shared Ten-Year Plan was approved by all Australian governments, with $411 million to deliver an expanded National RIFA Eradication Program (the Program).

Biosecurity Queensland commissioned Outline Global to deliver a broad scale remote sensing solution to locate Fire Ant Nests more efficiently and effectively. The result was a world-first ultra-high resolution surveillance system that records the spectral signature of RIFA nests, distinguishing them from other features such as rocks, manure, wood, and bare earth. An associated AI model was developed to process and interpret the imagery, and ultimately increase accuracy by matching remote sensing images against validated field data.

The National Red Imported Fire Ant Eradication Program (NRIFAEP) estimates that if RIFA spread unchecked, annual impacts could amount to $2 billion. Geospatial information and services are playing an important role in avoiding such damage costs.

Protecting Australia's honeybees - The role of Foundation Spatial Data Framework in the Varroa Mite response plan.

The Varroa mite is a devasting pest of European honeybees. It feeds on bees at all life stages, aids viral infestations, and ultimately causes colony collapse. Australia was the only continent free of Varroa until June 2022 when it was detected in the Department of Primary Industry surveillance hives at the Port of Newcastle.

The response was the largest multi-agency biosecurity response in Australia's history, overseen by the National Management Group (NMG) with representatives from Commonwealth Government, every state and territory department, and executive from relevant industry bodies and Plant Health Australia.

The NSW Department of Primary Industries worked with the NSW Spatial Services Emergency Information Coordination Unit (EICU) to carry out spatial analysis to assist in the initial eradication program. The EICU prepared maps for emergency orders, modelled potential baiting locations, updated surveillance and eradication zones, and assisted with internal and public facing web maps.

The NSW Foundation Spatial Data Framework contributed to the Varroa mite Response through mapping, risk assessment, and emergency coordination. The Department of Agriculture, Fisheries and Forestry estimate that an unhindered spread of Varroa mites could cause economic losses of $1.3 billion over 30 years in Australia (ABARES, 2012).

Full list of case studies relevant to biosecurity

A full list of case studies relevant biosecurity, including the above 2 case studies, is provided in Table **3.9** below.

Table 3.9 Biosecurity

		Description	Impacts
62	Management of red imported fire ants [Agricultural industry, tourism, telecommunications, schools.]	Developing a remote sensing solution to efficiently detect and destroy new RIFA nests to prevent further spread.	The National Red Imported Fire Ant Eradication Program (NRIFAEP) estimates that if RIFA spread remained unchecked, annual impacts could amount to $2 billion per year.
63	Protecting Australia's Honeybees - Impact of the NSW Foundation Spatial Data Framework on Varroa mite response. [Bee industry, pollination-dependent crops]	Geospatial data enables efficient and effective emergency response to the spread of Varroa mite.	The NSW Foundation Spatial Data Framework contributed to the Varroa mite Response through mapping, risk assessment, and emergency coordination. The Department of Agriculture, Fisheries and Forestry estimate that an unhindered spread of Varroa mites could cause economic losses of $1.3 billion over 30 years in Australia (ABARES, 2012).

		Description	Impacts
64	Protecting Australia' horticulture from Leafminer [Vegetable and ornamental crop farmers]	An online web map of VLM distribution, host plant distributions, VLM establishment risk predictions, and VLM spread risk predictions was created as a decision-making tool. This map also facilitated the communication of risk during extension activities via a depiction of the presence of plant hosts for VLM.	This project has led to an improved understanding of Australian VLM populations, development of cost-effective surveillance techniques and improved industry preparedness for incursions.
65	Protecting Australian grain producers from the Khapra beetle [Grain producers]	A project by the Centre for Excellence for Biosecurity Risk Analysis (CEBRA) developed a framework for creating maps of pest establishment likelihoods to inform surveillance of pests not currently present in Australia.	CEBRA has established a pragmatic framework for creating defensible maps of pest establishment likelihoods, informing targeted surveillance efforts for pests not currently present in Australia, and enhancing our ability to model, detect, and manage khapra beetle incursions. It is estimated that lack of control of the Khapra Beetle that it would cost the Australian economy $1 billion over years (DAWE, 2021).

3.3.4 Overall assessment for industry

Our overall assessment of the level of adoption of geospatial information technology and services is provided in Table 3.10.

The table shows the high levels of adoption of geospatial information services in surveying and mapping, design and construction, resources exploration, oil and gas extraction, mining, agriculture, transport, and professional and technical services.

Other areas such as health and social services, rental, hire and real estate, education and health care and social assistance have lower levels of adoption but the evidence that its use in these areas is still important and adoption can be expected to grow in the coming 10 years. This is subject to some qualifications. There is a concern over the availability of suitably trained staff to support growth in the industry. There are also many challenges to be addressed in developing spatial digital twin models including ownership and sharing of data, cooperative arrangements to support sharing of data and progress in digitisation of geospatial data.

The projections of future growth in adoption used to estimate the economic impacts described in Chapter 4 take into account different levels of adoption over the 10 years to 2033-34.

Table 3.10 Impacts on industry

Sector	Type of application	Estimated adoption 2023-24	Future possibilities to 2033-34
Agriculture	Controlled traffic farming Variable rate technologies Remote sensing Location based marketing Supply chain management Biosecurity	High in broad acre agriculture Well established in cotton and sugar Growing in horticulture	Growth in horticulture Increased data farming generally Air borne sensors Multispectral imagery Hyperspectral imagery
Forestry	Canopy mapping Change Monitoring	Medium to high	Increased use in environmental management and sustainable forestry

Sector	Type of application	Estimated adoption 2023-24	Future possibilities to 2033-34
Fisheries	Resource location services Maritime safety	High	Increased use in sustainable management of fisheries
Mining including critical minerals	Exploration Volume determination Autonomous vehicles Surveying and mapping Supply chain management Environmental management	High	Drone mapping Adoption likely to grow in mining operations Growth in automation New technologies in exploration
Oil & Gas	Exploration Autonomous vehicles Environmental management	High	Managing offshore operations Managing environmental impacts
Manufacturing	Supply chain optimisation Additive manufacturing (3D printing)	Low	Supply chain emissions reduction Use of digital twin concepts in manufacturing processes
Construction and infrastructure	Automated set out Engineering surveying As built and compliance Digital twin applications	High	Increase use of the benefits of digital twin technologies
Electricity/gas/water	Network management System optimisation Asset Management Digital twins	Medium to high	Spatial analysis of demand Improved asset management Demand analysis Fault location Digital twins for location and management of assets
Communications	Satellite based communications Network management Fault correction	Medium	Wider access to communications Asset management Integration of communications with geospatial data Improved PNT accuracy Ubiquitous 5G Coverage with positioning services
Wholesale and retail trade	Location based marketing Online retail Ride share	Low to high depending on area	Increased use of spatially enabled digital technologies for marketing, supply chain management and on-line shopping
Road Transport	Asset management Route selection and design Traffic management Route optimisation	Medium to high	Increase in road asset management, planning, safety and traffic management
Accommodation and food services	Consumer search for hotels and accommodation Food delivery	Low to medium	Increased adoption in accommodation bookings and customer engagement Growth in online groceries and food delivery

Sector	Type of application	Estimated adoption 2023-24	Future possibilities to 2033-34
Rail Transport	Asset management Automated Train Management Operation optimisation Network controls	Low to medium	Increased use in asset management Growth in use in intelligent transport systems High levels of adoption in logistics
Air Transport	Navigation Safety Route optimisation Air Traffic Management Airport approaches and departures	Medium to high	Increased use of GNSS (GNAN) for navigation and safety SBAS for improved approaches with vertical guidance in regional and remote airports
Water transport (maritime operations)	Maritime navigation and safety of live at sea Management of depth at ports to optimise tonnage	Medium to high	Growth in use for route optimisation, bathymetry, and port operations
Other transport	Management of electric vehicles Management of charging infrastructure Fuel efficiency maximisation Logistics Route optimisation	Medium	Autonomous vehicles Traffic management systems Accident prevention Spatial applications in logistics Tourism transport management
Finance and insurance	PNT support for ATM operations Risk assessment in the insurance sector Customer engagement where location is relevant such as in insurance services	Medium	Adoption projected to increase in insurance sector Increased use of geocoded customer data in banking
Rental hire and real estate	Use of geospatial services in hiring services for vehicles and personal transport Geospatial services in conveyancing, marketing and analysis	Low to medium	Adoption expected to increase in hiring and rental services including personal transport Applications in real estate marketing and analysis projected to increase
Professional and technical services	Geospatial information services embedded in surveying, mapping and bathymetry Applications in architecture, engineering, design and engineering surveying	Medium to high	Adoption projected to increase to high across all areas as spatial digital twin models increasingly adopted across the sector
Education and training	Increasing use in asset management of secondary and tertiary education facilities Used in analysis of demographics and analysis as part of the education curriculum	Low to medium	Use in asset management is projected to increase substantially over the next decade. Geographic information systems projected to increase in teaching at secondary and tertiary levels.

Sector	Type of application	Estimated adoption 2023-24	Future possibilities to 2033-34
Health care and social assistance	Increasing use in planning and operations of ambulance services and delivery of primary health care and public health decision making Geospatial information plays a crucial role in epidemiology	Low to medium	Application of geospatial information is projected to increase significantly in planning and operation of health care services and in responding to disease outbreaks. It is projected to increase in epidemiology studies.
Arts and recreation	Geospatial information is used in the tourist industry for analysis and consumer experience. It is implicit in location and mapping services for hikers and adventure experience	Low to medium	The use of geospatial information in recreational activities is projected to increase Use in the tourism industry for market in facilities analysis is projected to increase over the coming decade.
Resource availability shocks			
Oil	Improved identification of resources	High	Adoption is already high in exploration and development. Its use and application will continue with increased demand on environmental management grow.
Gas	Improved identification of resources	High	Adoption is already high in exploration and development. Its use and application will continue with increased demand on environmental management grow and in maintaining the role of gas in the transition to net zero emissions of greenhouse gases.
Minerals nec.	Improved identification of resources	High	Applications in exploration particularly for critical minerals projected to increase.

Estimates of productivity impacts varied widely across different sectors. Productivity impacts in surveying and mapping for example were estimated to be as high as 50% in specific cases. Estimates of impacts of EOS and PNT in forestry monitoring were estimated to be of the order of 20% to 30% for monitoring and management. These estimates were referenced to specific applications and would be diluted across the business operations and across the sectors. Other estimates of productivity impacts were based on estimates of savings delivered by geospatial information systems from past reports and papers and from the case studies. These have been taken into account in assessing the sector wide impacts in Chapter 4.

Finding 3 Geospatial information in industry

The research found that there are few areas of industry that are not utilising geospatial information to support their business activities. Levels of adoption are highest in surveying and mapping, design and construction, exploration and production of minerals and energy, agriculture and transport.

Levels of adoption are lower in areas such as finance and insurance, health and social services, arts and recreation, rental hire, real estate, and education and training. However, there are areas of high use such as in insurance and asset management in education. The use and application of geospatial services is projected to increase in most of these areas over the next 10 years under the right circumstances.

3.4 Benefits to society and consumers

3.4.1 Introduction

Geospatial technologies offer a broad range of benefits to consumers, so much so that their use is now ubiquitous in everyday life. Many apps on a smartphone harness geospatial information.

From finding the nearest and nicest café to navigating unfamiliar streets, consumers rely heavily on navigation apps which leverage geospatial data to provide real-time directions. These technologies not only save time but also enhance safety by reducing congestion and warning drivers about road closures.

Weather applications and services, such as the BoM radar, use geospatial data to provide local forecasts, alerting consumers to upcoming weather events such as storms, heavy rain, or extreme temperatures. This information allows individuals to plan their activities accordingly, whether it's adjusting travel plans, or ensuring the safety of outdoor activities. Moreover, geospatial weather information contributes to public safety by providing early warnings for natural disasters such as hurricanes, tornadoes, and wildfires. By alerting consumers in at-risk areas, authorities can mitigate risks and ensure that residents have enough time to evacuate or prepare for emergencies.

There are also numerous health benefits to consumers. Through mobile apps and wearable devices, consumers can monitor their physical activity and track health metrics. These technologies provide individuals with valuable insights into the impacts on their health. Geospatial data enhances the accuracy and relevance of personal health information, empowering individuals to take proactive steps towards improving their health and lifestyle.

A study commissioned by Google in 2022 used a willingness to pay survey to place a value on the economic benefits to Australian consumers from the use of their products. It did this by asking consumers how much they would value the service if it was no longer free. (AlphaBeta, 2022). Google's mapping and search services depend heavily on geospatial information and services. While Google is only one of several web-based mapping and search services, this study provides a conservative insight into the value of such services to consumers.

The value of digital maps

Digital maps available on consume devises have revolutionised the way in which consumers navigate while driving, walking and even taking public transport. The use of current mapping data, real time traffic information and satellite positioning is saving time and, in some cases, stress for consumers in reaching their target destination. In the study commissioned by Google, time saved per user from using maps was estimated by calculating the difference in kilometres driven by consumers using geospatial maps relative to the situation where consumers are assumed to have access only to satellite positioning technology.

Overall, the study estimated that the value of Google Maps was **$6.3 billion** for commuters in time saved and convenience during commutes. This study focusses only on the use of digital maps and not on the added value of satellite positioning. Therefore, this figure is likely to be a conservative estimate of the value for consumers of navigation services using digital maps and positioning.

Geolocated internet searches

The study also provided insights into the value of geospatial services as they support internet searches. The 2022 study estimated time saved for consumers in internet searches by applying estimates of time saved from an experiment that measured the time taken to internet search verses the time taken to search at a library (Yan C., Grace Y., Yong-Mi, 2014).

The 2022 study estimated that Google Search saves the average Australian user 115 hours per year in time saved searching on the internet. We estimate there are approximately 18.6 million adult Google Search users in Australia, meaning these users have saved a total of 2.14 billion hours per year (by multiplying number of Australian adult Google Search users by the number of hours saved per user).

By multiplying the 2.14 billion saved hours, by the median hourly earnings of adult Australians ($39.50) and applying a value of 40% to this saved time (which is a percentage used by government to estimate the value of time-saved with infrastructure) we arrive at an estimate of the value of time saved from Google Search. Finally, this must be adjusted to only measure the value of time saved with Google Search that can be attributed to the use of geospatial information.

Approximately 30% of Google searches are related to location and 42% of all internet traffic accessed in Australia is via mobile phone. By multiplying these values, we can assume 13% of internet traffic on google is via mobile and related to location, and as such is utilising geospatial information. Therefore, we attribute 13% of this value to the geospatial information leveraged on Google Search. This comes to a total of $4.2 billion in time saved using Google Search that can be attributed to geospatial information.

Delivery tracking

Positioning technology currently plays a major role in the consumer sector by supporting delivery tracking. Last mile delivery is the transport of goods between the supplier and consumer by postal and courier services. As consumers increasingly shift to online shopping, so have their expectations of reliable and fast services. In 2017, there was a 49.2% increase in shipping consignments within Australia which was attributed to an increase in online shopping. Geospatial technology provides greater in-transit visibility and tracking throughout the supply chain, allowing a supplier to know where a parcel is.

In the future, there is the potential for automated delivery through robots which use sensors and navigation technologies to transport goods. A study of the potential benefits of automated delivery enabled by positioning technologies found that in Australia and New Zealand, a total of 16 million hours saved that could be used for other tasks from the reduction in labour required. This results in a present value of $34 million of economic savings over a 30-year time period. (EY, 2019)

The future of road transport

Traffic congestion arises when the demand for travel exceeds the capacity of existing roads. Connected Autonomous Vehicles (CAVs) are unlikely to change the physical capacity of roads but can impact congestion by increasing vehicle throughput. In 2017, Australia had 1,225 fatalities, with associated costs of approximately $30 billion, including costs from injuries, loss of life, reduced quality of life, and property damage.

To address this, Australia is implementing strategies to reduce crashes and improve road safety. They are exploring the use of Cooperative Intelligent Transport Systems (C-ITS), which can benefit from Satellite-Based Augmentation Systems (SBAS) signals. SBAS signals can improve the accuracy of vehicle positioning, enabling better demand management options such as real-time road pricing.

The implementation of CAVs and C-ITS with SBAS signals is expected to result in significant benefits. These include improved travel time reliability, reduced emissions, and increased economic productivity. Over a 30-year period, it is estimated that there will be $760 million in productivity gains in the road sector due to reduced travel times across Australia and New Zealand. Additionally, it is anticipated that 45 fatalities and 2,800 serious injuries will be avoided, resulting in an economic saving of $277 million (EY, 2019).

The Queensland Government undertook a trial of C-ITS systems under its Cooperative Autonomous Vehicles program between 2017 and 2022. Research from the trial suggested that the benefit cost ratio of investment in C-ITS systems would be around 3.7 in Queensland. The cumulative savings from crash reduction would be of the order of 2 billion over 20 years (Queensland Department of Transport and Main Roads, 2020).

Finding 4 The benefits of geospatial information to Australian consumers and society

This section highlights the varied use cases of geospatial information to consumers and society. Geospatial information is so well integrated into our devices – and indeed our lifestyles – that we often fail to comprehend the true breadth and depth of its applications. From transport to online shopping, geospatial information has been harnessed in our devices to bring great improvements to the ease and quality of life.

While it is challenging to quantify, the literature and our calculations find consumer benefits of:

- $6.3 billion per year from navigation services (in particular, Google Maps) and $4.2 billion per year from time-saved using geospatially enabled functions in search engines (Google Search)
- a present value of $34 million to consumers from delivery tracking
- reduced congestion, injury and fatality on Australian roads.

4 The economic impacts of geospatial information

This chapter reports the economic impact of the estimated productivity impacts on the national and state/territory economies. It also summarises the estimated benefits for consumers and society from geospatially enabled technologies.

4.1 Economic impacts from improved productivity

ACIL Allen's CGE model, Tasman Global, was used to calculate the economic impact of geospatial information systems and services for 2023-24 and 2033-4 for 2 scenarios in line with the methodology set out in Chapter 1.3.

The findings of the research, surveys, case studies and consultation for this study project were used to develop an assessment of the current and potential productivity impacts for sectors of the Australian economy based on the ANZSIC codes. These assessments were based on a body of evidence approach taking into account the assessment undertaken in the 2008 report.

The impacts are summarised in Table 4.1.

Table 4.1 Table of productivity impacts

	Productivity impact	2023-24	2033-34 Business as usual (BAU)	2033-34 Favorable operating environment
Grains	Multifactor productivity	7.409%	7.780%	12.000%
Livestock	Multifactor productivity	2.500%	2.750%	6.000%
Horticulture	Multifactor productivity	3.000%	3.300%	10.000%
Cotton	Multifactor productivity	3.059%	3.365%	10.000%
Sugar	Multifactor productivity	3.083%	3.237%	7.000%
Fisheries	Multifactor productivity	4.000%	4.400%	10.000%
Forestry	Multifactor productivity	4.000%	4.200%	5.500%
Mining	Multifactor productivity	2.093%	2.100%	2.500%
Oil and gas	Multifactor productivity	2.000%	2.050%	2.300%
Exploration	Multifactor productivity	10.000%	10.500%	14.000%
Manufacturing	Multifactor productivity	0.050%	0.053%	0.150%
Construction	Multifactor productivity	3.881%	3.939%	6.173%
Electricity, water and gas	Multifactor productivity	2.000%	2.030%	3.000%
Communications	Multifactor productivity	1.320%	1.386%	1.400%
Wholesale and retail (trade)	Multifactor productivity	0.080%	0.084%	0.200%
Accommodation and food services	Multifactor productivity	0.048%	0.051%	0.057%
Road transport	Multifactor productivity	3.944%	4.141%	5.371%
Rail transport	Multifactor productivity	0.621%	0.652%	0.735%
Water transport	Multifactor productivity	0.394%	0.414%	0.790%
Air and space transport	Multifactor productivity	1.713%	1.798%	1.947%

	Productivity impact	2023-24	2033-34 Business as usual (BAU)	2033-34 Favorable operating environment
Other transport and warehousing	Multifactor productivity	0.494%	0.504%	0.543%
Financial and insurance services	Multifactor productivity	0.050%	0.053%	1.000%
Rental hire and real estate	Multifactor productivity	0.087%	0.091%	0.114%
Professional, technical and scientific services	Labour productivity	0.606%	0.667%	1.028%
Administrative services				
Public administration and safety	Labour productivity	3.000%	3.120%	4.000%
Education and training				
Health care and social assistance	Multifactor productivity	0.076%	0.078%	1.000%
Arts and recreation				
Resource availability oil	Resource availability	4.000%	4.060%	4.900%
Resource availability gas	Resource availability	5.000%	5.100%	5.940%
Resource availability minerals	Resource availability	9.000%	9.180%	13.860%
Coal	Resource availability	1.500%	1.50%	1.50%
General savings from natural disasters reduction	Multifactor productivity	0.187%	0.190%	0.230%
General time savings for administrative functions in government and business ($m)		103,025,696	103,025,696	103,025,696

Source: ACIL Allen estimates based on research

4.1.1 Results

The results of the CGE modelling are summarised in Table 4.2. The results of the modelling reflect the direct impacts of the productivity gains in each sector plus the indirect or economy wide impacts of the gains on the whole economy as the gains work their way through the economy.

Table 4.2 Impact of geospatial information services on GDP, Income and Employment

	2023-24	2033-34 BAU	2033-34 Favourable operating environment
	$million	**$million**	**$million**
Gross Domestic Product	38,568	62,394	89,514
Real income	29,290	55,895	76,880
Employment	12,114	21,674	31,849

Source: ACIL Allen

Impact on GDP

The impact of modern geospatial information services on GDP in 2023-24 is estimated to be **$38,568** higher than it would have otherwise been.

— This represents a Compound Average Annual Growth Rate (CAGR) of around **9%** over the 17 years from 2006-07 to 2023-24.

The impact of geospatial information services on GDP is projected to be:

— **$62,394 million** higher in 2033-34 under the BAU scenario.
  – This represents a CAGR of **5%** between 2023-24 and 2033-34.
— **$89,514 million** higher under the favourable operating environment.
  – This represents a CAGR of around **9%** between 2023-24 and 2033-34.

The favourable operating environment scenario will return the CAGR to the earlier growth rates that were observed between 2007-08 and 2023-24.

Impact on real income

Real Income (RI) represents the income to Australian citizens plus company profits. Income is an indication of the economic welfare of all Australians.

The impact of modern geospatial information services on RI in 2023-24 is estimated to be **$29,290 million** higher than it would have otherwise been.

The impact of geospatial information services on RI is projected to be:

— **$55,895 million** higher in 2033-34 under the BAU scenario
— **$76,880 million** higher than it would otherwise be in 2033-34 under the favourable operating environment.

Impact on employment

The impact of modern geospatial information services on employment in 2023-24 is estimated to be **12,114 FTE** higher than it would have otherwise been.

The impact of geospatial information services on employment is projected to be:

— **21,674 million FTE** higher in 2033-34 under the BAU scenario
— **31,849 million FTE** higher than it would otherwise be in 2033-34 under the favourable operating environment.

Impacts by State and Territory

The impact on GDP by State and Territory for the BAU and favourable operating environment is summarised in Table 4.3. The table shows that all states and jurisdictions benefit from higher Gross State Product (GSP) in 2023-24 as a result of the impact of geospatial information services. Western Australia benefits the most as a result of the large component of mining and agriculture in its economy followed by New South Wales, Queensland and Victoria.

A similar pattern is projected to occur in 2033-34 with a significant difference between the BAU and favourable operating environment scenario.

Table 4.3 Impact on Gross State Product (GSP) by State and Territory of geospatial services

Jurisdiction	2023-24	2033-34 BAU	2033-34 Favourable operating environment
	$million	**$million**	**$million**
New South Wales	9,757	15,017	21,660
Victoria	6,285	10,556	15,414
Queensland	8,170	14,058	19,825
South Australia	2,057	3,092	4,546
Western Australia	10,731	17,371	24,764
Tasmania	591	795	1,190
Northern Territory	496	712	1,049
Australian Capital Territory	481	794	1,064
Australia	38,568	62,394	89,514

Source: ACIL Allen

Note: all amounts are in $A (2023-24)

Impact by sector

The economy wide impacts on selected sectors are shown in Table 4.4. The table shows that the sectors that benefit the most in 2023-24 are mining, government services, construction and agriculture. Under the favourable operating environment, the impact grows for all sectors.

Table 4.4 Additional Gross Value Added for selected industry sectors

Sector	2023-24	2033-34 BAU	2033-34 Favourable operating environment
	$million	**$million**	**$million**
Mining	11,685	11,543	17,561
Government services and health	4,093	7,535	9,499
Construction	3,498	4,398	6,557
Manufacturing	1,468	4,279	5,510
Financial services an insurance	1,641	4,055	6,289
Agriculture, fisheries and forestry	2,344	3,097	6,572
Transport	1,456	2,808	3,544
Utilities (electricity, gas and water)	1,778	2,330	3,180

Source: ACIL Allen CGE modelling

Note 1: All amounts are in $A (2023-24)

Note 2: Table does not include all sectors of the economy

4.2 Benefits to consumers and society

The value of benefits to consumers and society are likely to be very large given the ubiquity of geospatial information that is now available through smart phones, personal computers and increasingly integrated into machines and equipment such as car navigation systems. The Internet of Things (IoT) is a reality for geospatial information.

Our assessment of this value is based only on a selection of use cases discussed in Section 3.4 above. The examples we have drawn on are savings in commuter times, future savings in delivery services, improved travel times, emissions reductions from future use of CAV and C-ITS services and reduced fatalities for such services. The last 2 examples are expected to have their main impact in the future. The results are shown in Table 4.3 below.

Table 4.5 Consumer benefits

	2023-24	2033-34 BAU	2033-34 Favourable operating environment
	$ billion	**$ billion**	**$ billion**
Value of maps to consumers from willingness to pay survey	6.300	7.280	7.740
Contribution of geospatial information in savings in time for internet searches	4.200	4.841	5.163
Last mile delivery savings for consumers		0.002	0.003
Improved travel time and emissions reductions		0.056	0.060
Reduced fatalities		0.020	0.022
Total	10.500	12.200	12.988

Note: Benefits for transport related items are also likely in 2023-24, however there was limited data available for that year.

Source: Based on estimates from (AlphaBeta, 2022) and (EY, 2019)

Note: all amounts are in $A (2023-24)

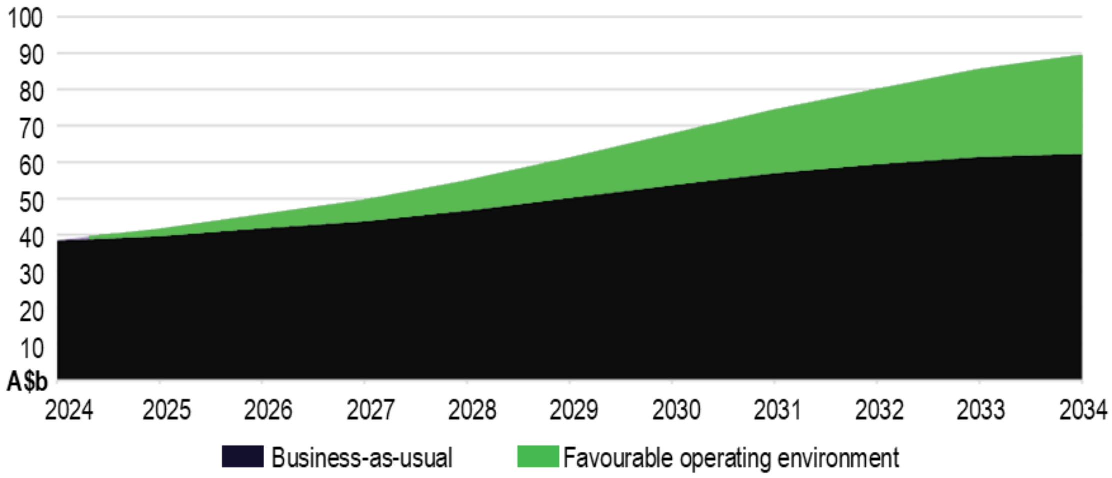
Geospatial services have created value to consumers of around $10.5 billion in 2023-24. With population and economic growth, this value could rise to between $12.2 billion and $13.0 billion by 2023-34

The increases in 2033-34 are based on an assumption that the growth under the BAU case will be consistent with projected growth in population of 1.43% per year annum under the business-as-usual scenario and growth under the favourable operating environment scenario of 2.09% per annum in line with projected growth in economic output of 2.09%.

4.3 What would shift the dial

There is a large difference in the estimate of economic impact for in the 2 scenarios assessed in this study (see Figure 4.1). These projections are a best estimate of a BAU and a favourable operating environment scenario. It is possible that the BAU scenario could be lower, and the favourable operating environment could be higher depending on the future operating environment.

Figure 4.1 Impact on GDP of the 2 scenarios



Source: ACIL Allen

Which path is realised depends on a number of variables. To achieve a higher outcome, it will be necessary to regain the momentum of adoption and innovation that was maintained over the 2008 to 2020 period and lost to some extent over the COVID period.

Which path is realised depends on a number of factors including:

Digital and data frameworks inclusive of geospatial

— mechanisms and policies for sharing geospatial data including ownership, access and security, in the course of progressing the digital transformation agenda

Strengthening linkages with adjacent parts of the economic ecosystem

— consolidating the relationship between geospatial information, digital engineering and critical infrastructure

— progress on spatial digital twins by State/Territory, local government and the private sector with strong overlap of digital twins and digital engineering

Enhance essential enabling technologies and systems

— the level of investment in geodesy, the Foundation Spatial Data Framework and bathymetry

— secure access to space-based systems and services including Earth observations from space, Position Navigation and Timing, and satellite communications, through system redundancy or sovereign alternatives

— progress in adoption of automated technologies such as applied AI and PNT to support greater application of autonomous machinery, vehicles, vessels and aircraft

Innovation for economic and social impact

— research and development to build knowledge and innovation to empower Australia's geospatial sector to better enable key industries and professions as well as governments and public programs

Build professional communities

— workforce availability in the geospatial field at both professional and technical levels with accelerated education and training availability.

There are risks in some areas. For example, the United Nations – Global Geodetic Centre of Excellence reported on concerns over the global geodesy supply chain and the linkages to critical infrastructure (UN-GGCE, 2024). The report estimated that outages of just 48 hours on PNT services would have an impact exceeding $2 billion. There are also concerns over workforce availability in the geospatial sector in Australia. These are examples of factors that are likely to influence future outcomes.

Realising the full potential of geospatial information services will depend on progress on the above factors.

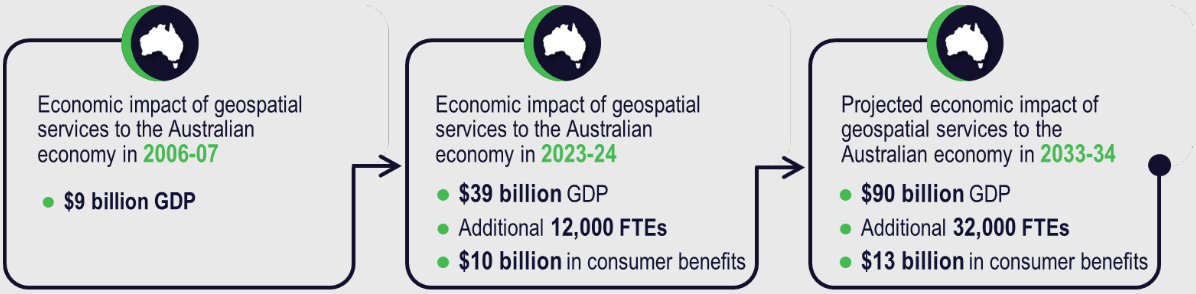
Finding 5 Summary of economic impacts

Geospatial information and services are critical to increasing productivity, managing natural resources and the welfare of all Australians.

Every one of us uses geospatial information and services on a daily basis, to help make our lives easier.

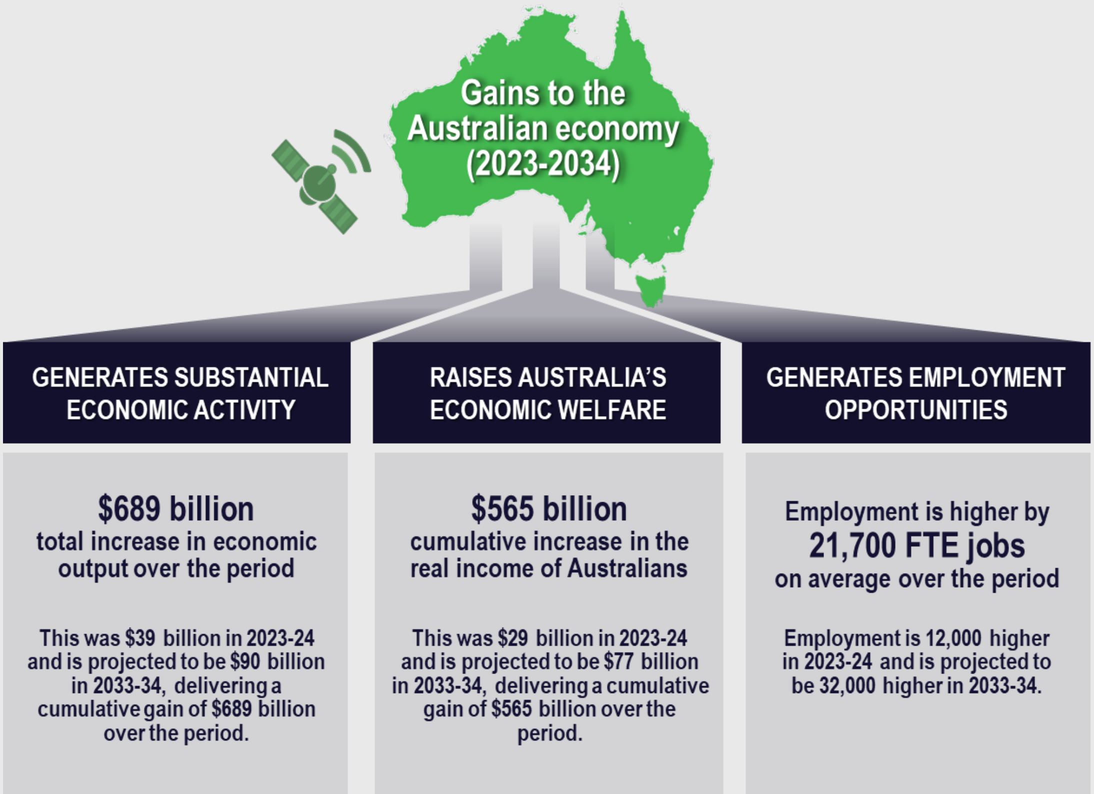
The sector in 2023-24 will contribute an additional $39 billion to Australian gross domestic product (GDP) and over 12,000 jobs.

By 2033-34, it is projected that the contribution could be an additional $89.5 billion in GDP and an additional 22,000 jobs.



Geospatial services have a range of economic and other impacts. Some other impacts can be difficult to quantify and monetise. The economic analysis only captures the direct and indirect economic impacts of geospatial services in Australia and in each state and territory.

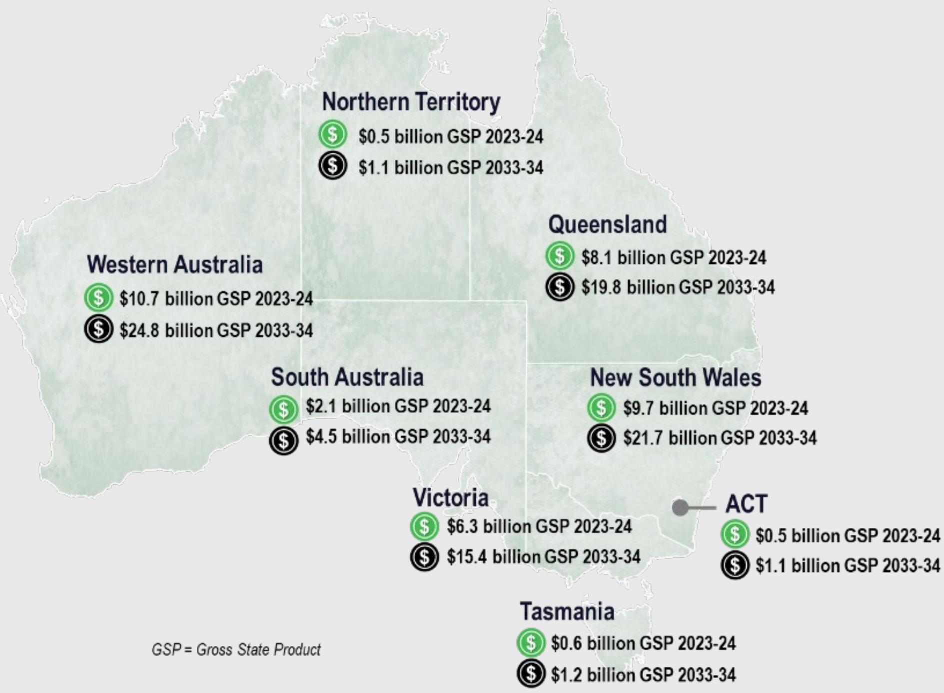
Over the next decade, the economic impacts in terms of economic activity, economic welfare and the employment opportunities generated are significant.



Finding 6 Impacts by state and territory and by industry

Geospatial services and information deliver economic benefits to a broad range of end-users and beneficiaries in each Australian state and territory.

Each state and territory's economy is structured differently. This means that economic impacts are not evenly distributed across Australia but are proportionate to the size of the economy in each state and territory.



Geospatial services and information significantly contribute to the gross value add for a broad range of industries important to the Australian economy. The figures below are the total accumulated increase in Gross Value Add over the period from 2024 to 2034 (undiscounted).

	Under the business-as-usual scenario increases GDP by 2023-24	Under the favourable operating environment scenario increases GDP by 2033-34
Mining	$126.8 billion	$160.7 billion
Government services	$63.2 billion	$72.4 billion
Construction	$43.7 billion	$54.7 billion
Manufacturing	$31.3 billion	$36.9 billion
Financial services & insurance	$32.5 billion	$42.2 billion
Agriculture, forestry and fishing	$30.0 billion	$47.9 billion
Transport	$23.2 billion	$26.7 billion
Utilities	$22.8 billion	$27.2 billion

Finding 7 Value consumers

Geospatial information and services create value for consumers of **$10.5 million in 2023-24** and between **$12.2 billion and $13.0 billion by 2033-34**.

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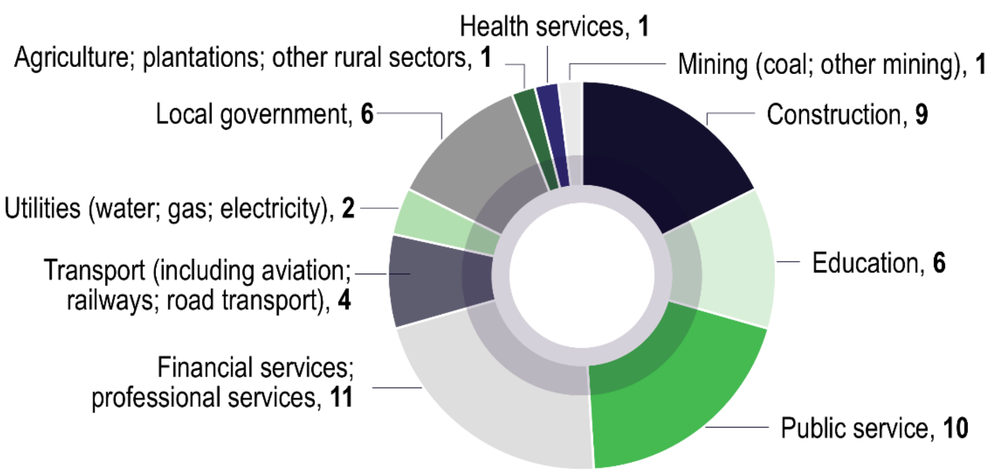
Appendices

A Survey

An online survey was conducted and promoted by the Geospatial Council of Australia. At total of 51 responses were received. The largest number of responses came from financial and professional services (11), the public sector (14) and construction (9).

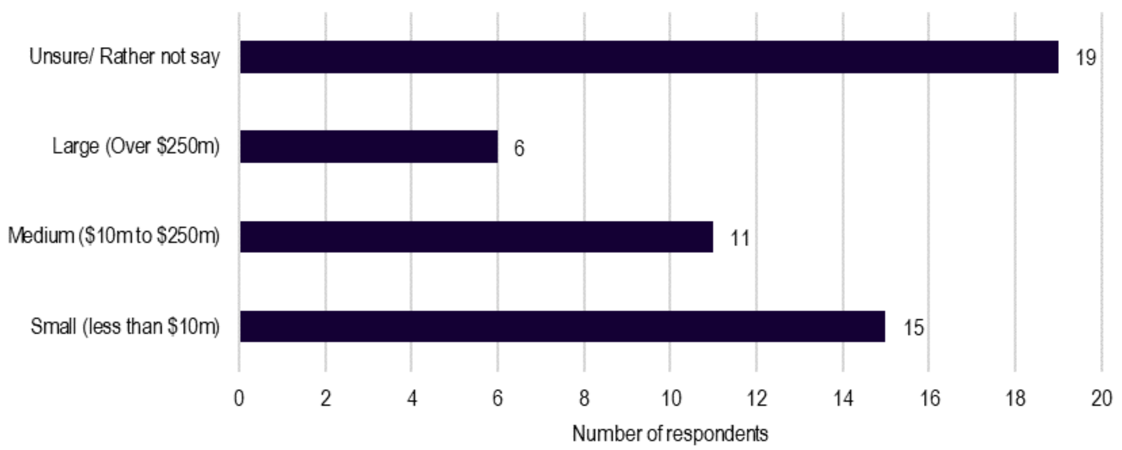
Of the total responses, 15 were from smaller organisations with annual turnover of less than $10 million, 11 were from medium sized organisations with annual turnover between $10 million and $250 million and 6 were from large organisations with annual turnover in excess of $250 million. Nineteen respondents did not give a turnover figure.

Figure A.1 Breakdown of respondents' industry



Source: ACIL Allen

Figure A.2 Organisation size



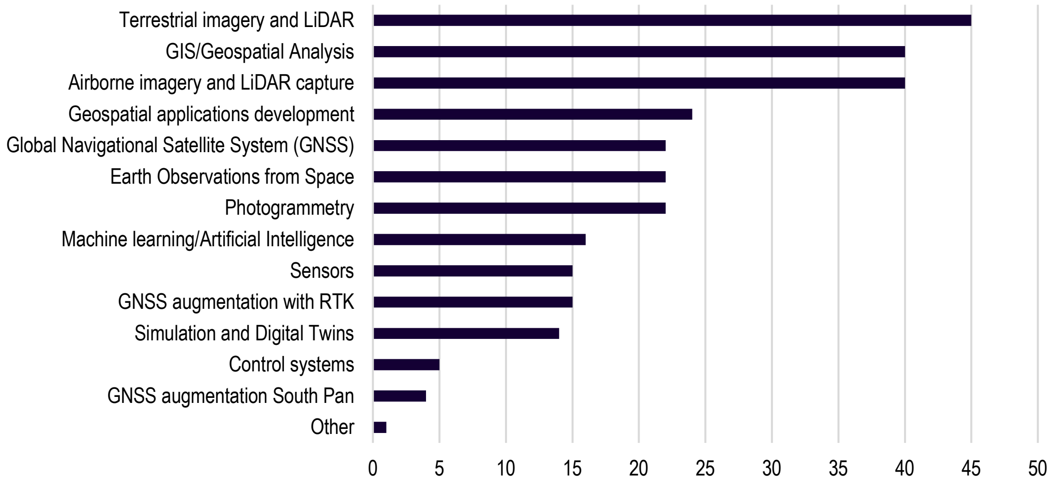
Source: ACIL Allen

The survey discussed included a question on what technologies were used be respondents. While only 51 organisations responded the distribution of technologies shown in Figure A.3 below provides some insight into the current use of geospatial information services in Australia.

The results show the current dominance of terrestrial imagery and LIDAR, GIS and geospatial analysis airborne imagery and LIDAR, geospatial applications development, GNSS, EOS, photogrammetry and machine learning and AI. It is interesting to note the level of use of machine learning and artificial intelligence.

Other areas, such as application of digital twins and SouthPAN are low because the technologies and applications are only in the early stages of introduction.

Figure A.3 Geospatial information services reported by respondents to the survey



Source: ACIL Allen

Some respondents only completed parts of the survey. The results of those that did respond were analysed and used to support estimates of productivity impacts for this study. The results of this analysis are summarised in Table A.1 below.

Table A.1 Data from survey

Sector	Number of responses	Main use	Adoption levels	Local productivity impact
Agriculture	1	Farm mapping for nutrient and environmental mapping	Not reported	11% in 2023-24 rising to 36% in 2033-34
Construction	9	GNSS, location-based data, plan production, engineering surveys, design construction and mapping.	11% to 50% in 2023-24	11% to 36% in 2023-24
Education	6	Asset management, ecosystem monitoring, land cover and urban planning, data collection	11% to 50% in 2023-24	36% to 50%
Professional services	10	Surveying and mapping subdivision and land development, asset management, critical infrastructure and risk prevention, provision of geospatial services including remote sensing and positioning, project support, machine learning and artificial intelligence.	11% to 50 in 2023-24	11% to 50% In 2023-24
Health services	1	Geocoded patient demographic data , health service sites and data analysis.	~11%	Not reported
Mining	1	Applications of aerial imagery and LIDAR, EOS, positioning, machine learning and artificial intelligence applied to mining applications.	~11%	Not reported
Transport	4	Development and maintenance of road and rail corridors, road design, inventory, intelligent transport systems, safety.	36% to 50% in 2023-24	36%
Utilities	2	Infrastructure and asset management	50%	36%
Public service	10	Resources management, marine and coastal management, weather information.	11% to 50% in 2023-24	11% to 50% in 2023-24 and 2033-34
Local government	6	Property information, aerial imagery, fire management zones, soil nutrients conservation and monitoring.	36% to 50% in 2023-24	11% to 50% in 2023-24 and 50% in 2033-34.

Source: ACIL Allen

B Case Study List

Table B.1 Case Study List

Case study	Organisation	Beneficiary	Case study	Organisation	Beneficiary
Emergency Management					
Early warnings to attack remote bushfires	Tasmanian Government	Emergency services, society and businesses	Emergency Information Coordination Unit (EICU)	NSW Spatial Services	Insurance providers, emergency management, society and businesses
JLL and ESRI Australia	ESRI	Public administration and safety	Planned burns program	Victorian Department Environment Protection Branch	Insurance providers, emergency management, society and businesses
Australian Government's National Joint Common Operating Picture (NJCOP)	ESRI	Public administration and safety	Capturing data during flood incidents	Spatial services	Insurance providers, emergency management, society and businesses
Emergency services uses G-NAF for accurate address data	Geoscape	Public administration and safety	Telecommunications and utilities infrastructure	Spatial Services	Public administration and safety
Enabling Emergency Flood Response Deloitte Australia	Deloitte	Public administration and safety	Tsunami Modelling – The value of seabed mapping	Deloitte, Geoscience Australia	Marine sector, society and business
2022 NSW Floods Case Study	NSW Department of Customer Services	Insurance providers, emergency services, society and businesses	Speeding disaster assessments for A1 Services	NearMap	Insurance providers, emergency management, society and businesses
National Exposure Information System (NEXIS) and the Australian Exposure Information Platform (AEIP)	Geoscience Australia	Public administration and safety	Disaster recovery	NearMap	Public administration and safety
Severe Wind Hazard Assessment for Southeast Queensland	Geoscience Australia	Public administration and safety	Australian Red Cross	NearMap	Society and businesses
Satellite Tasking	Land Victoria	Public administration and safety	Digital Earth Australia Hotspots	CSIRO, GA	Public administration and safety
Machine Learned Data	Land Victoria	Public administration and safety	Economic study into an Australian continuous launch small satellite program for Earth observation	Deloitte, Aus Space Agency	Society and businesses
Forest Fire Management	Land Victoria	Insurance providers, emergency management, society and businesses	Consistent information in times of emergency	NSW Govt	Insurance providers, emergency management, society and businesses
Geospatial's role in government services	Spatial Source	Public administration and safety			
Planning, construction, and digital twins					
Greater Hobart Digital Twin	Hobart City Council	Society and businesses	Gravity Model	NSW	Researchers
SmarterWX	ESRI	Professional services	School Infrastructure	NSW	Society and businesses
Queensland Globe	ESRI	Society and businesses	Addressing data and Place Names in Australia	ICSM	Society and businesses
NSW Digital Connectivity Index	ESRI	Society and businesses	Visualising big construction	Here	Professional services
FSDF Case Studies	NSW	Society and businesses	Economic impact of NPIC	Geoscience Australia	Society and businesses
Victorias DCM and Digital Transformation program	Land Use Victoria and Spatial vision	Society and businesses	Economic impact of SouthPan	Geoscience Australia	Society and businesses
GIS in energy systems	ESRI	Energy sector	PlanSA portal	Dept of Trade and Investment SA	Society and businesses

Case study	Organisation	Beneficiary	Case study	Organisation	Beneficiary
Ambient Maps Geoscape Buildings	Geoscape	Planning and construction	Digital twin Victoria	NPIC Report, Land Victoria	Society and businesses
Buildings data increases efficiency in wind modelling by reducing manual drawings	Geoscape	Society and businesses	Great Ocean Road Survey	NPIC report	Society and businesses
Geoscape spatial data reduces cost of noise modelling by 50% for GHD	Geoscape	Society and businesses	Professional services	NPIC report	Professional services
The University of Queensland	Geoscape	Researchers	Digital transformation program	Land Victoria	Society and businesses
Altavec White Paper	Altavec	Society and businesses	Intelligent water networks	Position magazine	Water industry
DPLXML to SCIMS	NSW	Utilities and underground services	GIS Energy Networks	Position Magazine	Energy industry
Smart Places Acceleration program	Camden Council, NSW Department of Customer Service, Department of Planning and Environment, Live.NSW, NSW Spatial Services, Aerometrex, Giraffe Technology	Planning and construction	Planning and Land use studies	Dept of Trade and Investment SA	Planning and architecture
Cardinia Tree Location positioning	Veris	Planning and construction	Cadastre NSW Stakeholder Analysis Report	NSW Land and Property	Society and business
Hobart Rivulet	Veris	Society and business	Gunditj Mirring Traditional Owners Aboriginal Corporation LiDAR Capture	Victoria Department of Environment, Land Water and Planning	Society and businesses
Transport for NSW M6 Stage 1 project	Veris	Surveying and mapping	Digital twin white paper	Standards Australia	Society and businesses
Mount Crosby Pumping Station Digital Twin	Veris	Society and business	NSW Foundation Spatial Data Framework	Department of Customer Services, Spatial Services	Planning and construction
MTMS Central Station	Veris	Society and business	NSW Point	Spatial Services and Geoscape	Geospatial services
North West Coast Underwater Bridge Inspections	Veris		Before You Dig Australia (BYDA)	Before You Dig Australia	Construction sector
Paradise Gorge	Veris	Society and business	eComply	Land Use Victoria, Archistar	Planning and construction
Waterloo Integrated Station Development	Veris	Society and business	Virtual Asset Management	Tech Mahindra - Altavec	Planning and construction
Neighbourhood development plans	Fyfe	Society and business	Western Australia Digital Twin Program	Government of Western Australia, Landgate	Society and businesses
SmartNSW Case Study	NSW Government	Society and businesses	Bathurst Integrated Medical Centre (BIMC)	NSW Department of Customer Service, Spatial Services, Bathurst Regional Council	Society and businesses
TechnologyOne “OneCouncil” Property and Ratings database	Queanbeyan - Palerang Council	Society and businesses	GeoServer	OSGeo Oceania	Society and businesses
National Flood Information Data Base	Insurance Council of Australia and State Governments	Emergency services			
Resources and Mining					
SafeAI (collision avoidance systems)	ACIL Allen	Resources and mining sector	Blinman mines	Geoff Sandford	Resources and mining sector
Automated road trains	Hexagon	Resources and mining sector	Fairways project	Geoscience Australia	Resources and mining sector
Economic Fairways project	Geoscience Australia	Resources and mining sector	AusCope infrastructure program	Lateral Economics	Resources and mining sector
Identifying critical minerals	CSIRO	Resources and mining sector	Exosphere	Fleet	Resources and mining sector

Case study	Organisation	Beneficiary	Case study	Organisation	Beneficiary
Environment and Climate Change					
Climate Change and Extreme Weather	Spatial vision	Society and business	Coastal Climate Change Impact Assessment	Spatial vison	Government, society and business
National Greenhouse and Energy Reporting Scheme	Clean Energy Regulator	Government, society and business	AquaWatch	CSIRO	Society and business
Climate Risk Webmap	Spatial vision	Government, society and business	Drones	MPDI	Society and business
SECCA	Spatial vision	Government, society and business	Environment water and climate change	CSIRO	Society and business
Embedding climate adaptation in Agriculture in North East Victoria	Spatial vision	Society and business	Shared environmental analytics facility (SEAF)	WA Marine Science	Society and business
Dashboard for Environmental mapping	Spatial vision	Society and business	Regional and National Scale Airborne Electromagnetic (AEM) Data for Groundwater	Geoscience Australia	Society and business
Geoscape Australia Leveraging Property Intelligence for a Net Zero Future	Geoscape	Planning and developers	Robe coastline	Council of Robe	Society and business
South Stradbroke Island shoreline stabilisation	Geoscience Australia	Society and business	Climate change adaptation project - Public Transport Asset management	Victorian Department of Transport and Planning	Society and business
The Superbank and sand-dredging infrastructure at the Tweed River mouth	Geoscience Australia	Society and business	ELVIS	Geoscience Australia	Society and business
Australian Marine Information System (AMSIS)	Geoscience Australia	Society and business	SavBat	Spatial vision	Society and business
Australian Hydrological Geospatial Fabric	BOM	Society and business	K2Fly natural resource governance	Frontier SI	Society and business
Unravelling the mysteries of Norfolk Island's tiger sharks	ESRI	Researchers	Victoria Unearthed	Victoria Department of Environment, Land Water and Planning	Society and business
eReefs forecasting and modelling program	CSIRO	Researchers and Great Barrier Reef			
Defence					
Capability demonstrator	SmartSat CRC	Defence sector	Quantum-assured position, navigation and timing	Dept of Defence	Defence sector
GEO INT	Dept of Defence	Defence sector	Open space virtual walk through for Defence Estate	Dept of Defence	Defence sector
Agriculture					
LCAT - ESRI	ESRI	Agricultural businesses	Precision agriculture technologies in avocado production systems	AARSC	Avocado producers
Swarm farm	SwarmFarm Robotics	Agricultural businesses	Benefits of Satellite-Based Augmented Systems (SBAS) across Australia and New Zealand to broadacre production	Geoscience Australia	Broadacre production
Precision agriculture	US Congress GAO	Agricultural businesses	Benefits of the precise positioning to grain growers	Geoscience Australia	Grain growers
Rural intelligence platform	CSIRO	Agricultural businesses	Horticulture industry maps	The University of New England (UNE)	Horticulture industry maps
Australian citrus orchards	Citrus Australia, Agriculture Victoria, and the Applied Agricultural Remote Sensing Centre (AARSC)	Agricultural businesses			

Case study	Organisation	Beneficiary	Case study	Organisation	Beneficiary
Biosecurity					
Red Imported Fire Ant (RIFA)	Outline Global	Agricultural businesses and society	Khapra beetle	CEBRA	Agricultural businesses and society
Leafminer	Hort Innovation in partnership with Cesar Australia	Agricultural businesses and society	Impact of the NSW Foundation Spatial Data Framework on Varroa mite response	NSW Government	Agricultural businesses and society
Transport					
Road Management Information System (ARAMIS)	Qld Department of Transport and Main Roads Investment Program (QTRIP)	Society and businesses	Heavy Vehicle Access Management System	Tasmanian Department of State Growth	Society and businesses
ARTC – Inland Rail Project	Qld Department of Transport and Main Roads	Society and businesses	Integrity and efficiency monitoring for intelligent transport	ACIL Allen	Society and businesses
Cooperative and Automated Vehicle Initiative	Here and the Queensland Department of Transport and Main Roads	Society and businesses	Supply chain logistics	Here	Society and businesses
National heavy vehicle register	Spatial vision	Society and businesses	Port Hedland Under Keel Clearance	ICSM, Pilbara Port Authority and MMA Offshore	Society and businesses
Improving accuracy for Tom Tom	Geoscape	Society and businesses	Development of a point density map for automated ship identification system	AMSA	Society and businesses
Navigation technologies	Here	Society and businesses	Route optimisation	Here	Society and businesses
Government					
ABS's role in providing geographically categorised data	Australian Bureau of Statistics	Society and businesses	Wotchit Demonstrator	Numaps	Society and businesses
Digital Atlas of Australia	Geoscience Australia/Australian Bureau of Statistics	Society and businesses	Local government Planning approvals	Land Use Victoria	Local government
Mapping Indigenous place names in West Wyalong	ESRI	Society and businesses	Using Geoscape's predictive AI to assist responders self serve when responding to the census on line	Geoscape	Society and businesses
City of Sydney Tree Mapping	ESRI	Society and businesses	Address API provides accurate addresses to EWON, improving service delivery	Geoscape	Society and businesses
Mapping emergency medicine and hospital network	Spatial vision	Medical services, society and businesses	COVID border pass	Geoscape	Society and businesses
1800 My Options	Spatial vision	Society and businesses	Australian Analytical Statistics	ASA	Society and businesses
City of Kingston	Spatial vision	Society and businesses	Exploring heritage listings online	Tasmanian Government	Society and businesses
Cohga Case Study Cultural Heritage	Cohga	Society and businesses	Flood Awareness Online - Brisbane	ESRI	Emergency services, society and business
Women's health atlas	Spatial vision	Society and businesses	A study of the economic value of G-NAF	Geoscape, Lateral Economics	Society and businesses
DCS Spatial Services	Geoscape	DCS Spatial Services	Sensing Value uses Geoscape location data to design smart cities for Greater Launceston	Geoscape	Planning and construction
How address verification technology helps ACT Government reduce costs	Geoscape	Government	Data on demand simplifies noise modelling	SLR Consulting, Geoscape	Society and businesses
NSW Point makes finding your local council easy	NSW	Society and businesses			

Case study	Organisation	Beneficiary	Case study	Organisation	Beneficiary
Specific geospatial services					
Seabed Survey Coordination Tool	Geoscience Australia	Marine sector	Faster deliveries	Here	Society and business
MondoPin	ACIL Allen	Planning and construction	Deformation monitoring	Monitum Kurloo	Society and business
Public-private collaboration delivering a unified positioning network	ACIL Allen	Society and business	Navigation technologies – Safe remote adventures	Here	Society and business
Navigation technologies – What3Words	Here	Society and business			

C Overview of Tasman Global

Tasman Global is a dynamic, global CGE model that has been developed by ACIL Allen for the purpose of undertaking economic impact analysis at the regional, state, national and global level.

A CGE model captures the interlinkages between the markets of all commodities and factors, taking into account resource constraints, to find a simultaneous equilibrium in all markets. A global CGE model extends this interdependence of the markets across world regions and finds simultaneous equilibrium globally. A dynamic model adds onto this the interconnection of equilibrium economies across time periods. For example, investments made today are going to determine the capital stocks of tomorrow and hence future equilibrium outcomes depend on today's equilibrium outcome, and so on.

A dynamic global CGE model, such as *Tasman Global*, has the capability of addressing total, sectoral, spatial and temporal efficiency of resource allocation as it connects markets globally and over time. Being a recursively dynamic model, however, its ability to address temporal issues is limited. In particular, *Tasman Global* cannot typically address issues requiring partial or perfect foresight. However, as documented in Jakeman et al (2001), it is possible to introduce partial or perfect foresight in certain markets using algorithmic approaches. Notwithstanding this, the model does have the capability to project the economic impacts over time of given changes in policies, tastes and technologies in any region of the world economy on all sectors and agents of all regions of the world economy.

Tasman Global was developed from the 2001 version of the Global Trade and Environment Model (GTEM) developed by ABARE (Pant 2001) and has been evolving ever since. In turn, GTEM was developed out of the MEGABARE model (Hanslow and Hinchy 1996), which contained significant advancements over the Global Trade Analysis Project (GTAP) model of that time (Hertel 1997).

C.1 A dynamic model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare 2 equilibriums (one before an economic disturbance and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues for which both the timing of and the adjustment path that economies follow are relevant in the analysis.

C.2 The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the GTAP database (Aguiar et al. 2019). This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities. It is the most detailed database of its type in the world.

Tasman Global builds on the GTAP database by adding the following important features:

— a detailed population and labour market database

— detailed technology representation within key industries (such as electricity generation and iron and steel production)

— disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG

— the ability to repatriate labour and capital income

— explicit representation of the states and territories of Australia

— the capacity to represent multiple regions within states and territories of Australia explicitly.

Nominally, version 10.1 of the *Tasman Global* database divides the world economy into 153 regions (145 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian or international projects or policies at the regional level including at the or at the state/territory/provincial level for various countries.

The Tasman Global database also contains a wealth of sectoral detail currently identifying up to 76 industries (Table C.1). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands.

Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input.

Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, transport and iron and steel sectors are modelled using a ‘technology bundle’ approach. With this approach, different known production methods are used to generate a homogeneous output for the ‘technology bundle’ industry. For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which has its own cost structure.

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

Table C.1 Standard sectors in the *Tasman Global* CGE model

No.	Name	No.	Name
1	Paddy rice	39	Diesel (incl. nonconventional diesel)
2	Wheat	40	Other petroleum, coal products
3	Cereal grains nec	41	Chemical, rubber, plastic products
4	Vegetables, fruit, nuts	42	Iron ore
5	Oil seeds	43	Bauxite
6	Sugar cane, sugar beet	44	Mineral products nec
7	Plant- based fibres	45	Ferrous metals
8	Crops nec	46	Alumina
9	Bovine cattle, sheep, goats, horses	47	Primary aluminium
10	Pigs	48	Metals nec
11	Animal products nec	49	Metal products
12	Raw milk	50	Motor vehicle and parts
13	Wool, silkworm cocoons	51	Transport equipment nec
14	Forestry	52	Electronic equipment
15	Fishing	53	Machinery and equipment nec
16	Brown coal	54	Manufactures nec
17	Black coal	55	Electricity generation
18	Oil	56	Electricity transmission and distribution
19	LNG	57	Gas manufacture, distribution
20	Other natural gas	58	Water
21	Minerals nec	59	Construction
22	Bovine meat products	60	Trade
23	Pig meat products	61	Road transport
24	Meat products nec	62	Rail transport
25	Vegetables oils and fats	63	Pipeline transport
26	Dairy products	64	Water transport
27	Processed rice	65	Air transport
28	Sugar	66	Transport nec
29	Food products nec	67	Warehousing and support activities
30	Wine	68	Communication
31	Beer	69	Financial services nec
32	Spirits and RTDs	70	Insurance
33	Other beverages and tobacco products	71	Business services nec
34	Textiles	72	Recreational and other services
35	Wearing apparel	73	Public Administration and Defence
36	Leather products	74	Education
37	Wood products	75	Human health and social work activities
38	Paper products, publishing	76	Dwellings

Source: ACIL Allen

Note: nec = not elsewhere classified

C.3 Model structure

Given its heritage, the structure of the *Tasman Global* model closely follows that of the GTAP and GTEM models and interested readers are encouraged to refer to the documentation of these models for more detail (namely Hertel 1997 and Pant 2001, respectively). In summary:

- The model divides the world into a variety of regions and international waters.
  - Each region is fully represented with its own 'bottom-up' social accounting matrix and could be a local community, an LGA, state, country or a group of countries. The number of regions in a given simulation depends on the database aggregation. Each region consists of households, a government with a tax system, production sectors, investors, traders and finance brokers.
  - 'International waters' are a hypothetical region in which global traders operate and use international shipping services to ship goods from one region to the other. It also houses an international finance 'clearing house' that pools global savings and allocates the fund to investors located in every region.
  - Each region has a 'regional household'[5] that collects all factor payments, taxes, net foreign borrowings, net repatriation of factor incomes due to foreign ownership and any net income from trading of emission permits.
- The income of the regional household is allocated across private consumption, government consumption and savings according to a Cobb-Douglas utility function, which, in practice, means that the share of income going to each component is assumed to remain constant in nominal terms.
- Private consumption of each commodity is determined by maximising utility subject to a Constant Difference of Elasticities (CDE) function which includes both price and income elasticities.
- Government consumption of each commodity is determined by maximising utility subject to a Cobb-Douglas utility function.
- Each region has *n* production sectors, each producing single products using various production functions where they aim to maximise profits (or minimise costs) and take all prices as given. The nature of the production functions chosen in the model means that producers exhibit constant returns to scale.
  - In general, each producer supplies consumption goods by combining an aggregate energy-primary factor bundle with other intermediate inputs and according to a Leontief production function (which in practice means that the quantity shares remain in fixed proportions). Within the aggregate energy-primary factor bundle, the individual energy commodities and primary factors are combined using a nested Constant Elasticity of Substitution (CES) production function, in which energy and primary factor aggregates substitute according to a CES function with the individual energy commodities and individual primary factors substituting with their respective aggregates according to further CES production functions.
  - Exceptions to the above include the electricity generation, iron and steel and road transport sectors. These sectors employ the 'technology bundle' approach developed by ABARE (1996) in which non-homogenous technologies are employed to produce a homogenous output with the choice of technology governed by minimising costs according to a modified Constant Ratios of Elasticities of Substitution, Homothetic (CRESH) production function. For example, electricity may be generated from a variety of technologies (including brown coal, black coal, gas, nuclear, hydro, solar etc.), iron and steel may be produced from blast furnace or electric arc technologies, while road transport services may be supplied using a range of different vehicle technologies. The 'modified-CRESH' function differs from the traditional CRESH function by also imposing the condition that the quantity units are homogenous.

[5] The term "regional household" was devised for the GTAP model. In essence it is an agent that aggregates all incomes attributable to the residents of a given region before distributing the funds to the various types of regional consumption (including savings).

- There are 4 primary factors (land, labour, mobile capital and fixed capital). While labour and mobile capital are used by all production sectors, land is only used by agricultural sectors while fixed capital is typically employed in industries with natural resources (such as fishing, forestry and mining) or in selected industries built by ACIL Allen.
  - Land supply in each region is typically assumed to remain fixed through time with the allocation of land between sectors occurring to maximise returns subject to a Constant Elasticity of Transformation (CET) utility function.
  - Mobile capital accumulates as a result of net investment. It is implicitly assumed in *Tasman Global* that it takes one year for capital to be installed. Hence, supply of capital in the current period depends on the last year's capital stock and investments made during the previous year.
  - Labour supply in each year is determined by endogenous changes in population, given participation rates and a given unemployment rate. In policy scenarios, the supply of labour is positively influenced by movements in the real wage rate governed by the elasticity of supply. For countries where sub-regions have been specified (such as Australia), migration between regions is induced by changes in relative real wages with the constraint that net interregional migration equals zero. For regions where the labour market has been disaggregated to include occupations, there is limited substitution allowed between occupations by individuals supplying labour (according to a CET utility function) and by firms demanding labour (according to a CES production function) based on movements in relative real wages.
  - The supply of fixed capital is given for each sector in each region.

  The model has the option for these assumptions to be changed at the time of model application if alternative factor supply behaviours are considered more relevant.
- It is assumed that labour (by occupation) and mobile capital are fully mobile across production sectors implying that, in equilibrium, wage rates (by occupation) and rental rates on capital are equalised across all sectors within each region. To a lesser extent, labour and capital are mobile between regions through international financial investment and migration, but this sort of mobility is sluggish and does not equalise rates of return across regions.
- For most international regions, for each consumer (private, government, industries and the local investment sector), consumption goods can be sourced either from domestic or imported sources. In any country that has disaggregated regions (such as Australia), consumption goods can also be sourced from other intrastate or interstate regions. In all cases, the source of non-domestically produced consumption goods is determined by minimising costs subject to a CRESH utility function. Like most other CGE models, a CES demand function is used to model the relative demand for domestically produced commodities versus non-domestically produced commodities. The elasticities chosen for the CES and CRESH demand functions mean that consumers in each region have a higher preference for domestically produced commodities than non-domestic commodities and a higher preference for intrastate- or interstate-produced commodities than foreign commodities.
- The capital account in *Tasman Global* is open. Domestic savers in each region purchase 'bonds' in the global financial market through local 'brokers' while investors in each region sell bonds to the global financial market to raise investible funds. A flexible global interest rate clears the global financial market.
- It is assumed that regions may differ in their risk characteristics and policy configurations. As a result, rates of return on money invested in physical capital may differ between regions and therefore may be different from the global cost of funds. Any difference between the local rates of return on capital and the global cost of borrowing is treated as the result of the existence of a risk premium and policy imperfections in the international capital market. It is maintained that the equilibrium allocation of investment requires the equalisation of changes in (as opposed to the absolute levels of) rates of return over the base year rates of return.

- Any excess of investment over domestic savings in a given region causes an increase in the net debt of that region. It is assumed that debtors service the debt at the interest rate that clears the global financial market. Similarly, regions that are net savers gives rise to interest receipts from the global financial market at the same interest rate.
- Investment in each region is used by the regional investor to purchase a suite of intermediate goods according to a Leontief production function to construct capital stock with the regional investor cost minimising by choosing between domestic, interstate and imported sources of each intermediate good via the CRESH production function. The regional cost of creating new capital stock versus the local rates of return on mobile capital is what determines the regional rate of return on new investment.
- In equilibrium, exports of a good from one region to the rest of world are equal to the import demand for that good in the remaining regions. Together with the merchandise trade balance, the net payments on foreign debt add up, to the current account balance. *Tasman Global* does not require that the current account be in balance every year. It allows the capital account to move in a compensatory direction to maintain the balance of payments. The exchange rate provides the flexibility to keep the balance of payments in balance.
- Detailed bilateral transport margins for every commodity are specified in the starting database. By default, the bilateral transport mode shares are assumed to be constant, with the supply of international transport services by each region solved by a cost-minimising international trader according to a Cobb-Douglas demand function.
- Emissions of 6 anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6) associated with economic activity are tracked in the model. Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled but can be accounted for externally. Prices can be applied to emissions which are converted to industry-specific production taxes or commodity-specific sales taxes that impact on demand. Abatement technologies similar to those adopted in a report released by the Commonwealth Government (2008) are available and emission quotas can be set globally or by region along with allocation schemes that enable emissions to be traded between regions.

More detail regarding specific elements of the model structure is discussed in the following sections.

C.4 Population growth and labour supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for each region represented in the *Tasman Global* database is projected using ACIL Allen's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projected period.

For each of region, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc.). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and regional participation rates by age by gender. Over the projected period labour supply in most developed economies is projected to grow slower than total population because of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Allen's demographic module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

C.5 The Australian labour market

Tasman Global has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations
- changes to participation rates (or average hours worked) due to changes in real wages
- changes to unemployment rates due to changes in labour demand
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour, and
- limited labour mobility between states and regions within each state.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms that hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit Australian New Zealand Standard Classification of Occupations (ANZSCO) level which are presented in Table C.2.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three-stage process:

1. labour makes itself available to the workforce based on movements in the real wage and the unemployment rate;
2. labour chooses between occupations in a state based on relative real wages within the state; and
3. labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

The *Tasman Global* database includes a detailed representation of the Australian labour market that has been designed to capture the supply and demand for different skills and occupations by industry. To achieve this, the Australian workforce is characterised by detailed supply and demand matrices.

On the supply side, the Australian population is characterised by a five-dimensional matrix consisting of:

- 7 post-school qualification levels
- 12 main qualification fields of highest educational attainment
- 97 occupations
- 101 age groups (namely 0 to 99 and 100+)
- 2 genders.

Table C.2 Occupations in the *Tasman Global* database, ANZSCO 3-digit level (minor groups)

ANZSCO code, Description
1. MANAGERS
111 Chief Executives, General Managers and Legislators
121 Farmers and Farm Managers
131 Advertising and Sales Managers
132 Business Administration Managers
133 Construction, Distribution and Production Managers
134 Education, Health and Welfare Services Managers
135 ICT Managers
139 Miscellaneous Specialist Managers
141 Accommodation and Hospitality Managers
142 Retail Managers
149 Miscellaneous Hospitality, Retail and Service Managers
2. PROFESSIONALS
211 Arts Professionals
212 Media Professionals
221 Accountants, Auditors and Company Secretaries
222 Financial Brokers and Dealers, and Investment Advisers
223 Human Resource and Training Professionals
224 Information and Organisation Professionals
225 Sales, Marketing and Public Relations Professionals
231 Air and Marine Transport Professionals
232 Architects, Designers, Planners and Surveyors
233 Engineering Professionals
234 Natural and Physical Science Professionals
241 School Teachers
242 Tertiary Education Teachers
249 Miscellaneous Education Professionals
251 Health Diagnostic and Promotion Professionals
252 Health Therapy Professionals
253 Medical Practitioners
254 Midwifery and Nursing Professionals
261 Business and Systems Analysts, and Programmers
262 Database and Systems Administrators, and ICT Security Specialists
263 ICT Network and Support Professionals
271 Legal Professionals
272 Social and Welfare Professionals
3. TECHNICIANS & TRADES WORKERS
311 Agricultural, Medical and Science Technicians
312 Building and Engineering Technicians
313 ICT and Telecommunications Technicians
321 Automotive Electricians and Mechanics
322 Fabrication Engineering Trades Workers
323 Mechanical Engineering Trades Workers
324 Panel beaters, and Vehicle Body Builders, Trimmers and Painters
331 Bricklayers, and Carpenters and Joiners
332 Floor Finishers and Painting Trades Workers
333 Glaziers, Plasterers and Tilers
334 Plumbers
341 Electricians
342 Electronics and Telecommunications Trades Workers
351 Food Trades Workers
361 Animal Attendants and Trainers, and Shearers
362 Horticultural Trades Workers
391 Hairdressers
392 Printing Trades Workers
393 Textile, Clothing and Footwear Trades Workers
394 Wood Trades Workers
399 Miscellaneous Technicians and Trades Workers
4. COMMUNITY & PERSONAL SERVICE
411 Health and Welfare Support Workers
421 Child Carers
422 Education Aides
423 Personal Carers and Assistants
431 Hospitality Workers
441 Defence Force Members, Fire Fighters and Police
442 Prison and Security Officers
451 Personal Service and Travel Workers
452 Sports and Fitness Workers
5. CLERICAL & ADMINISTRATIVE
511 Contract, Program and Project Administrators
512 Office and Practice Managers
521 Personal Assistants and Secretaries
531 General Clerks
532 Keyboard Operators
541 Call or Contact Centre Information Clerks
542 Receptionists
551 Accounting Clerks and Bookkeepers
552 Financial and Insurance Clerks
561 Clerical and Office Support Workers
591 Logistics Clerks
599 Miscellaneous Clerical and Administrative Workers
6. SALES WORKERS
611 Insurance Agents and Sales Representatives
612 Real Estate Sales Agents
621 Sales Assistants and Salespersons
631 Checkout Operators and Office Cashiers
639 Miscellaneous Sales Support Workers
7. MACHINERY OPERATORS & DRIVERS
711 Machine Operators
712 Stationary Plant Operators
721 Mobile Plant Operators
731 Automobile, Bus and Rail Drivers
732 Delivery Drivers
733 Truck Drivers
741 Storepersons
8. LABOURERS
811 Cleaners and Laundry Workers
821 Construction and Mining Labourers
831 Food Process Workers
832 Packers and Product Assemblers
839 Miscellaneous Factory Process Workers
841 Farm, Forestry and Garden Workers
851 Food Preparation Assistants
891 Freight Handlers and Shelf Fillers
899 Miscellaneous Labourers

Source: ABS (2009), ANZSCO – Australian and New Zealand Standard Classifications of Occupations, First edition, Revision 1, ABS catalogue no. 1220.0.

The data for this matrix is measured in persons and was sourced from the ABS 2021 Census. As the skills elements of the database and model structure have not been used for this project, it will be ignored in this discussion.

The 97 occupations are those specified at the 3-digit level (or Minor Groups) under the ANZSCO (see Table C.2).

On the demand side, each industry demands a particular mix of occupations. This matrix is specified in units of FTE jobs where an FTE employee works an average of 37.5 hours per week. Consistent with the labour supply matrix, the data for FTE jobs by occupation by industry was also sourced from the ABS 2021 Census and updated using the latest labour force statistics.

Matching the demand and supply side matrices means that there is the implicit assumption that the average hours per worker are constant, but it is noted that mathematically changes in participation rates have the same effect as changes in average hours worked.

C.6 Labour Market Model Structure

In the model, the underlying growth of each industry in the Australian economy results in a growth in demand for a particular set of skills and occupations. In contrast, the supply of each set of skills and occupations in a given year is primarily driven by the underlying demographics of the resident population. This creates a market for each skill by occupation that (unless specified otherwise) needs to clear at the start and end of each time period.[6] The labour markets clear by a combination of different prices (i.e. wages) for each labour type and by allowing a range of demand and supply substitution possibilities, including:

- changes in firms' demand for labour driven by changes in the underlying production technology
  - for technology bundle industries (electricity, iron and steel and road transport) this occurs due to changes between explicitly identified alternative technologies
  - for non-technology bundle industries this includes substitution between factors (such as labour for capital) or energy for factors
- changes to participation rates (or average hours worked) due to changes in real wages
- changes in the occupations of a person due to changes in relative real wages
- substitution between occupations by the firms demanding labour due to changes in the relative costs
- changes to unemployment rates due to changes in labour demand, and
- limited labour mobility between states due to changes in relative real wages.

All of the labour supply substitution functions are modified-CET functions in which people supply their skills, occupation and rates of participation as a positive function of relative wages. However, unlike a standard CET (or CES) function, the functions are 'modified' to enforce an additional constraint that the number of people is maintained before and after substitution.[7]

[6] For example, at the start and end of each week for this analysis. *Tasman Global* can be run with different steps in time, such as quarterly or bi-annually in which case the markets would clear at the start and end of these time points.

[7] As discussed in Dixon et al (1997), a standard CES/CET function is defined in terms of *effective units*. Quantitatively this means that, when substituting between, say, X_1 and X_2 to form a total quantity X using a CET function a simple summation generally does not actually equal X. Use of these functions is common practice in CGE models when substituting between substantially different units (such as labour versus capital or imported versus domestic services) but was not deemed appropriate when tracking the physical number of people. Such 'modified' functions have long been employed in the technology bundles of *Tasman Global* and GTEM. The Productivity Commission have proposed alternatives to the standard CES to overcome similar and other weaknesses when applied to internationally traded commodities.

Although technically solved simultaneously, the labour market in *Tasman Global* can be thought of as a five-stage process:

— labour makes itself available to the workforce based on movements in the real wage (that is, it actively participates with a certain number of average hours worked per week)
— the age, gender and occupations of the underlying population combined with the participation rate by gender by age implies a given supply of labour (the potentially available workforce)
— a portion of the potentially available workforce is unemployed, implying a given available labour force
— labour chooses to move between occupations based on relative real wages
— industries alter their demands for labour as a whole and for specific occupations based on the relative cost of labour to other inputs and the relative cost of each occupation.

By default, *Tasman Global*, like all CGE models, assumes that markets clear at the start and end of each period. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model). In principle, (subject to zero starting values) people of any age and gender can move between any of the 97 occupations while industries can produce their output with any mix of occupations. However, in practice the combination of the initial database, the functional forms, low elasticities and moderate changes in relative prices for skills, occupations etc. means that there is only low to moderate change induced by these functions. The changes are sufficient to clear the markets, but not enough to radically change the structure of the workforce in the timeframe of this analysis.

Factor-factor substitution elasticities in non-technology bundle industries are industry specific and are the same as those specified in the GTAP database[8], while the fuel-factor and technology bundle elasticities are the same as those specified in GTEM.[9] The detailed labour market elasticities are ACIL Allen assumptions, previously calibrated in the context of the model framework to replicate the historical change in the observed Australian labour market over a 5 year period[10]. The unemployment rate function in the policy scenarios is a non-linear function of the change in the labour demand relative to the base case with the elasticity being a function of the unemployment rate (that is, the lower the unemployment rate the lower the elasticity and the higher the unemployment rate the higher the elasticity).

C.7 References

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[8] Aguiar et al. (2019).
[9] Pant (2007).
[10] This method is a common way of calibrating the economic relationships assumed in CGE models to those observed in the economy. See for example Dixon and Rimmer (2002).

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