Australian Government
Department of Infrastructure, Transport, Regional Development, Communications and the Arts
iMOVE
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Victoria University Melbourne Australia
University of South Australia

Validating the benefits of increased drone uptake for Australia: Geographic, demographic and social insights

30 March 2023

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Acknowledgements

This study is funded by the Commonwealth of Australia as represented by the Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA); and the iMOVE Cooperative Research Centre (CRC).

Abbreviations and technical terms

AAM	Advanced Air Mobility
ABS	Australian Bureau of Statistics
AI	Artificial intelligence
AIC	Akaike information criterion
BIC	Bayesian information criterion
BVLOS	Beyond visual line of sight
CAGR	Compound annual growth rate
CASA	Civil Aviation Safety Authority (Australia)
CASR	*Civil Aviation Safety Regulations 1998*
CDU	Charles Darwin University
CGE	Computable general equilibrium
CoPS	Centre of Policy Studies (Victoria University)
COVID-19	Coronavirus disease
CRC	Cooperative Research Centre (iMOVE)
DCE	Discrete choice experiment
DITRDCA	Department of Infrastructure, Transport, Regional Development, Communications and the Arts (Commonwealth Government)
EATP	Emerging Aviation Technology Partnerships
eVTOL	Electric vertical take-off and landing (drone)
FAA	Federal Aviation Agency (United States)
FPV	First-person view
GDP	Gross domestic product
GHG	Greenhouse gases
GPS	Global Positioning System
IoT	Internet of Things
LCCM	Latent class choice model
MoU	Memorandum of Understanding
PIA	Privacy impact assessment
PTSD	Post-traumatic stress disorder
RED	Rescue Emergency Drone
ReOC	Remotely Piloted Aircraft Operator’s Certificate
RPAS	Remotely piloted aircraft system
STOL	Short take-off and landing (drone)
SWOT	Strengths, weaknesses, opportunities and threats
TERM	The Enormous Regional Model
TfNSW	Transport for New South Wales

UAM	Urban Air Mobility
UAS	Uncrewed aircraft system
UAV	Uncrewed aerial vehicle
UniSA	University of South Australia
VOT	Value of time
VTOL	Vertical take-off and landing (drone)
WTP	Willingness to pay
WWF	World Wildlife Fund

SECTION INDEX

SECTION A: Preliminaries

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A.1 Executive Summary

This study was commissioned by the Commonwealth Government's Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) in 2022 through the iMOVE Cooperative Research Centre (CRC). The objectives were to

1. Provide an overview of the Australian drone sector and compare it with current and emerging sectors in other countries.
2. Assess the demographic and geographic determinants of increased drone uptake in Australia; and
3. Identify key benefits from, and challenges to, increased drone uptake from the perspective of different communities and sub-populations.

Uncrewed aerial vehicles (UAVs), or drones, have developed over time into high-tech sophisticated tools with a variety of potential use cases that could offer wideranging benefits to different industries.

To address the research objectives, this study comprised four complementary research activities: a comprehensive review of the academic and grey literature, such as industry or consulting reports, on drone technologies; an online survey of 1,000 Australian residents drawn from different communities covering all Australian States and Territories to understand public opinion on drone technologies; an adapted Delphi study of 22 drone experts, including private and public sector actors, involved in the development, operation and regulation of drone technologies; and a computable general equilibrium (CGE) model of the national economy to simulate the potential macro-economic effects of different drone technology use cases.

The development and application of drone technology for civilian use has accelerated in recent years. However, this study finds that many market segments are still in their infancy and the potential benefits of drone technology are yet to be fully realised in Australia. Drone technology is currently being tested and trialled across a wide variety of use cases. In the following sectors, there have been significant applications of drone technology in Australia, and the state of technology development and adoption appears not dissimilar to that of other international markets: (1) agriculture; (2) freight and last-mile deliveries; (3) public sector services; (4) mining and resources; and (5) media, recreation and entertainment. In contrast, there have been fewer applications in some sectors, such as construction and advanced air mobility (AAM), in Australia than in other countries.

In addition, the uptake of drone technology in Australia will depend upon the rate and scale of technology development and readiness. A few technological and operational challenges remain to be resolved. For example, battery life, drone performance in inclement weather, constraints on payloads, high initial costs and a lack of trained personnel continue to be factors that limit drone applications. Further, uptake will depend on market readiness. For drone technology to gain widespread application, it is necessary to identify clear and compelling value propositions to potential end-users, such as time and cost savings and increased safety. Public acceptance and support will be essential to its widespread adoption. Drone technologies pose concerns through their broader impact on safety, noise, privacy and the natural environment. The present study's findings indicate that broad stakeholder management and engagement as well as public campaigns are necessary to bring about full acceptance among the Australian public of widespread drone usage. Internationally, Australia is well placed to offer a testbed for different use cases, considering the nation's geographic and demographic characteristics. Fostering Australia's own supply chain and ecosystem could not only increase economic welfare but also be in Australia's interest in terms of ensuring national sovereign capability and addressing national security concerns regarding data collection, retention and distribution. Increased uptake could also enhance service and access equality between residents in remote, regional and metropolitan areas of Australia.

The summative productivity gains associated with drone technology adoption across sectors could be substantive over time. For example, in the case of emergency services, we estimate that a 10% net productivity gain due to the use of drone technologies could result in a long-run increase in national real gross domestic product (GDP) of 0.022%, or A$460 million in present-dollar terms. Similar effects could be realised in other sectors as well, such as agriculture, freight and logistics, construction and mining. However, drone technologies are also likely to lead to a few externalities. They could displace numerous existing jobs across sectors where they find widespread application. Privacy remains a major concern, and the noise generated by drones could have adverse effects on people's wellbeing and prove disruptive to wildlife. The risks of technical and operator failure and of malicious attacks by hackers or terrorists could pose a threat to the safety of residents and to public and private property. Hence, regulation, legislation and application development will need to be aware of and address the risk–reward balance.

The research suggests that the general public perceives drone technology offers the greatest value in emergency services and disaster recovery, such as to facilitate search and rescue operations and emergency response coordination and to provide emergency deliveries. Furthermore, they see benefits for security services, such as applications in police response coordination, crime scene investigation and criminal surveillance and tracking, as well as for environmental management, such as applications in environmental hazard assessment, wildlife and habitat monitoring and protection, and scientific research. They also consider agriculture, with applications in crop and yield management, pest and disease detection and treatment, water and asset management, as a useful use case of drone technology. Conversely, the general public does not consider applications of drone technologies to other industries, such as marketing, entertainment and recreation, to have as much value.

Australia's geographic and demographic profile, with its strong, open economy, low population density and large rural areas, creates opportunities for the use of drones. Experts expect that regional areas, more than urban areas, will benefit most by adopting drone technology since it will reduce isolation. Further, the country's rural areas may experience improved delivery services and benefits flowing from the greater access enabled by flying cars. The inequity gaps between geographical areas across Australia, especially in places where productivity and living standards are lagging, can potentially be closed. Increasing connectivity between metropolitan and regional areas seems to offer substantial benefits but comes with air traffic management challenges. The sectoral uptake and applications of drone technology will also be influenced by geography, whereby some applications, such as shark patrols, will have greater relevance to high population density areas, while other applications, such as locating missing people in remote bushland, may attract heavier usage in more isolated locations. Moreover, in high-volume use cases, such as agriculture and mining, regional and remote areas will likely see increased drone uptake in the foreseeable future. Once the AAM ecosystem has matured and air traffic management and regulatory hurdles have been addressed, higher volumes in metropolitan areas can be expected because of increased freight and passenger transport.

For governments that are inclined to take a more proactive role in supporting the uptake of drone technologies, the findings from this study offer four broad directions through which they could pursue this aim. First, government regulations will be essential to get the balance right between safety, security and innovation. Second, greater direct public sector investment, including in research and development, as well as incentives to encourage greater private sector investment in drone technology and the broader ecosystem, could expedite the rate of development and adoption of such technology and ensure secure supply chains and sovereignty over data and capabilities in Australia. Third, governments could have a role to play in educating and informing the public about the process of technology development and deployment. Fourth, governments may also need to help manage the negative effects of drone technologies, which are likely to influence public opinion and impede uptake.

While this study draws a comprehensive picture of Australia's current drone market, use cases, and the benefits and determinants of increased drone uptake, and also discusses the externalities, threats and challenges associated with increased drone usage across Australia, it does not claim to be exhaustive. The rapidly evolving field of drone technology constantly yields new insights, opinions and technological changes. Much more research is needed to stay informed about the opportunities, challenges and evolving applications in order to develop the best viable solutions and support services for a drone industry in Australia.

A.2 Introduction

This report provides detailed summaries and analyses of the iMOVE Cooperative Research Centre (CRC) project titled ‘Validating the benefits of increased drone uptake for Australia: Geographic, demographic and social insights’, which has been conducted for the Commonwealth Government’s Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) through the University of South Australia (UniSA). UniSA is an iMOVE CRC partner and has successfully executed several iMOVE CRC projects. UniSA, Australia’s University of Enterprise, undertakes research inspired by global challenges and opportunities that delivers economic and societal benefits and uses the acquired knowledge to inform its teaching. Research at UniSA is strongly aligned with industry, and the university is ranked #1 in Australia for industry research income[1] and research impact and engagement.[2]

The study was led by Dr Mirjam Wiedemann and Associate Professor Akshay Vij. Wiedemann is an aviation expert, and Vij specialises in economic transport studies. The other UniSA team members were Associate Professors Rajabrata Banerjee, an applied macroeconomist; Danny Soetanto, who brings engineering and economics together to inform regional economic growth; Professor Allan O’Connor, a specialist in entrepreneurial systems, policies and practices; Senior Research Fellow Ali Ardeshiri; and Research Assistant Anilan V. The UniSA team was supported by colleagues from the Centre of Policy Studies (CoPS) at Victoria University who specialise in computable general equilibrium (CGE) modelling. CoPS, a self-funded research unit has, for 40 years, specialised in building and using CGE models designed to support analyses of economic policy. The CoPS models and software are used globally to analyse various economic challenges. Its clients include not only universities and private firms from many countries but also Australian federal and state government departments as well as international development agencies and central government agencies, such as finance and trade ministries in several other countries including the United States (US) and China.

A.3 Background and Context

The use of drone technology is gaining rapid momentum as more businesses realise its new potential, global reach and greater applicability across a wide range of industrial and consumer operations. As for Australia, it has been estimated that even a medium level of drone uptake can boost the country’s productivity to a significant extent in the next few decades and that successful uptake will create 5,500 new jobs every year and boost real gross domestic product (GDP) by A$14.5 billion with a cost saving of A$9.3 billion across all sectors between 2020 and 2040 (Deloitte Access Economics, 2020). Thus, a technology that was built to support military operations is now proving to be beneficial to various commercial and government organisations. The applicability of drones is wideranging—for example, to improve urban and regional air mobility; increase public services; monitor environmental changes; facilitate the delivery of commercial and e-commercial goods and services, including medical and pathology supplies; enhance asset monitoring in agriculture, construction, mining and defence; and to support operations for media and entertainment, and recreational activities.

Although a greater number of industries and government organisations find the benefits of drone use appealing, many still doubt the cost-effectiveness, privacy, security and safety of various applications. Further, the market and non-market benefits and challenges of drones may not be identical across all sectors, use cases and geographies. Nevertheless, with

[1] The World University Rankings 2021

[2] 2018 ARC Engagement and Impact Assessment, Combined Impact – Approach to Impact and Engagement on Assessed Fields

advances in technology and regulation and reductions in operating costs, commercial drone uptake may increase significantly in Australia. In this context, analyses of international examples allow us to learn and draw conclusions from their experiences.

A.4 Aims and Objectives

Against this backdrop, in this project, we assessed the demographic and geographic determinants of increased drone uptake both at the aggregate level and for different communities and sub-populations.

The objectives of this project study were threefold:

1. Provide an overview of the drone sector in Australia, drawing upon comparisons with current and emerging sectors and other countries.
2. Assess the demographic and geographic determinants of increased drone uptake in Australia.
3. Identify key benefits from, and challenges to, increased drone uptake from the perspective of different stakeholders, communities and sub-populations.

Over eight months in 2022 and 2023, the research team conducted numerous concurrent research activities: A comprehensive community survey captured the opinions of the Australian public, while interviews and surveys with experts provided deep insights into benefits and challenges across different industries. We conducted CGE modelling to examine economic effects on the national, state and regional levels. Strong project management, regular meetings of the whole research group and catch-up calls and feedback from DITRDCA ensured that this research was not performed in isolation but in an integrative, iterative and enriching manner.

In this project, we conducted an in-depth review of the global literature, such as industry reports, policy documents, case studies and white papers, and of government initiatives, to paint a concise picture of the possible drone market in Australia on the basis of national and international experiences. We also assessed current Australian trials and evaluated the macro-economic effects of some use case scenarios through CGE modelling. Quantitative data from literature and a community survey were compiled from, and enriched by, qualitative interviews with key stakeholders and industry partners to specifically explore socio-economic effects in depth. Interpreting both qualitative and quantitative data assists to evaluate the future application of this technology in Australia and its macro-economic and socio-economic benefits and to identify challenges.

The research was undertaken in five stages. Stage I involved a review of the activities of existing work that provides an evidence-based snapshot of the Australian drone sector, including comparisons against current and emerging international examples, regulatory implications and the identification of factors that may affect drone technology adoption in Australia (see Section B of this report). Stages II and III comprised quantitative and qualitative data collection, respectively, to understand the opportunities and challenges for different communities, demographics and industries in more depth (see Sections C and D). Stage IV was the evaluation of the economic effects of drone technology adoption, using CGE modelling based on the regional adoption of drone uptake utilising the findings from the desktop studies of Stage I at industry and regional levels. This stage offered useful insights on the effects of drone technology adoption, creating impact assessments on productivity, employment and other macro-economic indicators (see Section E). Stage V involved synthesising the findings from Stages I to IV (see Section F). It elaborates on the value proposition of increased drone uptake, and the resultant benefits and challenges; compares Australia with international realities; provides a baseline for the Australian drone sector; summarises the results of the examination of existing trials; and provides insights on socio-economic effects, community concerns and possible mitigation strategies. It also discusses how these effects vary by sector and region. The report concludes by offering some key take-aways and policy recommendations.

Next, a summary description of each stage follows, and the remaining sections of this report detail the findings of each stage.

A.4.1 Stage I: Australian baseline & international case studies (Literature review and desk research)

In this stage, the UniSA team conducted an extensive, comprehensive literature review to map out the historic and current landscape in Australia and overseas, identify factors that affect drone technology adoption in Australia and internationally, and learn from international examples. They examined the current best use cases of drone technology to produce a summary of sectoral applications and compared it against current and emerging international examples. The review also identified the current reported benefits and challenges of drone uptake in different industries, regulatory implications and socio-economic effects. Last, but not least, the review listed a sample of current Australian trials. This comprehensive review serves as a starting point to evaluate any potential future uptake of this technology in Australia and is provided in Section B of this report.

A.4.2 Stage II: Survey to understand community- and demographic-specific concerns

In the second stage, an online survey of 1,000 Australian residents drawn from different communities covering all Australian States and Territories was conducted. The sampling strategy was to include a mix of different demographic sub-populations, drawn in rough proportion to the target population. Participants were recruited through the market research company PureProfile, which has proven experience at providing sample representativeness and quality responses.

The survey asked participating respondents about their perceptions of drones, such as concerns about drones in their neighbourhoods; their attitudes towards different modes of transport, including their willingness to use flying cars and taxi services; their willingness to work in the emerging sector of drones and advanced air mobility (AAM); and the impact on different industry sectors. The survey also included stated preference scenarios to test improved regional transportation using vertical take-off and landing and its impact on housing and work patterns. Additional information relating to participant demographics and attitudes was also elicited. The collected data help to understand how different Australian residents value each of these attributes differently, their perceptions about the economic impact on drone uptake in different regional centres and industries and their willingness to consider drones and flying car services as regional transport options.

Section C provides an in-depth description of the method used to observe the Australian consumer sentiment regarding various drone applications and reports the findings.

A.4.3 Stage III: Qualitative study engaging with drone experts

This stage comprised a mix of one-on-one interviews and the adaption of a structured method of gathering expert opinion, the Delphi method. Under the Delphi method, a panel of experts was assembled to represent a cross-section of actors involved in drone technology adoption in various sectors. The Delphi method is particularly beneficial when existing knowledge about a topic is incomplete, and it allows the researcher to collect experts' comments and identify a consensus by administering multiple rounds of surveys. Owing to time constraints, only one round each of interviews and survey was conducted for this project. The research team assembled and interviewed an expert panel with members from each of the following categories:

- drone operators (4 participants),
- representatives from peak industry bodies, and participants with wider knowledge, including academics (5 participants),
- industry representatives of different drone use cases (8 participants), and
- representatives of existing trials (5 participants).

The objective was to reveal the strengths, weaknesses, opportunities and threats (SWOT) currently observed by experts in the sector from across Australia and to determine the level of agreement between them.

Section D describes the interview and Delphi method in more detail and outlines the findings.

A.4.4 Stage IV: Assessment of existing trials and broader implications for future uses (CGE modelling)

This stage involved using a CGE model to assess the socio-economic impact of different drone technology use cases. Impact assessment studies measured potential effects on productivity, employment and macro-economic variables at the regional level as well as sectoral outcomes.

DITRDCA previously commissioned Deloitte to estimate the economic impact of drone technology adoption. This modelling provided an overview of the prospective impact across many sectors. This iMOVE CRC project extends this work by exploring more specific geographic and social (demographic) community dimensions. In our research, we analysed several industry use case scenarios and addressed the prospective use of drones in response to, for example, droughts or bushfires. This stage of the research was completed in partnership with Victoria University's CoPS, which owns and operates the VU-TERM (The Enormous Regional Model).

The VU-TERM tool is used to understand the economic impact across different industry sectors and consumer sub-populations in terms of changes in productivity, consumption, employment and welfare. VU-TERM is an appropriate model for assessing these macro-economic effects. The master database depicts the Australian economy in 216 industry sectors and 334 Statistical Areas at the regional level 3 (SA3) of geographic granularity. In addition to providing a high level of regional and sectoral detail, VU-TERM is also dynamic. This feature enables users to depict the investment and operational phases of a given scenario. For example, the model can be used to depict the short-run economic impacts of investments in research and development in drone technology in the early years of a project. The model can also depict the long-run economic impacts of realised technological gains when drone applications become operational.

Given the speculative nature of the scenarios, some explanation about factors driving the model results have been included in the scenarios. It is possible, for example, that the direct benefits of some drone applications do not cover their costs. Further, there are some broad indicators of applications that have widespread social benefits. For example, drone applications that improve the identification and management of bushfires have the potential to benefit many, whereas an industry-specific application may benefit a relatively narrow range of people. Section E describes the method, the scenarios and their prospective outcomes in detail.

A.4.5 Stage V: Synthesis

In this stage, the findings from the different research streams were synthesised and summarised and are presented in Section F. This section provides comprehensive evidence based on the following specific topics: (1) an overview of the drone sector in Australia, drawing upon comparisons with current and emerging sectors and other countries; (2) the demographic and geographic determinants of increased drone uptake in Australia; (3) benefits from, and challenges to, increased drone uptake from the perspective of different Australian communities and sub-populations; and (4) suggestions that could be considered by the Australian Government and industry to maximise benefits and overcome challenges.

The report concludes with some key take-aways and outlines possible policy implications.

SECTION B: Literature Review

Stage I Literature review of the development of drones (Australian baseline and international case studies)

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B.1 Introduction

Commercially licensed drones were first used in the United States (US) in 2005, in the aftermath of Hurricane Katrina (Rao et al., 2016). The Federal Aviation Agency (FAA) issued a licence after the hurricane to operate drones equipped with accurate infrared cameras over civilian airspace. Open source and maker culture nurtured drones for many years before drones burst into the mainstream market over the past 10 years (Maharana, 2017; Rao et al., 2016). Amazon, FedEx, UPS and other delivery companies started experimenting with small parcel delivery services by 2013. But it was not until the Chinese company DJI started selling a wide range of models of drones at very affordable prices that the use of drones proliferated across applications, industries and continents. DJI accounted for about 77% of drone sales in the US alone in 2019, with no other rival having more than 4% of the market share (Schmidt & Vance, 2020).

Aerial drones, or uncrewed aerial vehicles (UAVs), and more recently uncrewed aircraft systems (UASs), in cognisance of the wider ecosystem incorporating the network and personnel to control them, have been gaining popularity since 2015 (Deloitte Access Economics, 2020). A likely factor that makes the use of modern drones compelling is the ease with which these devices can be acquired and launched into the sky, for work or play, without the need for any infrastructure, and depending on the jurisdiction, without too many restrictions or regulations.

The enhanced ability of drones to see and sense have drawn the attention of scientists and researchers worldwide. An increasing number of vocations are finding use for them, from fire fighters to farmers, surveyors to real estate agents, to commercial companies such as UPS, Amazon and Domino’s Pizza. Many of these applications enjoy widespread support and acceptance, such as the use of drones for tracking and rescuing koalas during bushfires in Australia (Gimesy, 2020) and for inspection and rescue in the aftermath of the Fukushima nuclear plant disaster in Japan in 2011.

There has been exponential growth in the sales of drones for civilian use, which tripled from 2014 to 2020 (Oppenheimer, 2016) and are projected to treble from 2019 to 2024 (Abdukarimov & Ganiev, 2022; Ajmera et al., 2022). This rapid growth, the maturing of the technology and its integration with supporting digital technologies have been accompanied by concomitant growth in use cases for drones to solve real-world problems. Accordingly, agriculture, transportation, logistics, construction, mining, and urban and regional mobility are some of the industries that may have compelling use cases in Australia (Deloitte Access Economics, 2020).

Australia started its drone journey in 2002, when it introduced sophisticated legislation and became a world leader in creating advanced rules to govern civilian use of the technology (Chauhan, 2019; Moses, 2012). Yet, regulatory restrictions and concerns about real or perceived safety, security and privacy threaten to impede faster growth in the use of drones, which hinges on wider and deeper integration with other digital technologies to enable increased applications across many industries. A comparative study of drone regulations showed that there is much to be resolved in this space (Tsiamis et al., 2019). It is in this context that the present study attempts to draw out the current and potential benefits of civilian use of drones in Australia. The study will review the existing literature to discuss various use cases from Australia and other countries and to identify the key benefits and challenges of drone uptake and the ways in which they benefit different sections of the community.

The rest of this literature review is organised as follows: Section B.2 provides an overview of drones and their history, types and current usage; Section B.3 discusses factors affecting the uptake of drones; Section B.4 examines the use cases across promising sectors of the economy; Section B.5 discusses the socio-economic impact of drones; Section B.6 throws some light on current drone trials in Australia; Section B.7 examines the main benefits and challenges of increased drone uptake in Australia; and Section B.8 concludes the literature review by summarising its findings and discussing the outlook for drone uptake in Australia.

B.2 Drone: History, Types and Current Usage

B.2.1 History

There is some evidence indicating that the first recorded UAV operations occurred in 1839 in the form of uncrewed balloons filled with explosives used to attack the city of Venice (Engineering, 2020). UAVs have since developed to be high-tech sophisticated tools and vehicles controlled from the ground with integrated technology, which can transport goods and passengers. The major milestones in the development of modern drones are shown in Table B.1.

Table B.1: Milestones in the development of drones

Year	Milestones in Drone/UAV Development
1839	Venice was attacked by Austrian soldiers using uncrewed balloons loaded with explosives (Engineering, 2020), which could be an example of the first recorded uncrewed aerial vehicle (UAV) operations in history.
1896	In an experiment, Alfred Nobel, the inventor of dynamite, mounted a camera on a rocket.
1898	Nikola Tesla demonstrated a radio-controlled boat, a key technological component of UAVs.
1907	Another key conceptual component of modern UAVs was innovated when brothers Jacques and Louis Breguet, together with Professor Charles Richet, created the world's first quadcopter, although it reportedly lifted only two feet off the ground and needed four men to steady it.
1915	One of the earliest uses of orthomosaic aerial images was by the UK forces in the Battle of Neuve Chapelle (Consortiq, 2022).
1917	UK's Ruston Proctor Aerial Target, which used remote control technology, was possibly the first winged aircraft without a pilot.
1935	The De Havilland DH.82B Queen Bee aircraft was developed as a low-cost radio-controlled drone to replace the unrealistic aerial target previously used by the UK's Royal Air Force. It is considered the first type of modern drone (Consortiq, 2022).
1939	The Royal New Zealand Air Force assisted farmers to spread seeds mixed with fertilisers. Crewed aircrafts in agriculture became common over the following decades.
1941	Actor Reginald Denny invented the Radio Plane for the military, a radio-controlled target plane, contributing many innovations to drone technology and selling more than 70,000 target drones to the US Army.
1960s	With new transistor technology, the average consumer gained economic access to remote-controlled planes.
1970	Possibly the first radio-controlled helicopter was created by Dr Dieter Schluter (Frankelius et al., 2019; Thurling et al., 1985).
1973	Abraham Karem built the first fully functional drone for Israel, which used them initially for surveillance. Significant improvements were made to the capabilities of the technology for models such as the Mastiff and IAA Scout series, which enabled military commanders to increase their situational awareness in warzones.
1982	The success of Israeli drones against the Syrian Airforce in the Battle of Jezzine cemented UAVs' significance in warfare.

1985	Thurling used a gimbal-mounted 35 mm camera on a drone in his research for taking vertical images of oilseed rape (Frankelius et al., 2019).
1987	Yamaha demonstrated an R-50, considered to be the first UAV for dusting crops (Frankelius et al., 2019).
1991	The Swedish University of Agricultural Sciences conducted trials for an airplane mounted with a camera to map crops (Frankelius et al., 2019).
1996	The US introduced the Predator drone, which followed from the contribution of Abraham Karem. This drone deeply influenced the general public's perceptions about the immense capabilities of drones to strike targets with precision and power.
2006	Predator drones equipped with thermal scanners capable of detecting humans from 10,000 feet height were first employed for civilian use.
2013	Amazon's Chief Executive Officer Jeff Bezos announced it was considering using drones for delivery services.
2015	DJI released the first commercial quadcopter Phantom 1. One such small drone crashed on the lawn of the White House.
2016	Laws were enacted to control the use of commercial drones by the FAA in the US, and similar laws were passed in the UK and Sweden.
2018	The first civilian use of beyond visual line of sight (BVLOS) technology with radar was approved by the FAA on 16 October for Avitas Systems, a GE venture company, to fly a UAS over 55 pounds for visual inspections at low altitudes without a visual observer.
2019	Wing, a company owned by Alphabet Inc, started drone delivery service in Australia. Volocopter demonstrated advanced air mobility (AAM) capability in 2019 with a 3-minute flight over Singapore's Marina Bay waterfront.
2020	The European Aviation Safety Agency set out European Union regulations concerning civilian drone use. Some of the restrictions concerning drone use were eased in the US. The Civil Aviation Authority of Singapore authorised the first commercial BVLOS drone delivery service in Singapore by a startup, F-drones, to deliver medical supplies from shore to ship for shipping giant Eastern Pacific Shipping.
2022	Volocopter and Skyports signed a Memorandum of Understanding with the Singapore Government to establish an AAM hub at Seletar Aerospace Park. Volocopter announced it would launch an air taxi service in Singapore in 2024. Percepto became the first company to secure a nationwide waiver from having to obtain site-specific approval to operate BVLOS drones across the US.

Commercial drone uptake really took off around 2017 globally, as is evident from sales records and systematic literature reviews (Butilă & Boboc, 2022; Merkert & Bushell, 2020; Rachmawati & Kim, 2022; Rejeb et al., 2021b; Samaras et al., 2019). Possibly the most widespread use of drones has been in the field of research to facilitate cheaper or more effective or efficient acquisition of data and knowledge. Drones have been reported as an important asset in a broad range of applications, such as the study and preservation of species on land (Camarretta et al., 2020; Iseli & Lucieer, 2019; S. Park et al., 2021) and seas (Bevan et al., 2018; Chirayath & Earle, 2016; Colefax et al., 2020; Hamylton, 2017; Martin et al., 2022), the protection of the very habitats of species, the restoration of ecology (Robinson et al., 2022) and active intervention in firefighting and search and rescue operations (Gimesy, 2020; Lum et al., 2015; Subramaniam et al., 2012). The different functions and use cases of drones are discussed in detail in Section B.4 of this report.

B.2.2 Technology and classification

Many different types of drones have been developed, and these have different systems and capabilities. Using global navigation satellite systems, for example, a Global Positioning System (GPS), enables UAVs to typically fly farther than those not equipped with such systems. Drones fitted with additional advanced navigation systems, collision avoidance and environment detection systems can operate as automatic or autonomous systems with artificial intelligence (AI) and machine learning capabilities built in (A. Gupta et al., 2021).

Over the years, drones have been classified into various categories according to their size, weight, operational functions and wing type (Alghamdi et al., 2021; Arjomandi et al., 2006; Chan et al., 2018; Hassanalian & Abdelkefi, 2017) with several of these tracing back to the US Army's document on UASs (US Army UAS Center of Excellence, 2010). Singhal et al. (2018) acknowledged several ways to classify drones: by size, weight and range. For this review, the classification provided by the Civil Aviation Safety Authority (CASA) of Australia has been adopted as the baseline for comparing drone types. CASA defines drones by their intended use, flight technology and weight and provides the following categories and sizes (types):

- A model aircraft or remote-controlled aircraft is a drone flown for sport or recreation—for fun.
- A remotely piloted aircraft (RPA) is a drone flown for business or as part of your job—commercially. The acronym 'RPAS' (remotely piloted aircraft system) is commonly used to refer to the aircraft itself, but the term also includes all components of the system required for an operation, which include ground control stations, telemetry and communications, sensors and other hardware and software used to operate the aircraft (CASA, 2022e).

Drones come in all types of shapes and forms. Figure B.1 shows the categories of drones according to their take-off and flight behaviour with the plain English description used by CASA for general public communication. The formal definitions for each type can be found in various parts of the Civil Aviation Regulations (CASA, 2022e).

Fixed-wing drones largely resemble regular aircrafts and can fly faster and longer, owing to more efficient aerodynamics, and are thereby ideal for mapping large areas. In comparison, rotary wing drones (e.g. helicopter and quadcopter) are mechanically more complicated and have a shorter range and flight times, but they do not need runways because they take of vertically, can hover for long periods and have greater manoeuvrability in the air (Deloitte Access Economics, 2020).

Vertical take-off and landing (VTOL) aircrafts do not require a runway to land and may also include helicopters and thrust-vectoring fixed-wing aircraft and other hybrid aircraft, such as cyclogyros or cyclocopters and gyrodynes. As the name suggests, eVTOLs are electric-powered VTOL aircrafts (eVTOL, 2022). Within the context of drones, the term VTOL is often used specifically to describe uncrewed versions of the piloted eVTOL aircraft that are developed for applications, such as urban air mobility (UAM) and cargo delivery, but may also sometimes be used to describe any electric UAVs with VTOL capability (Unmanned Systems Technology, 2022).

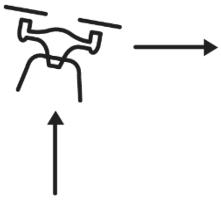
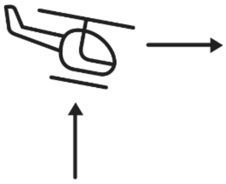
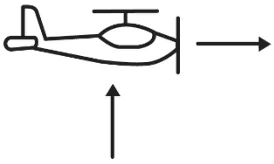
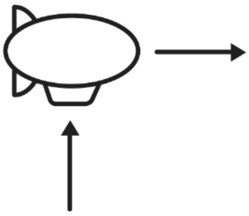
Multi-rotor helicopter	**Single-rotor helicopter**
 This type has more than one power-driven engine (rotor) that rotate or turn vertically. It takes off, lands, flies and hovers like a traditional 'single rotor' helicopter but has more than one rotor.	 This type has one power-driven engine (rotor) and looks a bit like a traditional helicopter. It usually has another rotor on the tail or end of the aircraft.
Aeroplane	**Powered lift**
 This type looks and flies like a regular plane—it has fixed wings. It also takes off and lands horizontally and usually can't hover.	 This type can take off and land vertically (straight up and down) like a helicopter but can then move forward like a traditional aeroplane.
Airship	
 This type is engine powered and is 'lighter than air'; it can be filled with a buoyant gas and usually 'floats' in the air.	

Figure B.1: Drones categorised according to their take-off and flight behaviour (source: CASA, 2022e; reproduced under creative commons licence)

Further to the distinction between intended use and aircraft type, drones are categorised by weight. Table B.2 summarises the definitions of each category in Australia, from micro drones of up to 250 gm to large drones of more than 150 kg.

Table B.2: Drones categorised by weight (source: CASA, 2022e; reproduced under creative commons licence)

Size	**Weight**
Micro	Up to 250 grams
Very small	Between 250 grams and 2 kg
Small	Between 2 and 25 kg
Medium	Between 25 and 150 kg
Large	More than 150 kg

Moreover, drones are used in many fields and can be classified by their areas of application. Three main areas of application are civilian, environmental and defence, as shown in Figure B.2.

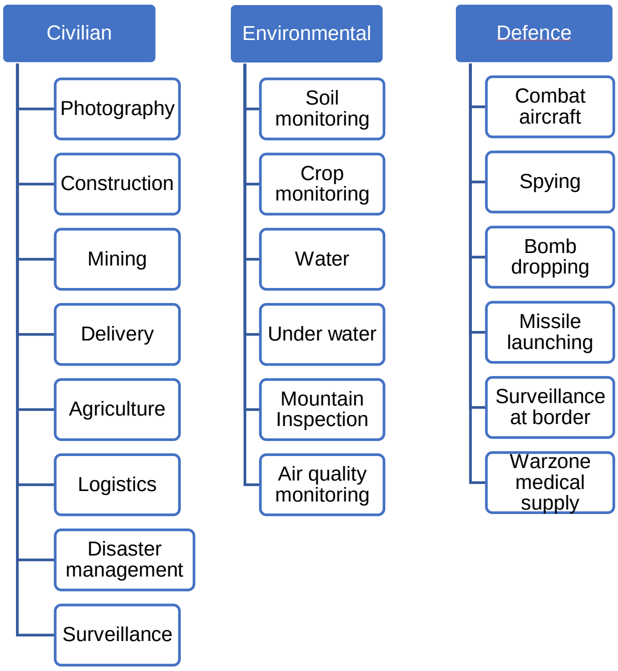


Figure B.2: Drones categorised according to potential applications (source: Macrina et al., 2020)

For the purposes of this review, the simplified classification developed by Deloitte Access Economics (2020) is adopted for grouping drones into either fixed-wing or rotary types, and where necessary, the specific features or attributes of the drone are referred to in greater detail. Throughout this report, the word 'drones' refers generically to UAVs, and where appropriate UAS, delimited to terrestrial airborne operations for non-military purposes. That is, the terms drones and UAVs are used interchangeably in this study; these vehicles may be crewed or uncrewed and include those capable of transporting passengers.

While there are not many differences between the definitions of RPAS and advanced air mobility (AAM), for the purposes of this report, RPAS refers to operations that use smaller aircraft with no passengers onboard, and AAM describes a range of aircraft types (both crewed and uncrewed) that transport passengers and larger freight. The current vehicle types for AAM are multirotor, tilt wing, tilt rotor and powered wing, which has short take-off and landing (STOL) through to VTOL capabilities (see Figure B.3). The different AAM concepts can be classified into two operational subcategories (CASA, 2022d):

- Urban air mobility (UAM): short-to-medium range. UAM is regarded as a subset of AAM that deals primarily with intracity transportation.
- Regional air mobility: short-to-medium range. Used for low altitude point-to-point passenger- or cargo-carrying tasks between regional areas (CASA, 2022d).

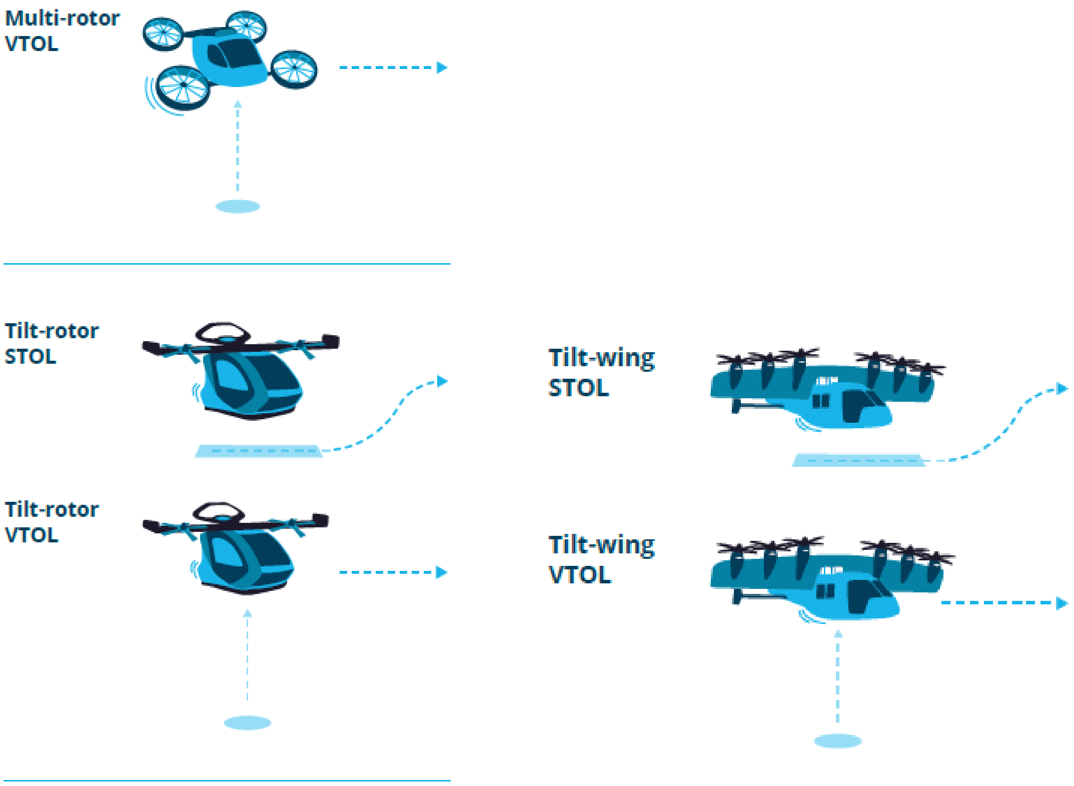


Figure B.3: Types of AAM (source: CASA, 2022d; reproduced under creative commons licence)

B.2.3 Current usage of drones

Drones were initially just an eye in the sky with features on aerial photography, photogrammetry and thermal imaging, in what Maghazei and Netland (2019) described as the 'see' capability. Drones were soon embedded with increasingly sophisticated sensors, controlled via smartphones and capable of 'sense' functions, such as measuring, monitoring and surveying. Growing demand, increased production and lower unit cost offered even more end-user applications across all sectors to do the 'dirty, difficult or dangerous' jobs, such as bushfire and flood monitoring and rescue operations, surveillance and last-mile delivery services (S. G. Gupta et al., 2013). Given that technological developments in drone applications are still in their initial stage in many sectors, there is significant potential for future growth (Deloitte Access Economics, 2020; Oppenheimer, 2016).

Further, the rapid growth of e-commerce has compounded traffic congestion in cities, particularly with the proliferation of traditional last-mile delivery services. This situation spurred delivery companies to explore drone-based delivery solutions as an alternative (Persson, 2021). In 2013, Amazon announced plans for drone deliveries and delivered the first parcel in 2016 (Macrina et al., 2020). The potential market for drone-based delivery services in Australia is estimated to be half a billion dollars by 2040 (Deloitte Access Economics, 2020).

In the agricultural sector in Australia and abroad, drones have already been used in operations such as irrigation, crop monitoring, soil and field analysis, crop spraying, planting and bird control (Ahirwar et al., 2019). The resultant benefits of reduced crop damage and increased yields, reduced risks and improved livestock production are significant for large farms, especially in poor and developing countries (Yawson & Frimpong-Wiafe, 2018).

As regards the construction and infrastructure sector, drone applications are projected to grow significantly, especially for the surveying industry (Fassbender et al., 2018). In 2016, a study conducted by Goldman Sachs (2016) projected that by 2021, the construction sector would account for US$11 billion of the projected US$100 billion in global expenditure on drones. In addition, there was clear evidence that companies using drone technology have achieved cost savings and improved project scheduling, leading to business expansion and the ability to redeploy labour instead of cutting jobs (Goldman Sachs, 2016).

The ability of drones to quickly and cost-effectively reach environments that are difficult and dangerous for humans make them attractive for many public services, such as firefighting, disaster management and emergency response. For example, the rescue of koalas affected by bushfires with the aid of drones in the Wimmera region of Victoria, Australia, was very well received by general public (Duckett, 2021; Gimesy, 2020). This operation included rigging the drones with aerial incendiaries to start the backburns in order to safely manage forest fires and using visual and thermal scanners to rescue the koalas.

The entertainment industry is increasingly using drones instead of expensive cranes and helicopters for aerial shots. Drone racing is also one of the fastest growing sports in racing circuits. With increasing measures to contain the fire and pollution hazards of traditional fireworks, reusable and nonpolluting light displays using drone swarms have grown in popularity (Zerlenga et al., 2021). The record-breaking 3,051 drone swarm display in China, the 2021 Tokyo Olympics fireworks and the Vivid display in Sydney in May 2022 are just some of the recent examples that have raised the profile of drone applications and the possibility of using these in major events. The recreation and entertainment sector is projected to have a market size of about A$900 million in Australia by 2040 (Deloitte Access Economics, 2020).

AAM describes the use of large-scale drones used to transport passengers and goods in regional, remote and urban areas. UAM is a subsection of AAM that provides commercial services to the public over densely populated cities in the form of a new transport service for passengers and goods. The sector is rising fast with new major investments announcements occurring frequently (Hill et al., 2020). As this is an emerging field of research, the terminology is not settled yet, and UAM and AAM are often used interchangeably. Sometimes, AAM and UAM refer to passenger transport only. Likewise, different players anticipate different technologies for this use case. Mainly eVTOLs were considered earlier, but currently, the discussion includes VTOL, STOL and fixed-wing drones. Nevertheless, before AAM can become a commercial reality, questions about air traffic management, technology and ground stations (vertiports) need to be resolved.

Freight and last-mile delivery services increased during the coronavirus disease (COVID-19) pandemic. It is estimated that by 2030, global growth may increase by up to 25 times from the 2022 figures and reach US$5.6 billion (Business Wire, 2022).

Given the wideranging current and potential applications for drones in numerous industrial sectors and consumer segments, we considered it necessary to restrict this research to the sectors with the most promising use cases. Several studies have been conducted to classify the most promising sectors (Deloitte Access Economics, 2020; Goldman Sachs, 2016; Mazur et al., 2016). A Deloitte report (Deloitte Access Economics, 2020) builds on the findings of an earlier PwC report (Mazur et al., 2016) and a Goldman Sachs (2016) report and offers a comprehensive classification for Australia. The following sectors were identified as the most compelling and innovative for the Australian market:

- Advanced air mobility: includes airport taxi trips, other taxi trips and intercity trips.
- Freight and last-mile deliveries: include the delivery of express parcels, food deliveries, imported pharmaceutical deliveries (with high value/low weight), regional and remote pathology drone deliveries, medical deliveries in remote areas and some cargo-airfreight.
- Government and community services: include emergency ambulance response, fire response, search and rescue, border patrol, local law enforcement, disaster management and monitoring, conservation management, mapping and research.
- Agriculture: includes crop, livestock and large land monitoring, and crop spraying/pellet application.
- Mining and resources: include stockpile measurement/geotechnical modelling, blast and mine reclamation monitoring, and equipment inspection.
- Defence: includes direct warfare and surveillance activities.
- Construction and infrastructure sectors: include inspections of, for example, power lines, bridges and rail.
- Recreation and entertainment: include recreational flights, photography and filming.

For this literature review, we adopted this list but excluded the defence sector in order to focus on the civilian and commercial sectors. In addition, we introduced Environmental Management as a separate sector to highlight the importance of conservation and sustainability management. On the basis of this initial review, AAM, freight and last-mile deliveries, construction, agriculture, public services, and recreation and entertainment are some of the sectors that call for greater attention owing to their substantial current and potential market size. The list of sectors reviewed in this report is shown in Table B.3.

Table B.3: Sectors of the Australian economy to be reviewed in the report

Industry/Sector	Subcategory (Type of Service/Role)	Rationale	References
Advanced air mobility	Taxis	Low current penetration in a potentially large market of about A$593 million by 2040.	(Deloitte Access Economics, 2020; Goyal et al., 2021; Mualla et al., 2019)
	Point-to-point services		
	Regional air mobility		
Environment management	Conservation & sustainability management	Drones can generate data, which was previously prohibitively expensive or technically challenging and is priceless in helping to arrest loss of biodiversity. Medium rate of market penetration.	(Duffy et al., 2020; S. Park et al., 2021; Rebolo-Ifrán et al., 2019; Robinson et al., 2022; Sexton, 2020)
Freight & last-mile deliveries	Express parcels	Low current penetration in a potentially large market of about A$575 million by 2040.	(Deloitte Access Economics, 2020; Garsten, 2022; Mazur et al., 2016)
	Food deliveries		
	Pharmaceutical/medical deliveries		

	Regional & remote pathology		
	Cargo-airfreight		
Public services	Emergency ambulance response	A projected market size of about A$1.3 billion by 2040 and covered in most reports.	(Deloitte Access Economics, 2020; Goldman Sachs, 2016)
	Fire response		
	Search and rescue		
	Border patrol		
	Local law enforcement		
	Disaster management		
	Mapping and research		
Agriculture	Crop, livestock and large land monitoring,	Among the early adopters of drone technology with a significant market penetration currently. Market projection is about A$1 billion by 2040.	(Deloitte Access Economics, 2020; Goldman Sachs, 2016; Mazur et al., 2016)
	Crop spraying, planting etc.		
	Forestry & fishing		
Mining & resources	Stockpile measurement/ geotechnical modelling	Already has a significant market penetration and has potential with the growing market for minerals for batteries in Australia. Market projection of about A$202 million by 2040.	(Deloitte Access Economics, 2020; Mazur et al., 2016)
	Blast and mine reclamation monitoring		
	Equipment inspection		
Construction	Inspections of power lines, pipelines, bridges and rail	Already has a significant market penetration and still holds great potential with a market projection of about A$1.5 billion by 2040.	(Deloitte Access Economics, 2020; Goldman Sachs, 2016; Mazur et al., 2016)
	Surveying		
	Project management		
Recreation & Entertainment	Radio-controlled planes & drone racing	Significant market penetration already and yet has a potentially large market of about A$891 million by 2040.	(Deloitte Access Economics, 2020)
	Entertainment industry		
	Photography		
Defence		Out of the scope of this civilian/commercial report.	
Health Services		Covered under e-commerce/logistics.	(Amukele, 2019)
Maritime		Offshore roles covered under Logistics.	(Sookram et al., 2021)
Manufacturing		Low penetration and fairly limited market size in Australia.	(Maghazei & Netland, 2019)
Insurance		Covered in US & European market forecasts but has not featured in Australia possibly owing to smaller market. Further, the role is covered under photography.	(Goldman Sachs, 2016)

Some of the other sectors that were not considered in this review are the maritime sector (Sookram et al., 2021), manufacturing (Maghazei & Netland, 2019) and healthcare services (Amukele, 2019). There is often an overlap in classifications from one report to another, and some of the promising applications from these sectors have been captured under other sectors. For instance, emergency and medical services are covered under the government and community services sector, while pathology deliveries are covered under e-commerce and deliveries. Similarly, delivery services would include offshore deliveries used by the maritime sector.

B.3 Factors Affecting Drone Adoption

Across all sectors, the main driving factors for drone adoption, as identified by Business Wire (2022), are technological advancements and cost-effectiveness, compared with electric ground delivery vehicles, and the reduction of carbon emissions. However, each sector slightly varies in terms of the specific factors that influence their drone technology adoption. For example, Tey and Brindal (2022) found that perceived profitability, the availability of consultants and the use of a computer are factors that have a medium-term effect on drone adoption in precision agriculture. However, Zuo et al. (2021) observed that the factors that affect farmer adoption of drones and other precision agriculture technologies have not been extensively covered in extant literature. One possible reason is that farming varies in terms of produce and type of operations, as well as farm size, which can range from a hectare or less to thousands of square kilometres.

Further, W. Yoo et al. (2018) identified a range of factors affecting attitudes to drone adoption in the last-mile delivery services sector. These are:

- relative advantages of speed,
- environmental friendliness,
- complexity,
- performance risk,
- privacy risk and
- personal innovativeness.

Regarding the Indian humanitarian logistics industry, Kamat et al. (2022) found that expensive commercial solutions, high transport energy costs, uncertain maintenance and repair costs and a lack of high-level computing are some of the factors that affect UAV adoption.

The most common factors cited in the literature as affecting the uptake of drones across all industries can be categorised as cost savings, time savings, ease of use, safety and security concerns and regulations, each of which is examined in the following sections.

B.3.1 Cost savings

The cost savings factor is a main driver of drone adoption in last-mile delivery services (Dorling et al., 2016). The cost of operating drones depends on energy costs and the price of the drone itself. The optimal weight ratio improves drone performance and reduces the cost substantially. The ability to reduce labour costs through drone deliveries is also an important factor that drives drone adoption (Dorling et al., 2016). Dukkanci et al. (2021) established that the total cost could be reduced by 30.08% on using multiple drones together with a delivery truck to decrease the total distance covered.

It is important for companies to reduce the total cost of deliveries, specifically in urban areas. Kitjacharoenchai et al. (2019) and She and Ouyang (2021) highlighted the potential of drones to reduce travel costs in logistics by reducing the use of land vehicles powered by fuels. However, various other usual delivery costs, such as costs associated with facilities, utilisation and operations, also need to be closely examined in this context (Persson, 2021; Shavarani et al., 2019).

It is cheaper and easier to use drones in agriculture than in other sectors (Mazur et al., 2016). Among other useful data, time series animations help farmers better manage crop production. The industry is also projected to become highly data-driven in the near future and thereby achieve increased productivity and yields (Mazur et al., 2016). As for the construction industry, cost savings and time savings are identified as the key factors that drive drone adoption (Vanderhorst et al., 2019; Zhou & Gheisari, 2018). Moreover, drones reduce the total operation cost when used in hazardous environments, such as to inspect wind farms and solar panels (Pradip et al., 2019). In addition, higher productivity and safety, a wider range of applications and cost savings are some of the benefits driving the increased use of drones in the mining sector (Global Data, 2022).

B.3.2 Time savings

Time is certainly money in the delivery business, and companies such as Amazon are heavy users of drone technology to deliver packages (Pope, 2022). Poikonen et al. (2017) showed that by deploying two drones that can travel 50% faster than a truck, delivery time savings can be up to 75%. In attempting to find the right balance between cost and delivery time, Dorling et al. (2016) showed that the minimum cost is inverse exponentially related to the delivery time limit, and the minimum overall delivery time is inverse exponentially related to the budget. Their study confirmed the benefits of using drones and of optimising battery size through drone delivery vehicle routing problems. Persson (2021), in a systematic literature review of drone use in last-mile delivery, found that several works (Kitjacharoenchai et al., 2019; Li et al., 2020) have offered solutions on how last-mile delivery companies can save time.

The ability of drones to save time is a major factor for the adoption of drones in the construction of large infrastructure and buildings. For example, the global engineering consultancy, Arcadis, performed construction works using drones in Qatar for the 2022 FIFA World Cup. To prove their case for drones, Arcadis set up a three-acre site and ran a test survey using both traditional and drone survey methods. The traditional survey was completed in three hours, whereas the drone survey took only 20 minutes (Beesley, 2020).

In search and rescue operations, where time is of essence to help save victims, drones can often be deployed instead of crewed helicopters, which take a longer time to be deployed and are more costly (Said et al., 2021). Numerous other research projects have reported that in mining surface surveys, drones provided higher accuracy in less time and were cheaper and safer in operations (Said et al., 2021).

B.3.3 Ease of use

Marshall et al. (2022) argued that rural and urban communities are digitally divided and pointed out that many farmers in Australia find it difficult to take up digital AgTech or smart farming. They classified the factors of digital AgTech adoption into three categories: technological factors (sufficiency of connectivity, availability of technology and servicing, and compatibility of technologies); discursive or content factors (orientations to technology, experiences of technology use and usefulness, and constructions of value of technology); and social factors (on-farm digital skills, digital innovation ecology, and government/industry authority and leadership).

Similarly, in a study within Jilin Province, China, Zheng et al. (2018) found that most farmers find UAV technology acceptable for plant protection application operations. Gender (males), income ratio in agriculture, knowledge of new technology, convenience and usefulness were some of the factors that positively affected farmers' willingness to adopt UAVs.

B.3.4 Safety and security

Despite the low numbers of actual accidents or crashes, and no known deaths anywhere from peaceful civilian drone operations, safety concerns about drone operations continue to be listed as a negative factor affecting adoption. As in the case of other emerging technologies, accidents always draw extra attention from public and media. For example, in 2010, a UAV flew 37 km towards and over Washington DC airspace before the US Navy was able to regain control. More spectacularly, in 2015, a Phantom drone of Chinese manufacturer DJI crashed into the garden of the White House, undetected by the radar system, which could not distinguish the drone from a bird (Gallacher, 2016). Similar events have evoked concern regarding the safety of drones. Given how challenging it is in urban cities to safely navigate the congestion on the ground, both on and off the roads, concerns over aerial vehicles falling from the sky because of malfunction, accidents (such as when drones collide into buildings and other tall structures, or other drones and birds) or weather conditions, must be managed early and effectively through regulations, which are already in place or being implemented in many countries. For example, in Australia, CASA issues regulations regarding drones (Alwateer & Loke, 2020). Nevertheless, the current air traffic management system will need to be adjusted to manage safely the increase of flying objects in the sky in order to avoid collisions between aircrafts of all types and disruptions to commercial aviation.

Stewart (2016) highlighted that despite a strict regulatory framework for their operations, an RPAS can cause significant damage to people or property on the ground. Statutory strict liability does not apply uniformly to all RPASs because the definition of 'aircraft' in legislation critically determines the RPASs that fall within the ambit of the law. In the absence of statutory remedies, aggrieved parties must rely on common law and be guided by statutory safety regulations to establish liability. The article suggests legislators should ensure uniform application of strict liability laws to all RPASs, as well as compulsory identification and insurance of RPASs. It should be noted that currently in Australia, CASA has strict regulations prohibiting the operations of drones over people and property and requiring safe distance from airports. The guidelines strongly encourage liability insurance, highlighting that most landowners and administrators, such as the various state park administrators, will not give a permit to operate an RPA unless they have an insurance certificate (CASA, 2020).

Drones flying over private property should not be used for anything beyond their intended flight purpose. For example, drones on delivery services should not click photos or capture unauthorised information (Alwateer & Loke, 2020). Certain developments enable property owners to set privacy preferences and prevent drones from flying over their properties. Future developments may even create 'airspace real estate' with owners charging for flights over their property (Alwateer & Loke, 2020).

Security concerns may also be heightened in certain applications of drones, for instance, regarding the use of drones to extend public safety wireless networks (He et al., 2017). Drones fitted with communication hardware can be used to extend or complement public safety wireless networks and be deployed as an aerial mobile station. This application of drones can carry sensitive and critical information and may require boosting information and communication security system protocols over and above those for standard wireless network systems. Drone-assisted public safety networks can cover large areas, be deployed in remote or isolated places at times, transmit a large amount of information and consume more power, which provides a set of conditions that makes maintaining the integrity and security of data and information more problematic.

B.3.5 Regulations

Some experts argue for a pre-emptive regulatory framework to permit the widespread use of drones in low altitude airspace in an orderly manner through a variable usage charge (Merkert et al., 2021), but others are very concerned about the increasing 'loss of freedoms' arising from such regulations (Kellermann et al., 2020). The regulation of drone operations, licensing, flight paths and flight priorities are all important aspects of managing the safety of people and drones. FAA in the US has already mandated the display of licence plates (Feist, 2019), and an electronic tagging system could be developed in the future (Alwateer & Loke, 2020). Further, many countries, including Canada, China, the UK, Germany and Poland, have instituted mandatory third-party insurance for drones. With the proliferation of drones and drone services, the insurance landscape will have to begin minimising liability and risk for drone owners and service providers (Alwateer & Loke, 2020).

Tsiamis et al. (2019) analysed and compared the regulations on drone use in the Organisation for Economic Co-operation and Development countries and concluded that the legislation differs, possibly because of differences in the timing of the enactment of legal frameworks in relation to the rapid advancements in the technology. Extensive attention has been paid to privacy, and on restrictions on flights above people and public areas. Despite a common policy on drone use within the European Union, categorisations vary in these countries, and they have different restrictions on piloting requirements. Calling for a more detailed legislative framework, particularly in relation to limitations and restrictions of drone use and how relevant authorities can have more effective control over drone flights, Tsiamis et al. (2019) recommended that these countries adopt a homogeneous legal framework for smoother and safer drone operations, with provisions for revisions as the technology and uses mature.

In Australia, CASA is responsible for ensuring the safety of all users of airspace as well as people on the ground. CASA administers the *Civil Aviation Safety Regulations 1998* (CASR), which are promulgated under the *Civil Aviation Act 1988* (Cth). People and organisations that do not comply with the CASR are liable to pay fines. The CASR specifies the types of flight activities permitted, the people authorised to conduct them and where and how such activities may be conducted. Details can be found in the *Federal Registrar of Legislation* 'Part 101 (Uncrewed Aircraft and Rockets) Manual of Standards 2019 (as amended)'. To improve understanding about the rather complex and technical set of regulations, CASA produced a set of simple advisory circulars in 2020 (CASA, 2020).

B.4 Use Cases

This section explores use cases in industrial sectors in which drones have shown the greatest potential. It first outlines the main functions that drones perform in each sector, and then examines the international drone use cases and compares them with the Australian use cases in these sectors. A summary of drone use cases by sector can be found in Table B.5.

B.4.1 Agriculture

Aerial intervention in agriculture dates back to the 1920s when the US Army researched with pesticides in what was called crop dusting and took photos for crop analysis. Such activities remained in the realm of research until the Royal New Zealand Air Force and the Ministry of Public Works spread seeds along with fertilisers in 1939 (Campbell, 1948). From then, the use of airplanes and helicopters in agriculture became fairly common (Frankelius et al., 2019).

Since 2011, when drones became more affordable, their roles in agriculture became widespread and progressively more intense, e.g., applications related to IoT or smart farming (Frankelius et al., 2019). Smart farming is the application of ICT in agriculture and could potentially increase productivity and sustainability by efficient and precise use of resources. Smart farming and IoT-driven agriculture includes devices, such as precision equipment, IoT sensors and actuators, geo-positioning systems, UAVs and robots. Drones are expected to improve productivity and profitability in agriculture by efficient use of modern technology, as well as reduce environmental footprint, through more efficient and targeted irrigation and use of pesticides and crop fertilisers (Islam et al., 2021).

With their seeing and sensing functionalities, drones support information management systems. Precision agriculture aims to effect greater control over production by recognising the spatial and temporal variables and by collecting relevant data to improve yields in accordance with economic and sustainability goals (Ruiz-Vanoye et al., 2022). Drones are also becoming an integral component of agricultural automation and robotics, which includes the application of robotic technologies, automated control and AI (Ruiz-Vanoye et al., 2022). Islam et al. (2021) outlined some major applications of IoT and UAVs in smart farming and the associated communication technologies, network functionalities and connectivity required.

One technological threat that could affect the adoption of drones in agriculture is the growing commercialisation of satellite images (Deloitte Access Economics, 2020). Satellites remain a serious and long-term competitor to drones in producing high-quality images. Drones have advantages over satellites in terms of higher-resolution imaging; greater precision, especially below canopy or cloud cover; and ease of deployment and can carry out interventions. However, they need to be more accessible, scalable and affordable (Satish, 2021).

B.4.1.1 International evidence

The agricultural drone market worldwide is forecasted to exceed US$1 billion with some 200,000 units shipped by 2024, and this growth is attributed to increasing awareness of the benefits and challenges of the use of drones in agriculture among farmers (Global Market Insights, 2017; Meola, 2021). Market Research Future has forecasted a global market size of US$22.1 billion by 2030, with a compound annual growth rate (CAGR) of 29.3%. The global scarcity of farm labourers is spurring farm owners to invest in technology alternatives, including agricultural drones, which perform well and save time as well (GlobeNewswire, 2022). As for the Asia-Pacific (APAC) region, the agricultural drone market is projected to increase by more than 300% to A$2.9 billion, by 2028, up from A$647 million in 2020 (Department of Agriculture and Fisheries, 2021).

In North America, the US is the key market for smart farming, and up to 80% of farmers in the US have already implemented it (Smart AKIS, 2016). Research suggests a significant impact on the bottom line of some farmers' budgets, with the average US farmer using drones obtaining a return on investment of US$12 per acre for corn, and US$2 to US$3 per acre for soybeans and wheat (Department of Agriculture and Fisheries, 2021). Further, Ruder (2019), who studied the experiences and beliefs of Ontario grain farmers, found that digital farming led to increased efficiency, productivity and profits. The farmers also faced many challenges, and their responses were complex, encompassing both pros and cons of technology adoption.

Using a deep learning instance segmentation method (Mask R-CNN) and drone images for olive tree crown and shadow segmentation, Safonova et al. (2021) were able to estimate the biovolume of individual trees and thereby monitor fruit production and the health of olive trees in Andalusia in Spain. In the UK, drone technology is being employed by police during night patrols to help prevent the theft and slaughter of sheep on farms. The drones were reportedly able to cover large areas and see better at night with thermal imaging than police officers in patrol cars on the road (Bryant, 2019).

B.4.1.2 Australian evidence

Currently in Australia, drones are used regularly for crop spraying and mapping, livestock management and, increasingly, as part of precision agriculture even though they are fairly expensive at about A$45,000 (for those capable of carrying larger payloads; Goldman Sachs, 2016). Deloitte Access Economics (2020) estimated that some 38,000 drones could be deployed in Australia by 2030 for agricultural uses.

Hobba et al. (2021) demonstrated how invasive weed species can be detected, classified and mapped using drone imagery. Using drone-mounted LiDAR and multispectral imaging sensors, Shendryk et al. (2020) monitored two sugarcane fields with variable nitrogen (N) fertilisation inputs in the wet tropical region of Australia. Islam et al. (2021) explored how the IoT and UAVs are being applied in smart farming and the necessary communication technologies, network functionalities and connectivity requirements. Nolan et al. (2015), in a study of vine rows in Lancefield, Victoria, described their automated algorithm that uses skeletonisation techniques to prove the efficiency of unsupervised detection and delineation of vine rows by drones in a commercial vineyard.

Zuo et al. (2021), in a study of irrigators across the Murray–Darling Basin, identified a host of factors that could affect the uptake of drones. From a base of 5% adoption across the sample in 2015–2016, adoption was predicted to increase dramatically to 29% over the next five years, but this is likely to vary significantly based on farm type. Irrigation broadacre farms are most likely to adopt drones (45%). Horticulture is next (24%), followed by dairy/livestock farms (22%). The more educated, irrigators who use more water, those with larger farms, and those experiencing labour shortages were more likely to be early adopters (Zuo et al., 2021). The study also highlighted the dependence on access to financing, and the ability to service debt as influencing factors. Notwithstanding the benefits, future adoption will depend on the relative advantage of drone technology over other technologies and tools. Another important factor is how privacy, data sharing, insurance and regulations around safety and privacy develop over time (Zuo et al., 2021).

A farm in Queensland (QLD) has experimented using a drone to deposit tens of thousands of sunflower seeds and claimed to record the first flower in the world planted by a drone. The drone distributed 45,000 seeds per hectare with the aim of sprouting 30,000 plants (Hewson, 2021; Katanich, 2022). Drones may even be better at herding sheep than dogs or people. An Australian study reported that farmers who used drones to herd their flock had less stressed sheep, which affected their animals' welfare (Yaxley et al., 2021).

Jamin Fleming, from Bundaberg, QLD, has been using drones for spraying to control pests, weeds and diseases as a service for farmers since June 2020 (Spires, 2020). Apart from being better able to reach the top of canopies, the drones could reduce the use of chemicals by 30% and water by 90%, and they were able to reduce carbon emissions from heavy diesel machinery, which would otherwise pollute the environment (Spires, 2020).

Australia is an agricultural powerhouse that produces food enough for 75 million people and exports about 70% of this produce. However, more innovation is needed to cope with climate change challenges. Farmers are likely to use more high-tech solutions, such as drones to ensure the efficient use of fertilisers and water, robots for labour shortages and sensors for various measurements of the ecosystem (Rudd & Evans, 2022).

To help improve the protection, resilience and productive capacity of Australian soils, water and vegetation, which underpin successful primary industries and regional communities, the Australian Government allocated A$136 million to the Smart Farms program over a five-year period from 2017–2018 to 2022–2023.

B.4.2 Freight and last-mile deliveries

Since 2013, when Amazon, DHL and Google announced plans for drone-based delivery systems, researchers have been trying to investigate the feasibility of drone delivery, especially given the average drone's limited flight duration.

There are three main drone delivery network models (Cokyasar, 2021). The first is where drones deliver parcels directly but may use any of the charging or battery swap facilities installed enroute. The second is a hybrid drone–truck model that eliminates the need for separate charging infrastructure for the drones since the truck is equipped with the necessary charging facilities. In this model, drones effectively execute the last-mile delivery. The third suggested model uses the roof of public transport vehicles for drones to 'hitch a ride' and then, at some ideal point, leave the vehicle for the end point or hitch on to another public transport vehicle (Cokyasar, 2021; Gabani et al., 2021; Huang et al., 2020; H. D. Yoo & Chankov, 2018). Each of these delivery system solutions have their advantages and disadvantages, but the preference for any application is likely to depend on many other factors, such as the state of technology, the regulatory environment and geographical and demographical factors.

Raj and Sah (2019) presciently revealed 12 factors that were important to the adoption of drone delivery services. Technological advancements and government regulations are found to have the greatest impact. The 12 critical success factors are:

- customer perception,
- technical aspect,
- government regulations,
- low initial cost,
- environmental considerations,
- consideration of low operational costs,
- better responsiveness,
- effective traffic management,
- leadership commitment,
- skilled workforce,
- better infrastructure and
- conducive research environment.

B.4.2.1 International evidence

According to Business Wire (2022), technological advancements, such as VTOL, geospatial mapping, IoT and machine learning, have increased the accuracy and reliability of drone-based package delivery. The COVID-19 pandemic demonstrated the abilities of drone technologies, and since then, many governments have relaxed their regulations related to drones, which has resulted in the proliferation of drone start-ups and drone delivery service providers. The global drone package delivery market is estimated to hit a CAGR of 49% by 2030, on the back of growing demand for e-commerce and contactless delivery and snowballing private investments.

North America and APAC are considered drone package delivery markets with high growth potential. In the US, liberal rules regarding drone flights have paved the way for the legal use of drones in delivery services in civil and commercial airspace. US companies are increasingly commercialising drone package delivery services for the food, pharmaceutical, logistics and retail sectors. Wing, a drone delivery service of Alphabet, is partnering with FedEx (US) and Walgreens (US) to deliver select FedEx packages and Walgreens' health and wellness products. Wing is able to deliver packages weighing between two and three pounds right to the doorstep of customers faster and cheaper than traditional services (Business Wire, 2022).

APAC's huge population and its higher demand for online shopping are expected to result in it accounting for the highest market share of drones (Statista, 2017). Major players, such as JD.com and Alibaba, are investing heavily in this space. Heavyweights such as Alphabet Inc. (US), DHL International GmbH (Germany), Zipline (US), United Parcel Service of America, Inc. (US), FedEx (US), Airbus S.A.S. (Netherlands) and EHang (China) have strong global distribution networks and are driving demand for drone package last-mile deliveries (Business Wire, 2022). In a survey in the US, customers were found to be more trusting of drone deliveries for books (74%), clothes and apparel (73%) and pet items (54%) than for luxury goods (15%) and electronic goods (32%; Statista, 2017).

Drones are also used extensively to transport medical supplies. For example, Manna Aero delivers essential medical supplies in the small rural town of Moneygall in Ireland, using autonomous drones made in Wales (Molloy & Copestake, 2020). In December 2021, a batch of 300 vaccines was transported over rugged terrain in Palghar (Maharashtra), India, within 10 minutes via a partially autonomous drone (Business Wire, 2022). The journey would otherwise have taken more than 90 minutes using traditional transportation. Such time-saving deliveries could be the future for the drone package delivery market in 2022–2030. The company in charge, Flexport, Inc, expects e-commerce giants, such as Amazon.com, to charge more for short duration (<30 minutes) drone deliveries than for longer duration ones (>30 minutes). Notably, Boeing (US) and Wingcopter (Germany), two major original equipment manufacturers of delivery drones, focus on developing drones that can operate for more than 30 minutes without recharging or refuelling (Business Wire, 2022). The growth of the long duration segment is riding on the anticipated demand for instant intercity package delivery.

In the US, temperature-controlled vaccines were first delivered by the homegrown company Volansi in partnership with Merck, in 2020 (Snouffer, 2022). The pilot program was run in eastern North Carolina where those in remote rural communities and on barrier islands have limited access to healthcare services (Snouffer, 2022). Further, in a collaboration between drone manufacturer Zipline, and vaccine manufacturers Pfizer and BioNTech, drones were used in Ghana to deliver COVID-19 vaccines, which needed ultra-cold chain (Pfizer, 2021).

Switzerland's national postal service, Swiss Post, tested the use of drones to transport laboratory samples in urban areas between two hospitals in the city of Lugano; it operated many test flights and had been confident of establishing a regular service in 2018 (Pathology Awareness Australia, 2017). After some initial setbacks, Matternet, the California-based drone logistics company, declared that it will take over drone delivery operations from Swiss Post from 1 January 2023, after having worked with it since 2017. Matternet plans to develop Europe's first city-wide drone delivery network by 2023 (de Jager, 2022; Singh, 2022b).

In 2018, the Vanuatu Ministry of Health, in collaboration with United Nations Children's Fund (UNICEF) and the Australian Government, contracted commercial drone delivery systems to help local healthcare workers deliver essential childhood vaccines to remote villages and communities across the country's 83 islands. Supplies and medicine would otherwise have to be delivered by boat and then by foot (Snouffer, 2022). Further, a Mexican company, Sincronia Logistica, delivered clean medical supplies to hospitals using drones during the coronavirus pandemic. Uncrewed drones delivered personal protective gear and other essential equipment to public hospitals in Queretaro and restricted the spread of coronavirus by using quick, contact-free drop-offs (Chowdhury, 2020).

Business Wire (2022) has projected that increased demand for quick and same-day delivery, including of emergency supplies, will drive the market for drone delivery services. It has forecasted that the short range, short duration, less than 2 kg parcels and medical aid segments will experience the highest growth, particularly in the APAC region.

B.4.2.2 Australian evidence

Express parcel deliveries in Australia are performed using automated drone technology for the 'last leg' of a delivery. Currently, using GPS and smart phones and starting from a distribution centre or retail shop, drones can be directed to a pre-specified drop-off location (Deloitte Access Economics, 2020). Drone delivery competes with traditional van deliveries, and estimates indicate that the number of express parcel deliveries by drones in Australia will be between 37 million trips and 61 million trips in 2040, depending on the level of uptake (Deloitte Access Economics, 2020).

Alphabet's Wing celebrated exceeding 100,000 deliveries in Australia by releasing a publicity video. According to Wing, the deliveries in Logan, where they operate from in Australia, have included, among other food items, 10,000 cups of coffee and 1,700 snack packs for children (Kwan, 2021). COVID-19 triggered regulatory changes, which allowed Wing to execute more operations to improve their service, and it now aims to expand to other Australian cities (Ahmed et al., 2022).

Food delivery services intend to use automated drone technology to deliver food from outlets or restaurants directly to consumers by using technology similar to that used for express parcel deliveries, and they compete primarily with existing food delivery service providers (e.g. UberEATS, Menulog and Deliveroo; Deloitte Access Economics, 2020). It has been estimated that the demand for drone food deliveries in Australia will be between 46 million trips and 65 million trips by 2040 (Deloitte Access Economics, 2020). KFC Australia has teamed up with Wing to pilot a delivery service of both hot and fresh menu items in Australia (Cameron, 2022).

The Goondiwindi Region became the first community in Australia to trial deliveries of medications to rural residents via an autonomous drone in a pilot, partnering with TerryWhite Chemmart; drone logistics company, Swoop Aero Pty Ltd (Swoop Aero); and healthcare wholesaler, Symbion, with funding from the EBOS Group (Goondiwindi Regional Council, 2022). Drones are used to deliver pathology samples from local medical and pathology centres are delivered directly to testing facilities, such as hospitals, in direct competition with traditional delivery methods. The demand for this service is expected to range from 8 million trips to 17 million trips in 2040 (Deloitte Access Economics, 2020).

The geography of Australian cities and Australians' propensity to embrace new technologies could boost drone technology uptake (Deloitte Access Economics, 2020). To realise the cost and time savings and reductions in emissions and energy consumption possible with drone-based last-mile delivery, some of the barriers to drone adoption, such as government regulations, need to be addressed first (Persson, 2021).

B.4.3 Construction sector

Allied Market Research has estimated that the global market for construction drones will reach US$11,968.6 million by 2027—an increase at a CAGR of 15.4% in the 2020–2027 period (Amar et al., 2020). Drones are primarily used for building inspection, damage assessment, site surveys, safety inspection, progress monitoring, building maintenance and other general construction applications (Zhou & Gheisari, 2018). Cost savings, time efficiency and improved accessibility are the primary reasons for choosing drones. Rotary wing drones with cameras, LiDAR and Kinect are the most common onboard sensors integrated in construction UAS applications (Zhou & Gheisari, 2018).

Elghaish et al. (2021), who reviewed the literature on drones in the construction industry, similarly found that UAV-based applications in this industry have, thus far, focused on two early streams; one is automated surveying, information management and visualisation, and the other is construction inspection, monitoring and safety management. Highlighting the need for more focus on the implementation process, they called for more in-depth exploration of UAV utilisation in construction site management. They asserted that greater clarity is required on the extent to which UAVs can disrupt existing practices and increase costs, as well as how UAV technology integrates and interfaces with other technologies within the broader construction operations.

Greenwood et al. (2019), in a comprehensive review of drone use in civil engineering, highlighted that they are primarily used for structural assessments of buildings, surveys, mining and construction monitoring. Reflecting on some of the recent drone research, they predicted that drones would become a powerful autonomous system that has the ability to develop an action plan and enhanced abilities to collect, process and compute data to make next-level decisions. The authors listed the following six knowledge gaps that they believe will become major research thrusts in future:

- integration with workflows and data fusion,
- autonomous frameworks,
- subsurface sensing systems,
- swarms and UAV cooperation,
- interfacing with humans and
- actuation of infrastructure.

Golizadeh et al. (2019) identified five categories of barriers to drone adoption in the construction industry: weather, organisational barriers, technical difficulties, restrictive regularity environment and site-related problems. Rachmawati and Kim (2022) investigated the rising trend of integrating drones with digital technologies, such as building information modelling and extended reality, its application areas and technology trends. They identified seven areas of such integration. Some of the prominent ones are monitoring and inspection services, construction education and safety, and transportation. They revealed three technology trends that encourage automation and digitisation, namely, automated UAV inspection planning, real-time video streaming and parametric model development of historic buildings.

The primary reasons for choosing UASs in the construction sector drill down to cost and time savings and enhanced accessibility (Zhou & Gheisari, 2018). Vanderhorst et al. (2019) opined that currently, the most valuable benefits of UASs in construction are that it facilitates process automation, cost reductions, speed increase and safer real-time data collection, compared with traditional methods. UASs are also a sufficiently reliable source of high-resolution images, which can replace satellites and crewed vehicles.

B.4.3.1 International evidence

The inspection drone market is expected to expand at a CAGR of 24.1% for the forecast period of 2022–2031 (Bloomberg, 2022). For E-Construction, which is among Western Canada's largest paving contractors with 650 employees, drones are increasingly important for efficiency and for reporting on project progress. The company estimated that using drones saved them US$50,000 to US$60,000 annually (Powell, 2019). The Canadian town of Battleford started using drones for inspection work underneath its bridges in 2020 (Cairns, 2020).

As early as 2016, Brasfield & Gorrie, one of the largest privately held US construction firms, relied on drones for access to high-quality aerial data throughout every phase of their award-winning construction projects. The company chose the drone services of Skyward, a Verizon company, to maximise utility over multiple distant locations (Bloomberg, 2022). In the UK, drone adoption in the construction sector is led by high-profile businesses, such as Kier, Costain and Mitie, Strabag, a European construction leader that provides a wide range of services, is among the early movers that have invested in drone technology in Europe (Microdrones, 2017). Qatar achieved its ambitious construction goals for the 2022 FIFA World Cup with the construction firm Arcadis using drones for its massive highway project in Doha (Antunes, 2017).

B.4.3.2 Australian evidence

In Australia, Transport for New South Wales (TfNSW) has been conducting trials using drones and 3D mapping software to inspect bridges and identify maintenance requirements (Crozier, 2022). Sphere Drones, an Australian drone company, has been successfully trialling this technology at bridges across NSW, including the Sydney Harbour Bridge. Minister for Metropolitan Roads, Natalie Ward, observed that the technology would maintain all bridges across the NSW road network to the highest standard (Crozier, 2022).

CPB Contractors (2021), one of Australia's largest construction companies, employs the latest technology fitted to drones to capture realistic images in real time and streamline the way they survey and map large areas. Bechtel Corporation (2015), one of the largest construction companies in the US by revenue, is also examining drone technology to help with future construction projects. Starting in 2015, Bechtel has partnered with Skycatch to use their drone imaging technology across its constructions. Bechtel tested Skycatch's drones at its liquid natural gas processing facility project on Curtis Island, Australia. The drones conducted real-time analyses of environmental conditions, including temperature and air quality.

Li and Liu (2019) reported that the main contributions of drones in the construction sector are ensuring the safety of workers and cost reductions and working towards a better and sustainable future. They asserted that although multirotor drones have been applied to various fields, such as agriculture and mining, and may facilitate operations in the construction sector, they are still not widely used in this sector.

B.4.4 Public services sector

In Australia and worldwide, public service sectors, such as policing, border control, firefighting, disaster management, patrolling coastlines and environmental protection, have seen drone use. Some use cases, such as search and rescue missions, and disaster management operations, have received widespread public approbation (Aydin, 2019; Katwala, 2018; Markowitz et al., 2017; Sakiyama et al., 2017).

In the area of emergency medicine, drones hold great promise, particularly for quick delivery of medical equipment and medicines for self-administration or by a bystander (Johnson et al., 2021). Cameras on drones can assist in medical assessment and improve emergency response. For instance, drones can initiate patient evaluation, deliver blood and other emergency products and provide treatment more rapidly than ambulance response alone, particularly in areas that have historically experienced longer emergency medical services response times. Other important applications are search and rescue and mass casualty responses (Johnson et al., 2021).

In a study with citizens who have called emergency services, Khan and Neustaedter (2019) showed that drones bring great benefits since callers receive feelings of assurance that help is on the way. While participants had no concerns about privacy, they were concerned about safety, especially for indoor flying. The results suggest opportunities for designing drone systems that help develop people's trust in emergency response drones and mitigate their privacy and safety concerns with more complex drone systems. This study showed that callers trusted emergency drones, and compared with common notions about video streaming, these drones had a high level of public acceptance. Therefore, emergency service drones should be clearly identifiable. Callers found drones useful to communicate with actual 9-1-1 dispatchers or even first responders, and effectively personified drones. However, there is a possibility of information overload for call takers or first responders because of two-way communication.Moreover, in recent years, the use of drones to monitor road traffic has grown, and the main benefit is that they can be deployed rapidly to different places for monitoring the usage of various public infrastructure, such as roads, bridges and train tracks (Butilă & Boboc, 2022).

Alon et al. (2021) explored the role of drones in firefighting support beyond the present practice of providing images and live visuals as a remote-control tool. With increasing autonomy, drones are envisaged to have the potential to support firefighters more actively in their mission with improved human–drone interaction. Experts in firefighting were optimistic about the future of drones in firefighting and would like to have drones operating in every fire station and involved in both indoor and outdoor missions. They emphasised that drones should have situational awareness, which is critical in firefighting missions, such as detecting and analysing the main and secondary spots of a fire, their locations, numbers, and type of fuel, and be able to identify firefighters on the scene and civilians in immediate danger. This study also emphasised the need for future drones to have voice and gesture recognition ability and to provide processed data rather than raw images and videos when firefighters are under high mental and physical workload. Another future improvement is to go beyond the single integrated drone to an integrated swarm of drones.

The research of Alon et al. (2021) identified four tasks that were deemed most important in human–drone interactions:

- Mapping: Drones could be sent to map an entire building, its layout and structure.
- Identifying hazardous materials: Drones could be used to identify hazardous material (e.g. gas and chemicals) and the source and size of leaks.
- Detecting fires: Drones could identify fire spots.
- Finding survivors: Drones could search for trapped civilians or people otherwise in danger, such as in situations of ‘fear for human life and aid to civilians’ when drones could easily search a building or house before deciding whether it is necessary to break down doors or break into the house or apartment.

B.4.4.1 International evidence

Swoop Aero, an Australian company, has been playing an important role in providing public medical services on the African continent (Crumley, 2022a; Fortune Business Insights, 2022). After successful first-phase trials to transport COVID-19 and tuberculosis samples and test results between villages and labs, Swoop Aero has been permitted to expand the services offered in Mozambique to improve the country’s healthcare and disease prevention programs (Crumley, 2022a). Similar operations of public service, in collaboration with international agencies, have been conducted in countries such as Malawi and the Democratic Republic of the Congo in Africa, and in the Pacific Island country of Vanuatu (Chanthadavong, 2022). In 2017, a Colombian company, Nuba Drones, launched the AirMed project to transport medicines and blood samples safely and efficiently between the rural and hilly areas around the city of Cali and hospitals by using drones. The project was developed 100% locally in Colombia and provided access to fundamental medical services to almost 20,000 people (Gallan Herranz, 2017).

Moreover, smart and innovative technologies are critical in improving responses to traffic crash emergencies. For instance, Kristensen et al. (2017), in their study in Esbjerg, Denmark, showed that Rescue Emergency Drone (RED) can provide fast real-time risk assessments of crash sites to emergency medical services. This can help them to assess a situation, dispatch the right equipment and assist bystanders to treat inflicted persons properly, quickly and accurately. Their study demonstrated how RED can help save lives during an emergency. A

RED flying at 100 km/h was able to reach the incident point in 5.16 minutes, compared with the incident commander who took 10 minutes in a vehicle, and sometimes 12 minutes during peak hours, which proved that RED has a better response time than a conventional response vehicle (Kristensen et al., 2017).

In the US, many municipal fire departments are increasingly using drones. One of the market leaders to use drones for firefighting is the New York City Fire Department's FDNY Robotics Team (Ciobanu, 2022).

Drones are ideal for inspection works, particularly in tall structures and buildings. Regulatory measures following the UK's Grenfell disaster have mandated annual inspections of buildings with a render or brick-slip finish external wall insulation (Government Business, 2022). Drones can perform such inspections repeatedly and cost-effectively and provide valuable data to improve the maintenance regime. Further, the use of drones rather than traditional methods has cut inspection times for more than 600 council properties in the UK significantly. This has also helped to minimise the safety risks from working at height and the risk of further damage to property from physical inspections (Government Business, 2022).

B.4.4.2 Australian evidence

In the Australian context, the Western Australian police force used drones in 2020 to deliver public announcements at beaches, parks, café strips and other public places to assist in the enforcement of COVID-19-related rules, such as social distancing (Government of Western Australia, 2020). Most states and territories in Australia have recently committed to greater investment in order to introduce technology to help detect, prevent and mitigate natural disasters, such as bush and forest fires and floods. Drones have proven to be essential these days. An estimated 6,200 units to 26,350 units could be used by Australian Government services by 2040 (Deloitte Access Economics, 2020).

The NSW Government spent about A$57 million on technology and IT systems, including 30 drones for live streaming thermal images to incident command, in order to better inform firefighters (Lal, 2021). The drones can also drop fireballs to allow for better bushfire management. In 2022, two teams of RPAS pilots from the Bushfire and Aviation Unit were deployed to the Northern Rivers to identify and map the location of dangerous debris (Ethan, 2022).

Fire Rescue Victoria created an aviation unit in 2021 that is equipped with drone technology to assist in firefighting and other emergency services. The unit has four drones that support high-definition thermal imaging and the live streaming of videos, can fly for 30 minutes and can withstand strong winds. The unit is staffed by drone pilots and aviation-trained personnel as well as specialist firefighters (Chanthadavong, 2021).

The Australian National University, in collaboration with the ACT Parks and Conservation Service and the ACT Rural Fire Service developed an innovative national system to detect bushfires as soon as they start and to extinguish them within minutes (Yebra et al., 2021). Drones equipped with thermal scanners and using the beyond visual line of sight (BVLOS) technology play a pivotal role in the fast identification, location and verification of bushfire ignitions due to lightning during dry thunderstorms to enable rapid tactical support for subsequent suppression activities.

During Tasmania's Huonville floods in July 2016, the Department of Primary Industries, Parks, Water and Environment in Tasmania used drones to capture and map information relating to more than 80 ha of flood-affected land, enabling the State Government to determine the full extent of the deluge and for the Department to better direct its response and recovery efforts. Within minutes, an accurate picture of the number of private properties and schools affected, their locations were determined and immediate actions were taken, using the high-definition 3D imagery from drones. Imagery during and post the event helped to create modelling that would be essential to help mitigate future risks (Mullens, 2016).

Not-for-profit organisation Surf Life Saving NSW (2022) has a UAV program funded through the NSW Government Shark Management Strategy that covers about 50 locations, including popular tourist destinations on the far north and far south coasts of NSW and in the Greater Sydney region. In addition, Sunshine Coast Regional Council (2020) have been using drones since 2015 for inspections, especially for maintenance activities where jobs are dangerous, difficult or too hard to access. The QLD Government has complemented their sharing of policy experience and recommends that more councils take the cue.

B.4.5 Mining and resources

Drones in the mining industry are used in surface, underground and abandoned mines and can be categorised as in Table B.4.

Table B.4: Drone applications in mining (sources: Lee & Choi, 2016; Shahmoradi et al., 2020)

Surface Mine	Underground Mine	Abandoned Mine
Mine operation	Geotechnical characterisation	Subsidence monitoring
3D mapping	Rock size distribution	Recultivation
Slope stability	Gas detection	Landscape mapping
Mine safety	Mine rescue mission	Gas storage detection
Construction monitoring		Acid drainage monitoring
Facility management		

Drone technology is widely used in surface mining because it is an efficient and low-cost tool compared with traditional monitoring methods (Shahmoradi et al., 2020). The various applications of drones include ore control, rock discontinuity mapping, 3D mapping of the mine environment, blasting management, post-blast rock fragmentation measurements and tailing stability monitoring. The challenges in surface mines are the weather and the need for increased battery life. Drones in the mining industry need to be waterproof, dustproof and shockproof and be able to withstand pressure, temperature and humidity changes throughout the mine site (Shahmoradi et al., 2020).

Although some drones can be used in underground mines, their use is limited because of challenges such as the loss of GPS signals and wired signals, the confined space and other environmental challenges (Shahmoradi et al., 2020). Drones help with health and safety through surface roughness mapping, rock mass stability analysis, ventilation modelling, hazardous gas detection and leakage monitoring.

The US and Australia have about 500,000 and 60,000 abandoned mines, respectively, which are not only an environmental hazard but also a health and safety hazard to humans. Drones could play a significant role in monitoring those mines and in mitigating health, environmental and safety risks (Shahmoradi et al., 2020). Drones can be also used for search and rescue operations by the mining industry in vast and remote areas (Shahmoradi et al., 2020).

The use of drones for mining applications has been growing particularly in the areas of exploration, surveying and mapping as well as in enhancing the safety, security and oversight of operations over the past 10 years (Position Partners, 2022). Australia and Africa lead the way in drone adoption, and with improving technology, more drones have been deployed on mine sites for a variety of new applications. Most large mine sites in Australia in 2020 were equipped with a couple of roustabout drones on site with trained, licensed pilots to deploy them at short notice (Position Partners, 2022).

B.4.5.1 International evidence

According to Global Data's (2022) surveys of surface and underground mine sites, 44% of mines had invested in drones in 2018, which increased to 65% in 2022. Moreover, 32% of the industries surveyed in 2022 stated that they had either fully invested in drones or had made significant investments. With 75% of respondents declaring full investment or considerable investment in drone technology, mines in the Australasia region lead the way.

Surveying and mapping were listed as the top use; 83% of respondents used drones for this purpose, with claims of about 90% of cost per hour saved over a piloted plane and the ability to obtain unlimited aerial data, including fine measurements. Monitoring and inspection were the second most popular usage (68% of respondents agreed), followed by site safety (44% of respondents agreed), managing stockpiles (42% of respondents agreed) and tailing dam monitoring (21% of respondents agreed; Global Data, 2022).

At the Bingham Canyon Mine in Utah, US, the largest open pit mine in the world, owners Kennecott had deployed 30 FAA-certified drone pilots running four to five flights per day using 10 drones in 2017, after a four-year effort to boost employee safety and enhance surveying capabilities. The drones gave employees access to locations that were previously unreachable owing to safety concerns, large amounts of useful data, and real-time connectivity with other mining operations technologies to make quicker and better decisions (Moore, 2017). Similarly, at the Nevada Gold Mines, one of the largest gold-producing complexes in the world, there were 11 licensed drone pilots out of a team of 17 surveyors to collect data especially for stockpile measurements (Propeller Aero, 2020).

ArcelorMittal has had a long history of using aerial photography, starting with air balloons in 2004 and remote-controlled helicopters in 2010, before eventually moving into drone technology. This early adoption has helped their Fos-sur-Mer plant in France to be a major contributor to ArcelorMittal's Drone Cell Division worldwide. All ArcelorMittal plants, including 30 industrial sites in Europe, Africa, America, Asia and Australia, organise quarterly web conferences to share best practices and push for smarter integration of drones (sUAS News, 2021).

Meanwhile, drones are being used in South African coal mines to help battle coal theft and ensure the safety of staff and mines (Burkhardt, 2021).

B.4.5.2 Australian evidence

In the Australian mining sector, drones are increasingly used for the following reasons (Position Partners, 2022):

- Drone mining surveys produce highly accurate measurements using photogrammetric cameras and software.
- A survey drone can capture data or images from the field 30 times faster and more easily than can traditional onsite surveying or inspection methods.
- Drone surveys can help identify safety hazards to improve worker and mine site safety.
- Drones can provide real-time monitoring with live images from site.

Fortescue Metals Group, Australia, deployed drones as early as 2015 to survey its Cloudbreak mine in the Pilbara region in order to reduce the health and safety risks to its survey staff.

They tested many drones at Cloudbreak in stockpile volume and topographic surveys (Coyne, 2015).

The adoption of drones in the mining sector also increased during the pandemic. For example, Rio Tinto, the UK-based global mining group, increased its drone use to conduct visual inspections of facilities and equipment from anywhere in the world without violating the safety and social distancing measures imposed by COVID-19 restrictions (Spires, 2021). Other mining companies, such as BHP, are also following to adopt drone and uncrewed technology to improve safety, operations and financials. Savings of more than A$5 million per year from using drones for conducting various hazardous and long inspections were reported (Innovate Energy, 2021). In addition to time and money savings, there is the benefit of improved safety. BHP has also trialled inspection drones on its ocean freighters to improve safety of workers and to collect data (Spires, 2019). In 2021, Rio Tinto announced that it was expanding its use of drones, which it had already commenced in its Western Australian, QLD and NSW aluminium, coal and diamond operations (Spires, 2021).

With thousands of abandoned ‘bord and pillar’ underground mines beneath residential areas in Newcastle (NSW) and Ipswich (QLD) in Australia, there is a risk of ground subsidence. Methane emission from these abandoned mines pose a further danger. Drone imagery can be a cost-efficient alternative to the expensive and hazardous manual mapping of such vast mines (Shahmoradi et al., 2020).

B.4.6 Environmental management

Over the past decade, drones have emerged as a relatively risk-free and low-cost way to quickly and systematically observe and study natural phenomena with high spatio-temporal resolution, creating a major trend in wildlife research and management (Jiménez López & Mulero-Pázmány, 2019). Drones are increasingly used for conservation management, in activities such as monitoring and tracking animals, anti-poaching interventions and sample collection. Increasingly sophisticated technologies are being used as payloads on drones in various studies because of cost savings and their ability to be less intrusive than crewed aircrafts (Pozner, 2020).

Drones offer a wealth of opportunities to improve the scientific and social understanding of a broad spectrum of water resource management issues (DeBell et al., 2015). This is despite the fact that there remain challenges, such as reducing the size of certain sensors, such as LiDARs; regulations; and issues surrounding the societal ‘trust’ of UAVS and the delivery of high accuracy spatial data.

Environmental impact assessments require constant updates of imagery over specific geographical areas, which drones can deliver effectively. Using features such as pre-programmable flights and low flying altitudes, drones can capture detailed data down to 1.7 cm/pix and deliver some of the most up-to-date accurate information available to support such assessments (Global Drone Surveys, 2022).

The rapidly growing use of drones in the field of conservation has also raised concerns about the negative impact on wildlife, particularly endangered species, when used without careful consideration. This is particularly significant in the case of wildlife in aerial and terrestrial habitats. A recent study found that approximately 26% of the of the species that were disturbed by drones are considered endangered by the International Union for Conservation of Nature (Rebolo-Ifrán et al., 2019).

In addition, the British Trust for Ornithology reported that the habitats of wintering waterbirds are disturbed by drones (Sexton, 2020). The researchers found that many waterbirds, such as ducks, geese and swans, are easily frightened away by drones. This reduces their feeding time and wastes their energy. Their responses to drones can vary, depending on the extent of human interactions and their habitat ecosystem. For example, birds in inland areas where human activities are more common were very unlikely to respond to drone disturbances. In contrast, waterbirds in coastal habitats with less human presence were highly likely to respond to drones (Sexton, 2020).

B.4.6.1 International evidence

A published study by Towner et al. (2022) incorporated video footage shot by drones of orca whales hunting, killing and eating white sharks off the South African coast, which had previously only been theorised. This study made headlines in the media (Winter, 2022). While the footages were dramatic, the ability to capture such clear empirical evidence demonstrates the power of drones to aid in increasing environmental understanding and management.

The World Wildlife Fund's (WWF) 2020 report, titled '*Drone Technologies for Conservation'*, is a very informative, illustrative guide on how drones can be used in the study of conservation and in conservation efforts itself (Duffy et al., 2020). The report provides some actual case studies of such conservation efforts using drones. These are:

- monitoring plant biomass with drone photogrammetry,
- using drones to collect whale lung samples,
- empowering traditional communities and front-line staff to use drones for conservation,
- using drones for ecological research: UAS4Ecology,
- mapping habitats of the Great Barrier Reef,
- surveying river dolphins in the Amazon,
- assessing mangroves in the Rufiji Delta, Tanzania,
- delivering food to bear cubs,
- assessing animal sounds in forest, and wild-life conservation programs, and
- assessing local-scale effects of boat anchorage on seagrass meadows.

B.4.6.2 Australian evidence

Trials are ongoing in Australia to explore the potential of drone use in wildlife conservation. One such program run by Charles Darwin University (CDU, 2022) works with First Nations rangers in trialling thermal imaging drones to track the endangered black-footed rock-wallaby species in the Kimberley region of Western Australia to save them from extinction.

In a first of its kind in Australia, Danyi Wang working under the guidance of Professor Javaan Chahl of University of South Australia (UniSA), and Thron, a very high-profile drone pilot, used sophisticated signal processing techniques to detect the heart rate and breathing of animals such as zebras, antelopes, waterbucks and giraffes from drone footages taken at long distances. Prof Chahl reported that the results of their experiment had demonstrated that a drone can be used to film wildlife at long distances without disturbing or stressing them and, using AI techniques, still manage to extract cardiopulmonary signals to monitor their health remotely (Gibson, 2022).

In the field of reforestation, AirSeed Technologies, a pioneering Australian company, has trialled drone seeding to help plant trees on the scale needed to support struggling koala populations in Australia (WWF, 2020). Drones flying over terrain at varying heights deliver tailored solutions, depending on the species of tree, soil penetration required for germination and protection from the wind, rain and erosion. Compared with the traditional planting of about 800 seedlings a day, drones can plant 40,000 per day, planting up to 1,000 seed pods in 10 minutes. Their system can also be deployed faster and has the advantage of easier access to difficult terrain, enabling lands to be restored up to 25 times faster and 80% cheaper than with traditional planting. Equipped with AI, their drones can identify the species that have been successfully established and control weeds (WWF, 2020).

Karen Joyce, a researcher from QLD, Australia, found that instead of satellites, drones are increasingly being used to create maps, which are particularly useful for the conservation of the Great Barrier Reef. They offer the flexibility to capture data at preferred times. With the help of drones, her team has collected data over the Heron Reef study site and can now quantify changes occurring at very fine spatial scales, with which they previously had difficulties (Duffy et al., 2020).

B.4.7 Advanced air mobility sector

AAM is a broad concept and important for aviation in urban, suburban and rural communities. AAM also includes intraregional use cases of up to a few hundred miles within, or between, urban and rural areas (Cohen et al., 2021).

UAM is viewed as a form of alternate transportation system for passenger mobility, goods delivery and emergency services within and across urban cities. Some pre-COVID-19 market studies had projected the total market potential for UAS and UAM to increase substantially over the coming decade (Cohen et al., 2021). For example, it was estimated that the total global market in 2035 would be between US$74 billion and US$641 billion. Similarly, the market for goods delivery and passenger mobility services was also projected to increase. The wide variance in projections is due to differences in assumptions, methodologies and the use cases examined.

B.4.7.1 International evidence

Goyal et al. (2021) examined two potential AAM passenger markets; first, an airport shuttle, envisioned as a market for AAM passenger transport services connecting airports along fixed routes, and second, an air taxi market, envisioned as a more mature and scaled service that provides on-demand point-to-point passenger services across urban areas. They estimated a 0.5% mode share in the US for the air taxi and airport shuttle markets and concluded that conventional non-discretionary trips exceeding 45 minutes could be replaced by drone trips, subject to the price point. While acknowledging the limitations of the uncertainties around the study, they projected that in the US, about 4,000 aircrafts of four to five seats could ferry about 82,000 passengers daily in the most conservative scenario in their model, accounting for an annual market valuation of about US$2.5 billion.

Currently, the countries at the head of the AAM development race are Germany, the UK, France, Singapore, the United Arab Emirates and the US. One way forward could be that today’s dominant companies, such as Volocopter, Lilium, Joby Aviation, EHang, Airbus, Boeing, Eve and Wisk, collaborate with complementary suppliers and take advantage of synergies to access different market niches. Most important now is government involvement and support to guarantee a prosperous future for UAM, particularly for air taxi services. Researchers have anticipated many needs, including (Trabado, 2022):

- recognition of eVTOLs/STOLs as a strategic technology of the future;
- provision of a complete legal and regulatory framework that allows the development of technology in a safe and open environment;
- protection of the investment climate, expansion and flexibility of financing programs;
- acceleration of planning and approval procedures;
- investments in UAM infrastructure; and
- reinforcement of social acceptance.

Several companies are trialling AAM services using VTOL and other models of aircraft, such as Volocopter in Singapore; EHang in Linz, Austria; and Vertical Aerospace in London (Goyal et al., 2021).

Eurocontrol's U-Space project is a set of new services supported by AI and designed towards safer and efficient access to airspace for large numbers of uncrewed aircrafts. This follows trials for the U-Space sandbox in Hamburg focused on studying the interaction of the various U-Space services. The project recommended several actions in 2022, which are under examination by the funding body, the German Federal Ministry of Transport and Digital Infrastructure. The European Union's U-Space Regulation is expected to be included in national law in early 2023, and the first U-Spaces are expected to be recognised in Germany from 2023 (Unmanned Airspace, 2021).

Commercial air taxi services are expected to be launched by air taxi pioneers Volocopter and Skyports in Singapore in 2024. This could possibly be expanded to include cross-border air taxi trips to cities in Indonesia and Malaysia to significantly reduce the travel time, compared with travel by cars or ferry. Volocopter claimed that flights to Batam (Indonesia) would take less than 20 minutes (instead of the approximately 45 to 70 minutes by fast ferry) and flights to the business district in Johor Bahru would take about 30 minutes instead of the 2 to 3 hrs by car across the causeway. Volocopter demonstrated its capability in 2019 with a 3-minute flight over Singapore's Marina Bay waterfront and claimed the technology is now close to commercial rollout. The Singapore government, which has supported these efforts, has designated the Seletar Aerospace Park as a possible AAM hub as it signed a Memorandum of Understanding (MoU) with each company (Yong, 2022).

Meanwhile, London-based aircraft developer Vertical Aerospace is working with civil aviation authorities in the UK and European Union in pursuit of vehicle validation of its VX4 air taxis. Vertical aims to extend to markets in Japan, Brazil and Singapore. Its eVTOL air taxi, which is designed to fly up to 200 miles per hour and has a range of about 100 miles, claims an order book of more than US$2 billion. Vertical also seeks to operate air taxis integrated within the platform's air space for service to and from Central London (Crumley, 2022b).

Kencoa Aerospace Corporation, a South Korean drone maker, has reported that it has completed a first 'air taxi' test flight demonstration in Jeju Island. It was reported that the electrically powered taxi can travel up to 80 km with one passenger or about 100 kilograms of cargo (Urban Air Mobility, 2022).

Despite the growing list of applications of UAM in various industries, most flight tests in Europe are still conducted in a less than ideal environment. Therefore, the German Aerospace Centre is setting up a model city in Cochstedt, Germany, to investigate UAM operations, including drones and future air taxis, in an urban model environment. The facility will enable all types of UAM tests in a protected environment, including vehicle concepts, flight planning, sensor technologies and acceptance studies (Wendt et al., 2022).

Several other UAM test sites are being built worldwide. For instance, there are two sites in Spain, one is in Villacarillo and the other is in Barcelona, namely the Barcelona Drone Centre. In the US, there are numerous test sites in and around San Diego County, and there are also others in New York, New Mexico, North Dakota, Nevada, Texas, Alaska and Virginia (Wendt et al., 2022).

In November 2022, Percepto, the Israeli autonomous inspection company renowned for its Autonomous Inspection Monitoring platform, became the first service provider to secure a nationwide waiver for BVLOS flights in the US. The Percepto system can now be operated at qualifying sites across the US without having to experience all the delays in securing site-specific BVLOS approvals from the FAA, which is expected to benefit users such as electric utilities, oil and gas companies, and solar power stations (Singh, 2022a).

The Japanese government has established a task force to ensure that eVTOLs will be operational in Osaka for Expo 2025. In addition to Japan's All Nippon Airways, EHang from China and Volocopter from Germany are also working towards such AAM operations (Head, 2021). Japan Airlines Group is also working with drones as part of a bigger sustainability project on Amami Islands. They have agreed on a partnership with Setouchi-cho, Oshima County, Kagoshima Prefecture, to tackle several problems in the region, such as assistance during natural disasters and the transportation of medical supplies and daily necessities (Air Transport News, 2022).

The FAA and the Japan Civil Aviation Bureau signed a Declaration of Cooperation to support future AAM aircraft development and operations. The declaration continues the safety agencies' long partnership and formalises ongoing discussions on certifying and validating new AAM aircraft, production, continued airworthiness, operations and personnel licensing (Head, 2021). Similar arrangements have been established by the FAA with the aviation authorities of the UK, Canada, Australia and New Zealand (US Department of Transportation, 2022).

Italy too has rolled out a National Strategy Plan 2021–2030 to foster sustainable air mobility, and as part of these efforts, the city of Rome will be working with Volocopter to operate drone air taxis during the Jubilee celebrations in 2024 (Olivares & Gallo, 2022). Similarly, during the Milan-Cortina Winter Olympics in 2026, drones will transport the goods necessary to prepare for the event in order to reduce the road traffic and environmental impact.

B.4.7.2 Australian evidence

Although there are no AAM/UAM trials underway in Australia after Uber pulled out of a planned trial for eVTOL in Melbourne, an increasing number of companies are signalling interest in the Australian market. In June 2022, Wisk Aero, a leading AAM company from the US, which claims to be the developer of the first all-electric, self-flying air taxi, displayed an eVTOL in Brisbane City Centre. It has signed an MoU with the QLD Government to operate accessible, autonomous and sustainable flights and intend to hire people soon (Wisk Aero, 2022).

Another company, the Adelaide-based V-Star Powered Lift Aviation, announced plans to operate VTOLs in South Australia by 2023 as part of its AAM services and is preparing to bring in at least three types of VTOL aircrafts. The first of these is a 6–9-seater twin-engine AW609 tiltrotor aircraft from Leonardo Helicopters, which is expected to be the first commercially certified powered lift aircrafts. The company is also working with the Swiss company, Dufour Aviation, to bring Aero3, a tilt-wing hybrid-electric plane. The Chief Executive Officer of the company, Tony Laws, a pilot with experience in search and rescue operations, said the Aero3 is perfect for emergency services in Australia, given its ability to hold a stretcher and two medics and to land on almost any helipad. He also added that in terms of operating costs, the aircraft could be three times cheaper than a fixed-wing plane and 10 times cheaper than a helicopter (Plouffe, 2022).

To help coordinate regulation and support the establishment of a safe, sustainable and resilient AAM ecosystem, the Commonwealth Government's Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA), CASA, Airservices Australia and the State Government of Victoria signed an MoU in late 2021. The MoU will assist the industry and regulatory bodies to prepare for a national AAM ecosystem (Department of Treasury and Finance, 2022b). The Victorian Government also launched an AAM Industry Vision Statement on 30 August 2022, outlining its plans to develop an AAM ecosystem to save cost and time in critical functions for companies across various industries (Department of Treasury and Finance, 2022a).

CASA published ‘The RPAS and AAM Strategic Regulatory Roadmap’, indicating readiness to forge ahead with AAM. As per the roadmap, in the immediate term (2022–2023), CASA plans to (inter alia) conduct research and review around RPASs and AAM related to existing separations standards, flight rules, maintenance policies, certification and assurance work to identify gaps and publish acceptable industry consensus standards. CASA will also work with DITRDCA to establish the National Drone Detection Network and support all safety aspects of the infrastructure planning framework (Unmanned Airspace, 2022).

On 30 November 2022, CASA called for feedback on its draft advisory circular (Draft Advisory Circular 139.V-01 v1.0) for vertiport design. Beyond providing important relevant guidance and information for vertiport constructions and operations, the guidelines aim to support the development of aerodrome infrastructure and to continue to evolve with the sector (CASA, 2022c).

At the AAUS Advanced Air Mobility Summit held in Melbourne in August 2022, the infrastructure group Skyportz presented the design and plans for what it claimed to be Australia’s first vertiport for eVTOL aircraft. This is being built at Caribbean Park in the South-east suburb of Victoria in association with Contreras Earl Architects, To70Aviation, Arup and Microflite (Alcock, 2022). The plan is to let Microflite operate helicopter transfers until the eVTOLs, currently being tested in many places overseas, obtain a certificate to carry passengers, possibly by 2024 (Schlesinger, 2022).

Australian company AMSL Aero, founded by Andrew Moore and Siobhan Lyndon, has recently secured A$23 million from institutional investors to develop a hydrogen-powered version of its Vertiaa prototype and take it to commercial production. Given its estimated range of 1,000 km on hydrogen fuel and cruising speed of 300 km/hr, it is said to possibly be the world’s most efficient eVTOL powered by clean electricity and hydrogen fuel. In 2020, the NSW Government had provided a grant of A$950,000 to AMSL Aero to establish a testing facility at Narromine’s Aerodrome and the aim then was for the aircraft to achieve certification for operations by 2023 (Nichols, 2022). Moreover, AMSL Aero was successful in the first round of the Emerging Aviation Technology Partnerships (EATP) Program of the Australian Government investigating regulatory barriers and planning trials of air ambulances in regional NSW.

B.4.8 Media, recreation and entertainment

The use of aerial photographs taken by helicopters and planes is not new, but drones could be operated remotely and hence are safer and cheaper, particularly in dangerous situations, which is also accepted by major newsrooms worldwide.

In the movie industry, drone usage is no longer limited to establishing spectacular shots, for example, of sprawling cities, but are used for stunning reveals, tracking and other creative shots; are helping to eliminate more expensive tools, such as cranes, jibs and tracks; and are making it cheaper to make films.

Drones are increasingly seen as an environmentally friendly way to have spectacular light shows instead of fireworks, and impressive shows have been put together in recent years in Sydney and at the Adelaide Fringe Festival.

B.4.8.1 International evidence

The use of drones in journalism is reported to have started around 2011 when The New York Times announced the arrival of drone journalism, and soon there was a 'nearly insatiable appetite for drones' (Sengul-Jones, 2021, para. 2). Newsrooms were able to report many events that were previously deemed too dangerous, such as protests and environmental disasters. While there was celebration of footages of the inside of a volcano, there was also concern about drones invading domestic spaces (Sengul-Jones, 2021).

At present, there is a greater examination of the way drone images are used in news reporting. There is appreciation that cinematic flyovers included in news segments tend to emphasise the entertaining or immersive aspects of news, which may threaten quality journalism in future (Adams, 2019). Yet, drones have brought about changes in the way news is provided, and a potential driver behind the uptake of drones in the media industry is consumer demand in a high-choice media market. With competition getting stiffer and budgets getting tighter among media businesses, they have had to consider innovative options. There is also new research into the ethical perceptions of audiences about drone use in the media, and it has been suggested that audiences that are open to personal technology use will perceive news media using drones as more ethical (Harvard et al., 2020).

After the ban on commercial use of drones was lifted in the US in 2012, drones began to complement or replace expensive, bulky equipment, such as camera cranes and car-mounted U-cranes, in many film and television productions in Hollywood. The size and manoeuvrability of drones not only made previously conceived but unrealised filming possible but also opened the doors to a whole new world of creative productions. Drones have also become an integral part of pre- and post-production works, such as remote location scouting and building shot lists (Ip, 2022).

Drone racing is one of the fastest growing racing circuits. MultiGP, DR-1 Racing, Drone Racing League and Fédération aéronautique internationale are just some of the organisations running racing events in different formats of first-person view (FPV) drone racing (*Drone racing*, 2022).

Further, with increasing measures to contain the fire and pollution hazards of traditional fireworks, reusable and nonpolluting light displays using drone swarms have grown in popularity (Zerlenga et al., 2021). The record-breaking 3,051 drone swarm display in China in 2020 and the 2021 Tokyo Olympics fireworks are just some of the recent events that have raised the profile and possible applications of drones.

B.4.8.2 Australian evidence

The use of RPASs has grown significantly in Australia in recent years, and it now has almost 35,000 distinct drone registrations as against just under 16,000 aircraft registrations. It has issued three times as many Remotely Piloted Aircraft Operator's Certificates (ReOCs) as Air Operator's Certificates. The sector has grown rapidly with two-thirds more ReOCs existing in 2022 than in 2017, while the number of Remote Pilot Licences doubled since 2018 (CASA, 2022a).

Drone use in Australia in the recreation and entertainment sector is generally not very different from that in overseas markets. This sector is projected to have a market size of about A$900 million in Australia by 2040–2027 (Deloitte Access Economics, 2020). In May 2022, Sydney made history by showcasing the largest drone swarm light show in the Southern Hemisphere when 600 drones flew in the sky over the Sydney Harbour for the Vivid event (Skynews.com.au, 2022). However, the technology for such swarm displays has yet to mature, which was made apparent when some 50 out of 500 drones dropped out of the sky into the

Swan River during a public Christmas display event in Perth on 21 November 2022 (Swain, 2022).

Alauda Aeronautics and Airspeeder, headed by Matt Pearson, have developed a flying race car from the ground up and completed an uncrewed inaugural race in May 2022. The aircrafts are currently flown by remote control, and the company expects to have pilots airborne inside the crewed aircraft by 2024. The company, based in South Australia, believes that this can become the most exciting motorsport in future, watched by millions of people globally (Brice, 2022). The company has invested A$10 million in the project thus far and has hired and trained professional pilots to fly the aircrafts (Brice, 2022).

The most recent Australian National Drone Racing was held at Duntroon Oval in August 2022. Organised by the Australian FPV Association, a national body representing affiliated FPV clubs in Australia, this event is the leading drone racing event and draws the most talented pilots from the region. Participants from Japan, New Zealand and Australia flew quadcopters around a track while negotiating vertical gates, chicanes and sharp turns and hitting speeds exceeding 200 km/h (Bickerton, 2022).

Drones have secured a key role in the Australian film and television industry (Crockford, 2017). Drones and virtual reality have had a dramatic impact on the industry and are projected to play a significant role in filmmaking. Screen Queensland Chief Executive Tracey Vieira reported that all major international productions in Australia use drones for both shooting and lighting. Quiet and manoeuvrable drones were found to be appropriate for lighting sets for night filming. Currently, such advanced technology is changing the panorama of filmmaking in Australia (Crockford, 2017).

Table B.5: Summary of drone use cases by sectors

Industry/Sector	Functions/Type of Service/Role	International Examples	Australian Examples	Comparison
Agriculture	Smart farming and precision agriculture Crop, livestock and large land monitoring	• Ontario grain farmers: example of digital farming • Olive tree crown and shadow segmentation in Spain • Night patrols in the UK • Use of drones for plant protection in Jilin Province, China	• Drones with sensors study wet tropics region of Australia • Unsupervised detection and delineation of vine rows in Victoria (VIC) • Irrigation support in Murray–Darling Basin • Depositing sunflower seeds in Queensland • Sheep herding in the Northern Territory • Spraying crops for pests, weeds and disease prevention in Bundaberg, Queensland (QLD)	Australia appears to be a leader in this sector. Australian Government allocated A$136 million to the Smart Farms programs in 2017–2023. Projected growth in Australia: A$1 billion by 2040.
Freight & last-mile deliveries	Express parcels Food deliveries Pharmaceutical/medical deliveries Regional & remote pathology Cargo-airfreight	• Wing for FedEx & Walgreens in the US • Swoop Aero delivers medical supplies in Malawi, Democratic Republic of the Congo, Mozambique & Vanuatu • Zipline deliveries in Ghana • Matternet postal drone delivery in Switzerland • Wingcopter and Boeing developing longer distance deliveries • Singcronia Logistica in Mexico delivers personal protective equipment and vaccines	• Wing delivers 100,000 food and parcel deliveries in Logan, Australia, which is more than in any other place; also delivers in Australian Capital Territory • Swoop Aero delivers medical supplies in QLD and New South Wales (NSW)	Australia appears on par with leading developments. Global drone package delivery market is projected to grow to A$8.7 billion by 2030. Australian market to grow to about A$600m by 2030.

Construction	Inspections of power lines, pipelines, bridges and rail Surveying Project management	• E-construction in Canada uses drones for surveying • Battleford bridge inspections in Cairns, Canada • Brasfield & Gorrie in the US uses Skyward for inspections • Kier, Costain and Mitie in the UK, and Strabag in Europe, use drones for inspections and surveying	• TfNSW uses Sphere Drones for bridge inspections in Sydney • CPB Contractors use drones for surveys • Bechtel tested Skycatch's drones at its liquid natural gas processing facility project on Curtis Island, Australia	Use of drones in Australian construction firms does not appear as widespread as in overseas firms. Global market for construction drones is expected to reach A$18 billion by 2027. Deloitte Access Economics (DAE) projected A$1.5 billion by 2040 for Australia.
Public sector services	Emergency ambulance response Fire response Search and rescue Border patrol Local law enforcement Disaster management Mapping and research	• Swoop Aero provides medical services for many countries in Africa & Asia-Pacific • Nuba Drones in Colombia delivered medicines & blood samples to remote villages in 2017 • Fire Services in Denmark uses drones & FDNY leads in using drones in NY, US • UK council property inspections by drones.	• Western Australia police used drones for delivering public announcements during COVID-19 control measures • NSW Government spent A$57m on IT systems, including drones for firefighting • VIC Government launched drone unit in Fire Rescue Victoria • Tasmania's Department of Primary Industries, Parks, Water and Environment used drones to assist in flood assessments • Surf Life Saving Australia uses UAVs for shark detection on beaches • Sunshine Coast Regional Council uses drones for inspections	Australian Governments (both federal and state) appear to have kept pace with developments in this sector. DAE projected A$1.3 billion for government services by 2040.

Mining & resources	Stockpile measurement/geotechnical modelling Blast and mine reclamation monitoring Equipment inspection	• Bingham Canyon Mine in Utah, and Nevada Gold Mines, US, use drones for surveying, inspections and mapping • ArcelorMittal uses drones for most of their mines worldwide • South African coal mines use drones to prevent theft	• Fortescue Metals Group, Australia, uses drones to survey its Cloudbreak mine in the Pilbara region since 2015 • Rio Tinto started using drones during the COVID-19 pandemic • BHP saves A$8m/year from using drones	Australia appears to be keeping pace in this sector. DAE projected a market of about A$202 million for this sector by 2040.
Environmental management	Water resource management Conservation management Environmental impact assessment	• Video proof of orcas killing white sharks captured • World Wildlife Fund's list of 10 uses of drone technology for conservation	• UniSA team uses drones to detect vital signs of wild animals • AirSeed Technologies uses drones for seeding in reforestation • Great Barrier Reef mapped using drones	Use of drones in Australia is widespread in this sector but there are more opportunities for growth in Australia and other countries.
Advanced air mobility	Air taxis Point-to-point services Regional air mobility	• Volocopter VTOL trials in Singapore • EHang VTOL trials in Austria • Vertical Aerospace VTOL trials in London • U-Space sandbox in Germany for U-Space services	• CASA published 'The RPAS and AAM Strategic Regulatory Roadmap' • Wisk displayed eVTOL in Brisbane CBD • Uber pulled out of possible trial in Melbourne	Australia lags in drone use in this sector compared with other advanced countries, (e.g. the UK, Germany and Singapore). DAE projects about A$600 million for this sector by 2040.
Media, recreation & entertainment	Radio-controlled planes and drone racing Entertainment industry Photography	• The *New York Times* started using drones in 2011 for news reporting, and today, many news channels use drones • Record-breaking 3,051 drone swarm display in China, and Tokyo Olympics drone display	• Drones are used extensively in the film industry in Australia • Vivid drone display in Sydney and Adelaide • Alauda Aeronautics tests 2 Airspeeders in a drone race for 6 mins in South Australia, which will eventually be crewed	Australia appears to be keeping pace in this sector. DAE projects about A$891 million for this sector by 2040.

B.5 Socio-economic Impact of Drones

Some of the factors usually considered in a socio-economic impact analysis (Mackenzie Valley Environmental Impact Review Board, 2007) are:

- environment and sustainability of wildlife;
- protection of heritage and cultural resources—responsible innovation;
- sustainable income, lifestyle and equity impact;
- equitable business and employment opportunities;
- adequacy of services and infrastructure;
- health and wellbeing; and
- land access and use.

The literature on the socio-economic impact of drones appears to be limited compared with that on other major technological developments, such as electric and autonomous vehicles. Possible reasons for this lack are that the technology is at the nascent stage and uncertainties surround the form and scale of the services to be rolled out. In this regard, Kellermann et al. (2020) asserted that there is a greater need for scientific evidence for the prevalent promises of drones, such as traffic reduction, travel time saving and environmental benefits from drone-based solutions and called for a stronger emphasis on societal benefits and public involvement in the debates on transportation.

Privacy and ownership, personal and commercial liability, safety issues and regulations were the four main socio-economic effects of drones addressed by Rao et al. (2016). The primary criticism with the flying of commercial drones over public space is that small mistakes could result in crashes that threaten the health and wellbeing of residents and may damage property. Safety, the freedom from harm, the freedom from fear of harm, and security could be compromised by failings of the technology or the users. Spoofing and jamming are real threats from saboteurs and others, which could complicate matters.

We found that the literature on socio-economic impact of drones could be categorised into:

- productivity and employment,
- environment and sustainability of wildlife,
- protection of cultural and heritage resources, and
- sustainability of income, equity and lifestyle (privacy and ownership).

The next sections review these four streams of literature.

B.5.1 Productivity and employment

Deloitte Access Economics (2020) has estimated that in the most likely scenario of medium uptake of drones across existing sectors and new use cases, the resulting economic dividend, or the Australian gross domestic product, will grow rapidly from 2025–2030 onwards to about A$15 billion (in present value and using a 7% real discount rate). The improvement in productivity is also highlighted in the field of surveying. Fassbender et al. (2018) suggests that the use of drones had increased productivity of companies involving surveying up to 50% through the implementation of drones because of their ability to take on more workload without increasing the workforce.

While new jobs are expected to be created with the adoption of drones, as is common with any innovation, existing jobs will be displaced and there is no guarantee that there will be adequate replacement of the same quantity and quality of jobs lost (Magnani, 2022). The new jobs created may not necessarily be suitable for the same group of workers who have lost traditional jobs during this transition. Furthermore, the rapid adoption of drones and the change in the work environment may not afford workers sufficient time to adapt and learn new skills. These factors can further increase inequality, social tensions and political repercussions, which can further weaken aggregate demand and negatively affect economic growth (Magnani, 2022). In contrast, this emerging technology holds opportunities for employment, especially in more remote areas of Australia where access to education and jobs may be currently limited, considering that it can take less than a week to obtain a remotely piloted drone licence.

B.5.2 Environment and sustainability of wildlife

J. Park et al. (2018) used the life cycle analysis method to show that drones are more beneficial than the alternative options to preserve the environment in Yangcheon-gu and Pyeongchang in Korea. The particulate emissions of drones were estimated to be about half that of motorcycles. From a comprehensive environmental impact assessment incorporating nine impact categories, drones were found to have only about 8% of the impact as that of a motorcycle.

B.5.2.1 GHG, noise emission, health and wellbeing

The type and source of energy used are key to the energy efficiency of drones. The matter is often oversimplified in the literature without sufficiently addressing all the parameters. Drones are shown to provide a better solution from an emissions standpoint than regular motorcycles and trucks (Figliozzi, 2020; Stolaroff et al., 2018), except when electrical fuel generation is sourced from coal, in which case the emissions could vary with the range, speed and weight of drones (Goodchild & Toy, 2018). Yet, even when ground vehicles are strictly regulated, drones may produce less carbon dioxide emissions (Elsayed & Mohamed, 2020; Persson, 2021).

Although noise pollution and its impact on the wellbeing of people affected by drone operations have attracted extensive attention, studies on the specific effects of drone noise on humans are scarce. Nevertheless, the literature has suggested it could be more harmful than the noise of other vehicles owing to the peculiar acoustics, such as pure tones and high-frequency broadband noise. Notably, other aspects that may influence noise remain largely unexplored (Schäffer et al., 2021).

B.5.2.2 Wildlife conservation

Mulero-Pázmány et al. (2017) found that wildlife reactions to drones depend on various drone attributes, such as flight pattern, engine type and size of aircraft, as well as the specific characteristics of animals. Wildlife reacted most to target-oriented flight patterns, larger UASs and noisier engines. They were also more likely to react to a UAS during the non-breeding period and when in large groups, with birds found to be more prone to react than other taxa. The authors debated the implications of wildlife disturbance and proposed guidelines for conservationists, users and manufacturers to minimise the negative effects of drones.

Further, Rebolo-Ifrán et al. (2019) indicated that wildlife in aerial and terrestrial habitats are more likely than aquatic creatures to show a behavioural response. Drones can also improve wildlife preservation efforts by monitoring the heart rate and other vital signs of health of wildlife in a non-invasive, non-intrusive way, as demonstrated by Gibson (2022).

B.5.3 Protection of cultural and heritage resources

Macdonald et al. (2021), in an Indigenous-led study in Kakadu National Park in Australia's Northern Territory (NT), revealed that drones can be used to monitor and manage World

Heritage areas. They explored how cultural responsibility for knowledge and country in innovation can be maintained by introducing drones to collect data for improved environmental decision-making.

Smith et al. (2022), in a critical analysis, found that because of the conflation of various drone applications, there has been ambiguity about the prevailing concerns. Furthermore, without clear parameters for drone use in the local transport context, the scope to develop informed opinion is limited. They suggested that studies that afford greater understanding of, and familiarity with, drones may yield more informed outcomes than generic surveys on attitudes.

B.5.4 Sustainability of income, equity and lifestyle (privacy and ownership)

The personal ownership and operation of drones could become a social equity concern, but with falling prices, more residents should have easy access to drones. However, lower prices, greater sophistication and functionalities, smaller size, availability and the proliferation of drones, also give rise to privacy concerns, as with greater sophistication and functionalities, smaller size and easy availability, anyone can breach privacy laws easily. Moreover, the laws around privacy and private uses have not fully matured. Hence, it may be necessary to restrict usage to community- or commercial-based activities and restrict personal usage to specified private areas or safe public spaces (Alwateer & Loke, 2020).

In 2019, a man allegedly shot down a drone being used by a real estate agent to film his property in NSW (Burt, 2019), highlighting the conflicts of interests arising from the use of drones, and the role of regulations in this fast-evolving domain. Regulations regarding drone use are expected to be created and updated as their uses increase. It is important to ensure compliance with licensing, safety and general common sense, but some hobby drone pilots may oppose more regulation as they are used to having unfettered fun with drones.

Today, just about everyone may, at a relatively affordable price, have drones equipped with a range of features and surveillance technologies and enabled to see, sense and do things previously not possible. According to Wright and Finn (2016), regulators are mindful that drones present threats and risks to data protection and privacy, in addition to other human rights. They recommended a privacy impact assessment (PIA) for the use of drones above and beyond the data protection impact assessment. They listed seven types of privacy and presented some examples of how drones can be intrusive, as shown in Table B.6.

Table B.6: Seven types of privacy (source: adopted from Wright & Finn, 2016)

Type of Privacy	Concern
Privacy of the: person behaviour data and image	Using face recognition software and other tools, a drone could easily be used to identify people and their behaviour in different settings and transmit their images to a third party.
Privacy of communications	Drones could carry microphones and record what someone is saying.
Privacy of location	Drones and GPS could be used to record a person’s location and transmit it to a third party.
Privacy of thought and feelings	Drone operators could make some assumptions about people’s feelings using information collected, such as images, location and behaviour.
Privacy of groups and association	Drones can monitor groups participating in, for example, demonstrations, marches and meetings.

The level of surveillance possible via drones is likely to continue increasing with improving technology. There are also the risks of mission creep in all fields; paparazzi abuse of authorisation given to journalists, checks on illegal immigrants being used for other law enforcement purposes, and other infringement of privacy rights by enforcement authorities (Wright & Finn, 2016). There is also concern around the identity of the people operating the drones and their remit.

Australia, New Zealand, Canada, the US, the UK, France, Hungary, Ireland, Slovenia, Mauritius and Japan are among countries where PIA methodologies are extensively applied. Wright and Finn (2016) contended that PIAs can help improve public acceptance but go further to question whether PIAs are sufficient to address the numerous ethical issues and called for consideration of a social impact assessment regarding the use of drones.

Currently in Australia, all government agencies, including the Norfolk Island Administration, that have an annual turnover of more than A$3 million have responsibilities under the *Privacy Act 1988* (Cth) (Office of the Australian Information Commissioner, 2022). However, this Act does not cover, inter alia, most government agencies, individuals acting in their own capacity, public schools and universities, small business operators, media operators covering journalism, and registered political parties and representatives.

B.6 Current Drone Trials in Australia

Literature on the development, regulation and application of drones across various industries suggests that while the Australian Government, businesses and people are generally not averse to the adoption of drones, doubts remain about their true potential and about potential hazards from their unregulated proliferation. Researchers, manufacturers and operators of drones, as well as governments and non-government organisations, are spearheading trials in Australia to be able to make informed decisions about drone uptake. Table B.7 provides a summary of the prominent ongoing and recent trials in Australia and the next sections discuss them in more detail.

Table B.7: Summary of drone trials in Australia

Trial Name	Organisations Involved	Industry/Sector	Trial Period	Place of Trial	Outcomes
Sydney Harbour Bridge	Transport for New South Wales and Sphere Drones	Transport	2018–2020	NSW	• Regular inspection of bridge • Trial successful
Medical delivery trials	Swoop Aero	Last-mile delivery	2021–2023	QLD and NSW	• Trial successful • Drones restricted to daytime flights • Collating all community feedback
Delivery trials	Wing	Freight/delivery services	2021–2023	QLD & ACT	• Drones restricted to daytime flights • Collating all community feedback
CASA airspace authorisation trials	CASA and Airservices Australia	Aviation management	2021–ongoing	Adelaide, Canberra & Perth	• Digital airspace authorisations for ReOC holders to fly within 5.5 km of a controlled airport • 70 requests for flight approved via app • More than 150 ReOC holders applied
Integrated Drone Surveillance System trial	CASA and Thales	Aviation management	2022–ongoing	Sydney	• 3D holographic radar to track all drones surrounding Sydney's airport • Already used in other airports overseas
Integrating drones into NT Health	NT Government, Charles Darwin University (CDU) and iMOVE CRC	Public services	2021–ongoing	NT	• Investigate feasibility of operations and integration of drones into health service transport in NT • Early stages of the trial
Tracking endangered rock-wallaby	Walalakoo Aboriginal Corporation, CDU and World Wildlife Fund-Australia	Environmental Management	2022–ongoing	NT	• Help local rangers track endangered elusive species • Proving to be an accurate and reliable way
EATP Program trials	Multiple organisations	Multiple sectors	2021–2024	All States	• Will encourage adoption of drones

B.6.1 Sydney Harbour Bridge: TfNSW

TfNSW, the agency responsible for the inspection and maintenance of bridges, is working with Sphere Drones, a leading drone services provider, to conduct trials using drones that can autonomously inspect bridges. Large bridges, such as the Sydney Harbour Bridge, need to be inspected regularly, and hence, a drone that offers high-quality data without requiring extensive pilot training was sought. Skydio 2+, a self-flying drone, was chosen and after extensive testing, there is confidence that high-quality reports with 4K images, both in traditional formats and 3D models, will enable TfNSW to conduct automated bridge inspections faster (Spires, 2022).

In 2022, TfNSW completed trials at various bridges in regional NSW as well as at the Sydney Harbour Bridge and the Gladesville Bridge over the Parramatta River. The agency has now more than a dozen drone pilots and has plans underway to expand and make the procedures a permanent part of the business model. TfNSW has also acquired water-resistant drones to enable inspections in the rain and also inspect structures underwater (Roads Australia, 2022).

B.6.2 Swoop Aero: Medical delivery trials in Queensland and NSW

Swoop Aero was given approval to operate drone delivery trials in Goondiwindi in QLD, and Moree Plains, Gwydir and Inverell in NSW, between 1 December 2021 and 30 November 2022 to understand the practical aspects of drone delivery services and the likely impact on the community, in order to inform government policies regarding drone use. Drones were restricted to fly during the day and were noise tested. Swoop Aero was also required to collate all community feedback, whether received directly or through the state and local governments for DITRDCA (2022a) to analyse.

B.6.3 Wing: Delivery trials in ACT

CASA approved the operations of drone delivery services in Australia by Wing Aviation Pty Ltd (Wing) and Swoop Aero (DITRDCA, 2022a). Wing operates in Gungahlin and Belconnen in the Australian Capital Territory (ACT) and in Logan in QLD.

B.6.4 CASA: Airspace authorisation trials

CASA (2022b) is trialling digital airspace authorisations for ReOC holders to fly within 5.5 km (3 NM) of a controlled airport. Chief remote pilots can apply using a CASA-verified drone safety app to fly near one of three selected trial sites:

- Adelaide Airport,
- Canberra Airport and
- Perth Airport.

Participation in the trial is free as will be the authorisations to operate, with no limit on the number issued. Since May 2021, when the trial began, 70 airspace authorisation requests have been submitted using a CASA-verified drone safety app and more than 150 chief remote pilots from approved ReOC holders have applied to participate in the trial (CASA, 2022b).

B.6.5 Thales: Air Services Australia

Thales was selected by Air Services Australia to work on an Integrated Drone Surveillance System trial (Air Traffic Management, 2022). Given the rapidly growing use of drones, it was considered necessary to identify and efficiently manage these drone activities near airports proactively. The trial, centred at Sydney Kingsford Smith Airport, began in 2022.

Using a multilayered sensor approach with advanced command and control for the detection, monitoring and identification of drones, as well as the location of the drone pilot, the system should be able to provide a comprehensive picture of the airspace around the airport in real time. A radar that is supposed to detect, track and classify small, slow, low UAVs, ranging from the smallest remote-piloted drones to more sophisticated autonomous drones, in particular for the glide path where the biggest risk exists, is at the core of the system (Air Traffic Management, 2022).

B.6.6 Charles Darwin University: Health service

In a first for the NT, the NT Government is partnering with CDU and iMOVE's Cooperative Research Centre to use drones for delivering health care to remote communities across the NT (CDU, 2021). The goal is to advance the delivery of time-critical medical items into difficult-to-reach and sometimes seasonally inaccessible remote communities with clear health benefits for residents and decreasing costs. Accordingly:

> 'It doesn't matter whether you live in the city or in the bush – Territorians deserve to have access to the very best health services, and this new technology will be a driving force in this space', said Minister for Health, Natasha Fyles (CDU, 2021).

She also expressed confidence that the technology will open the door to new jobs and opportunities, while keeping Territorians in remote areas healthy and safe. Professor Mike Wilson from the University related that the motivations for the research are the reduction of costs and the improvement of healthcare outcomes for remote communities in the NT (CDU, 2021).

The project is expected to examine the challenges of using drone delivery of health services in the Territory such as (CDU, 2021):

- procuring appropriate airframes for the tasks in the NT,
- adapting the technology for the NT climate,
- planning works with CASA over flight paths and
- integrating drones into the existing health transport network.

The project has received additional funding under the first round of the EATP Program to extend trial activities.

B.6.7 Charles Darwin University: Conservation management

In an exciting trial in the Kimberley region of Western Australia, First Nations rangers are trialling thermal imaging drones to track some rare and shy wallaby species (CDU, 2022). The endangered black-footed rock-wallaby, or wiliji, is a small and very agile animal that darts among rocky outcrops and caves, which results in challenges to find and track it. The wiliji population has shrunk to about 500 because of the impact of introduced predators and indiscriminate wildfires.

The Nyikina Mangala Rangers have been monitoring the wallabies using ground-based sensor cameras from as early as 2013 but information was delayed because it took weeks to retrieve mounted cameras after deployment (CDU, 2022). By combining modern science and traditional techniques, the Walalakoo Aboriginal Corporation, in partnership with CDU and WWF-Australia seeks to overcome the problem by using multirotor drones to capture more timely and cost-efficient population data. CDU's Research Institute for the Environment and Livelihoods has been contracted by this Corporation. The Institute's Rebecca Rogers said that the thermal camera installed on the drones could cover a large area faster and was able to detect the heat signature of the wallabies as well as that of feral cats that pose a threat to the wallabies (CDU, 2022).

To support the adoption of emerging aviation technology in Australia and to make the sector more competitive, efficient and sustainable, the Australian Government recently initiated the EATP Program in partnership with the industry and committed grants of up to A$32.6 million up to June 2024. The government awarded A$18 million for 12 projects as part of the first round of the EATP Program, which was announced on 7 November 2022 (DITRDCA, 2022b). The grants covered a wide spectrum of drone applications. Recipients include AMSL Aero, which is working to develop eVTOL aircrafts and conduct air ambulance trials in regional NSW; Praxis Labs, which is developing solar surfaces for the wings of an Australian electric aircraft; and Hover UAV and SORA Mate, which are developing an online risk assessment tool for drone operators (DITRDCA, 2022b).

B.7 Benefits and Challenges of Increased Uptake of Drones in Australia

B.7.1 Benefits

The main benefits of increased drone uptake include their ability to provide cheaper, faster, easier and possibly a safer, environmentally friendly way to see, sense and move than ever before. Drones have been shown to improve productivity by lowering operation costs in farms in Australia, especially in activities such as spraying, weeding (Hobba et al., 2021) and seed planting (Katanich, 2022). Drones not only offer time savings but also afford a more environmentally friendlier way of farm work, such as for herding livestock (Yaxley et al., 2021).

Even if there still has not been widespread adoption of drones in the construction sector in Australia, in addition to the cost and time savings, the safety and environmental benefits have been highlighted by Li and Liu (2019).

The benefits from the increased use of drones to detect, prevent and mitigate natural disasters, such as bushfires and floods, have been well chronicled (Duffy et al., 2020). Similarly, the benefits of faster and safer response, and the sustainable management of sharks and other wildlife, have become very apparent through the work of Surf Live Saving Australia (Thorn, 2021).

A study with citizens who have called emergency services revealed that drones bring great benefits because callers receive feelings of assurance that help is on the way (Khan & Neustaedter, 2019). Other studies and trials show the clear benefits of providing medicines rapidly and cost-effectively to remote communities by using drone delivery services.

In their review paper, Rejeb et al. (2021b) summarised the capabilities, barriers and performance outcomes of humanitarian drones used in logistics operations, management and governance in a comprehensive framework. They highlighted three key capabilities—transportation and delivery; surveying and monitoring; and communication and integration—alongside three performance outcomes—flexibility and responsiveness; cost reduction; and sustainability. The main benefits of applying drones in supply chain management and logistics were found to be (1) support of humanitarian logistics, (2) reduced delivery time, (3) reduced cost, (4) improved flexibility and (5) increased sustainability.

Drones benefit education with their ability to access data from inaccessible or dangerous locations, as well as collect and deliver temporal and spatial resolution information quickly (Shadiev & Yi, 2022). Drones in the classroom were found to not only help students acquire skills and knowledge, but also motivated them to learn and become more responsible. Students acquired mapping, programming, spatial visualisation and sequencing skills, as well as new perspectives in subject-specific areas, such as in STEM (science, technology, engineering and mathematics) and geography. Drones in education were found to be very valuable, and more teaching and learning with the support of UAV technology is required to help scholars explore the great potential and significance of drones for education (Shadiev & Yi, 2022).

A small-scale mixed methods study by Cliffe (2019) explored the potential benefits and challenges of using UAVs in fieldwork, and found benefits in geoscience fieldwork by offering students, for example, different perspectives of a landscape; collecting data from inaccessible locations and enhancing students' data collection skills.

There is growing interest in using aerial platforms for the non-destructive inspection of large and complex structures, such as buildings, bridges, oil and gas infrastructures, and refineries, that require regular and extensive inspections to plan and perform requisite maintenance for their structural health and ensure the safety of workers (Nooralishahi et al., 2021). Challenges, due to the size of the facility, difficulty or hazards in access, risks for the inspectors and other reasons, have motivated companies to increasingly use drones for such inspections. Moreover, the autonomous nature of drones can help reduce inspection time, cost and the number of personnel required, which contributes to workers' safety (Nooralishahi et al., 2021).

Bolfe et al. (2020) administered a survey to 504 Brazilian farmers to determine their use of digital technologies, as well as current and future applications, perceived benefits and challenges. They found that 84% of these farmers used at least one digital technology, including drones, in their production system. The farmers perceived the benefits of increased productivity, higher selling potential of products and better planning and management of production systems. About 95% of them were keen to learn more about new technologies to strengthen the agricultural development of their properties.

Highlighting the paradox in democratic societies wherein citizens may be willing to sacrifice a degree of order for increased liberty, Byrne and Marx (2011) contended that with criminals' propensity to use technology to commit crimes, law enforcement bodies should also leverage on technology when working for society's benefit. Being aware of this, worldwide, police are embracing this technology as part of their toolkit (Pantazis & Pemberton, 2009).

Drones can be applied for beneficial and humanitarian purposes despite the issues around regulation, privacy, security and safety and are, therefore, likely to become ubiquitous soon (Scott & Scott, 2017).

B.7.2 Challenges

The challenges drones pose include possible intrusion into what is often erroneously assumed to be a private air space, invasion of privacy through the type of data collected and any safety and security threats posed by drone operations. Challenges to drone uptake include regulatory responsiveness and technological limitations, such as battery life and robustness in inclement weather. Rejeb et al. (2021b) identified three main barriers to drone uptake for humanitarian logistics operations: technology, organisation and environment. Furthermore, Rejeb et al. (2021a) showed that the challenges posed by drones in broader supply chain management and logistics can be grouped into technical, organisational, safety-related and regulatory issues.

In the field of research, Cliffe (2019) highlighted that the substantial barriers to introducing UAVs in fieldwork include laws and licensing, privacy, time, cost and lack of provisions for students to legally fly aircrafts. Sood et al. (2021) in their bibliometric analysis of 10,786 articles on the journey of AI systems and techniques in agriculture, including precision agriculture and UAVs, explained that there are benefits associated with automation and AI that reduce human efforts and improve productivity, but there are also challenges in ensuring sustainability and the effectiveness of agricultural equipment and processes based on new technology. They outlined the following challenges to drone use in agriculture: environmental, operational, technological, economic and social. They suggested further research into those issues for increasing the usefulness of AI techniques in agriculture. Their study explored the opportunities in this area of research and raised the need for solutions to technology issues, and standardisation of systems, to harness the benefits of drone usage on a larger scale.

Khalid et al. (2021) suggested that adopting UAVs can expose staff to some work-related safety risks and that a high portion of the workforce was unfamiliar with the practical use of UAVs. They concluded that there was insufficient knowledge about safety related to UAV-based construction applications and related risks. They further expressed concerns about exposure to a high risk of collisions with humans, structures and properties, which can result in major financial and productivity loss, without the implementation of systematic understanding and successful hazard prevention techniques.

Agapiou (2020), in a review of regulatory frameworks in the US, UK, Japan, Australia and Hong Kong for drone operations within the construction industry, noted that the technology, infrastructure, regulations and standards were continually evolving at this stage of technology development. The author cautioned that the rapid change and growth posed a challenge for regulators to ensure that regulations and infrastructure are in place to manage and meet the changes in future.

Although drones offer several benefits in the emergency medicine delivery services and other sectors as highlighted above, there still are several technical and non-technical challenges to drone usages, such as:

- stability of flight,
- weight,
- flight time,
- flight range,
- the incorporation of machine learning,
- sensing of barriers and other aircraft,
- emergency landing procedures,
- regulatory framework,
- mitigation of privacy and safety concerns,
- feasibility in different aerial conditions,
- costs,
- maintenance and
- management of end-user experiences and expectations (Johnson et al., 2021).

Further, Alon et al. (2021) highlighted two main barriers regarding drone use in firefighting: legislative and technical. Legislative barriers were around the difficulties in getting permits to operate drones compared with getting a pilot’s licence. The technical limitations they highlighted are the need for drones with better cameras and thermal images and better GPS/GIS signal connectivity.

Ahmed et al. (2022) highlighted that despite Wing’s early success in express delivery, leading to the expansion of the business, there are concerns over regulations, privacy and noise pollution while delivering parcels. A technical challenge concerns the weight limit of parcels that drones can deliver. Similarly, Persson (2021) pointed out the following barriers that hinder the implementation of drones in last-mile delivery: governmental regulation, technical barriers, the lack of large-scale economies and social aspects, such as safety and integrity.

Kellermann et al. (2020), in their literature review of some 111 interdisciplinary publications on drones for parcel and passenger transportation, found that predominantly, technical and regulatory problems and barriers prevent the use of drones for parcel and passenger transportations. Complex and differentiated concerns about the impact on society and the environment are pitted against economic returns.

At a stage of technology when even military drones could be hacked, the chances of private information and the drones themselves being hijacked is a real danger. Furthermore, the traditional notion of privacy, where a person can be assured of privacy in their own private property, is under threat from distant flying objects. Furthermore, there is the issue of the airspace (low altitude) over a private property and the rights and expectations one can have around them. In NSW, farmers have been victimised by animal activists who took unauthorised films. The farmers complained about criminals using drones to monitor and raid farms and claimed that these incursions have caused emotional distress (Burt, 2019).

Business Wire (2022) listed the following as restraints on the growth of drone deliveries: the need to avoid power lines, bad weather, the high cost of infrastructure, limited bandwidth and battery life. Some of the major challenges faced by drone delivery businesses are in the areas of data security, risk management controls and public acceptance.

Pantazis and Pemberton (2009) argued that because non-police drone use has created negative perceptions of the technology, police organisations should be mindful when employing them, particularly considering issues related to social control, public privacy, ethics, governance and accountability.

Another challenge that drone deliveries could aggravate and suffer from is the congestion in the operating airspace and the need for what Kellermann et al. (2020) referred to as uncrewed traffic management or U-Space management, or what is alternatively referred to as low altitude airspace management (Merkert & Bushell, 2020; Merkert et al., 2021).

AAM and UAM face many challenges around safety and community concerns (Cohen et al., 2021). Sah et al. (2021), in their comprehensive review of literature on the barriers to the implementation of drones in the logistics industry, concluded that the two most critical barriers are regulations and the threat to privacy and security. Moreover, public perception; psychological, environmental and technical issues; and economic aspects need to be addressed as well.

B.8 Conclusion

This literature review briefly examined the history and types of drones and their capabilities and explored all the key factors that influence the uptake of drones, namely, cost and time savings, ease of use, safety and security and regulations. It then investigated the various use cases of drones across key sectors of the Australian economy and compared it with international developments in the respective sectors. The review also explored some of the socio-economic effects of drone uptake, covering productivity and employment, environment and sustainability of wildlife, culture and heritage as well as sustainability of income and lifestyle. Last, the review summarised the main benefits and challenges of increased uptake of drones.

Ultimately, the sustainability of UAVs or drones, especially in developing countries, is promising (Lalrochunga et al., 2020). However, considering the potential threat of deploying drones for improper purposes, proper policies are required for piloting drones. Trained drone pilots can secure employment in many industries, notably aerial cinematography where drones are mostly deployed. Lalrochunga et al. (2020) envisioned a time when entrepreneurs team up with professionals and specialists to operate in a multidisciplinary field. For example, a licensed soil and land surveyor may team up with drone operators to provide services for industrial and research projects. Such collaborations have become increasingly common in recent years (CompTIA, 2019).

The geography of Australia has posed more challenges for public transportation planning than most countries but perhaps it will be the distance between a regional or rural town and its nearest city that will favour drones and endear them with the public (Royal Flying Doctor Service, 2019). Businesses and private consumers have embraced drones, and governments have generally been tolerant, if not supportive, of the rapid growth. This has presented Australia a leadership position in drone technology and its applications and uptake in some sectors. However, the unbridled growth and operation of drones, both private and commercial, have led to some concerns. Given the obvious benefits that drones have in many sectors of the economy, such as in emergency and non-emergency delivery of medical products and services, productivity benefits in sectors such as agriculture, public services and environmental management, and even in recreation, there is still a need to study all the relevant challenges to the increased uptake of drones, as well as the challenges from such increased uptake.

According to this literature review, the future of drones is as bright as their aerial display in Sydney in May 2022. This is especially true in some sectors, such as agriculture, environmental management, public services and mining. And yet others have room for more growth, such as construction and AAM. In summary, drones have the potential to contribute significantly to the productivity and economic development of many countries, including Australia, and governments are taking many initiatives as evident from the trials and use cases in various sectors.

Internationally there has been tremendous growth in the use of drones in agriculture, mining, oil and gas, surveying, construction and infrastructure, and it is predicted to expand exponentially as a result of major players, including DJI, Yuneec and 3D Robotics, investing in extensive research and development efforts (Straits Research, 2022).

Bill Gates, arguably the most transformational pioneer of the IT era, remarked in response to the Chief Executive Officer of Amazon, Jeff Bezos’s exuberance about the future of drones, ‘Drones overall will be more impactful than I think people recognize, in positive ways, to help society’ (Bishop, 2013, p.1).

References

Abdukarimov, S., & Ganiev, A. (2022). Recent approaches and algorithms to solutions of the problems of collision avoidance of unmanned aerial vehicles. *European International Journal of Multidisciplinary Research and Management Studies*, *2*(05), 188–194. https://doi.org/10.55640/eijmrms-02-05-36

Adams, C. (2019). Tinker, tailor, soldier, thief: An investigation into the role of drones in journalism. *Digital Journalism*, *7*(5), 658–677. https://doi.org/10.1080/21670811.2018.1533789

Agapiou, A. (2020). Drones in construction: An international review of the legal and regulatory landscape. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, *174*(3), 118–125. https://doi.org/10.1680/jmapl.19.00041

Ahirwar, S., Swarnkar, R., Bhukya, S., & Namwade, G. (2019). Application of drone in agriculture. *International Journal of Current Microbiology and Applied Sciences*, *8*(1), 2500–2505. https://doi.org/10.20546/ijcmas.2019.801.264

Ahmed, J. U., Islam, Q. T., Islam, S., Ahmed, A., & Mim, K. P. (2022). Last-mile drone delivery: Is Wing's business model sustainable? In *SAGE Business Cases*. SAGE. https://doi.org/10.4135/9781529780451

Air Traffic Management. (2022). *Thales selected by Airservices Australia to carry out drone surveillance trials*. https://www.airtrafficmanagement.net/index.php/article/thales-and-airservices-australia-carry-out-drone-surveillance-trials

Air Transport News. (2022, 28 November). *JAL conducts demonstration of drone implementation model to support island life*. https://www.atn.aero/#/article.html?id=85354

Ajmera, D., Saroliya, M., & Arora, P. (2022). Unmanned aerial vehicles (UAVs). *International Research Journal of Innovations in Engineering and Technology*, *6*(1), 22–27. https://doi.org/10.47001/IRJIET/2022.601006

Alcock, C. (2022, 30 August). *Victoria seeks advanced air mobility leadership role in Australia*. FutureFlight. https://www.futureflight.aero/news-article/2022-08-30/victoria-seeks-advanced-air-mobility-leadership-role-australia

Alghamdi, Y., Munir, A., & La, H. M. (2021). Architecture, classification, and applications of contemporary unmanned aerial vehicles. *IEEE Consumer Electronics Magazine*, *10*(6), 9–20. https://doi.org/10.1109/MCE.2021.3063945

Alon, O., Rabinovich, S., Fyodorov, C., & Cauchard, J. R. (2021). Drones in firefighting: A user-centered design perspective. In *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction* (Article 24, pp. 1–11). Association for Computing Machinery. https://doi.org/10.1145/3447526.3472030

Alwateer, M., & Loke, S. W. (2020). Emerging drone services: Challenges and societal issues. *IEEE Technology & Society Magazine*, *39*(3), 47–51. https://doi.org/10.1109/MTS.2020.3012325

Amar, C., Satya, S., & Onkar, S. (2020, October). *Construction drone market*. Allied Market Research. https://www.alliedmarketresearch.com/construction-drone-market-A06247

Amukele, T. (2019). Current state of drones in healthcare: Challenges and opportunities. *Journal of Applied Laboratory Medicine*, *4*(2), 296–298. https://doi.org/10.1373/jalm.2019.030106

Antunes, J. (2017, 16 October). *Meeting 2022 FIFA World Cup construction goals with drones*. Commercial UAV News https://www.commercialuavnews.com/infrastructure/meeting-2022-fifa-world-cup-construction-goals-drones

Arjomandi, M., Agostino, S., Mammone, M., Nelson, M., & Zhou, T. (2006). Classification of unmanned aerial vehicles. *Report for Mechanical Engineering class.* University of Adelaide, Australia, 1–48.

Aydin, B. (2019). Public acceptance of drones: Knowledge, attitudes, and practice. *Technology in Society*, *59*, Article 101180. https://doi.org/10.1016/j.techsoc.2019.101180

Bechtel Corporation. (2015, 6 April). *Bechtel among first companies to use unmanned aircraft system technology in construction*. https://www.bechtel.com/newsroom/releases/2015/04/unmanned-aircraft-system-technology-construction/

Beesley, C. (2020). *Surveying with drones: Saving governments time and money without sacrificing accuracy*. GovDesignHub. https://govdesignhub.com/2020/02/20/how-surveying-with-drones-can-save-governments-time-and-money/#.Y0VYZHZBy3A

Bevan, E., Whiting, S., Tucker, T., Guinea, M., Raith, A., & Douglas, R. (2018). Measuring behavioral responses of sea turtles, saltwater crocodiles, and crested terns to drone disturbance to define ethical operating thresholds. *PLoS ONE*, *13*(3), Article e0194460. https://doi.org/10.1371/journal.pone.0194460

Bickerton, M. (2022, 25 August). *Buzz in the air at drone racing championships*. Australian Government – Defence https://news.defence.gov.au/technology/buzz-air-drone-racing-championships

Bishop, T. (2013, 4 December). Bill Gates: Jeff Bezos overly optimistic on drones, but they will have a positive impact. GeekWire,LLC. https://www.geekwire.com/2013/bill-gates-jeff-bezos-overoptimistic-drones/

Bloomberg. (2022, 20 July). *Inspection drone market estimated to be valued at US$ 33.8 Bn by 2031, TMR Report*. https://www.bloomberg.com/press-releases/2022-07-20/inspection-drone-market-estimated-to-be-valued-at-us-33-8-bn-by-2031-tmr-report

Bolfe, É. L., Jorge, L. A. d. C., Sanches, I. D. A., Luchiari, A., Jr., da Costa, C. C., Victoria, D. d. C., Inamasu, R. Y., Grego, C. R., Ferreira, V. R., & Ramirez, A. R. (2020). Precision and digital agriculture: Adoption of technologies and perception of Brazilian farmers. *Agriculture*, *10*(12), Article 653. https://doi.org/10.3390/agriculture10120653

Brice, C. (2022, 13 October). *In a world first, flying race cars reaching new heights from South Australia*. ABC News. https://www.abc.net.au/news/2022-10-13/south-australia-leads-the-world-in-flying-race-cars/101528548

Bryant, R. (2019, 29 August). Drone technology being used to tackle sheep rustling. *The Moorlander*. https://www.themoorlander.co.uk/drone-technology-being-used-to-tackle-sheep-rustling/

Burkhardt, P. (2021, 27 July). *South Africa coal producers bring in drones to contain theft*. Bloomberg News. https://www.mining.com/web/south-africa-coal-producers-bring-in-drones-to-contain-theft/

Burt, M. (2019, March). *Drones and farms: Know your rights*. NSW Farmers. https://www.nswfarmers.org.au/NSWFA/Posts/The_Farmer/Tools/Drones_and_farms_know_your_rights.aspx

Business Wire. (2022, 22 June). *Global drone package delivery market report 2022-2030: Increasing private investments in drones and increase in e-commerce sales – ResearchAndMarkets.com*. https://www.businesswire.com/news/home/20220622005509/en/Global-Drone-Package-Delivery-Market-Report-2022-2030---Increasing-Private-Investments-in-Drones-and-Increase-in-e-Commerce-Sales---ResearchAndMarkets.com

Butilă, E. V., & Boboc, R. G. (2022). Urban traffic monitoring and analysis using unmanned aerial vehicles (UAVs): A systematic literature review. *Remote Sensing*, *14*(3), Article 620. https://doi.org/10.3390/rs14030620

Byrne, J., & Marx, G. (2011). Technological innovations in crime prevention and policing. A review of the research on implementation and impact. *Journal of Police Studies*, *20*(3), 17–40.

Cairns, J. (2020, 24 May). *Town goes ahead with drones for bridge inspection*. SaskToday.ca. https://www.sasktoday.ca/north/local-news/town-goes-ahead-with-drones-for-bridge-inspection-4149691

Camarretta, N., Harrison, P. A., Lucieer, A., Potts, B. M., Davidson, N., & Hunt, M. (2020). From drones to phenotype: Using UAV-LiDAR to detect species and provenance variation in tree productivity and structure. *Remote Sensing*, *12*(19), Article 3184. https://doi.org/10.3390/rs12193184

Cameron, N. (2022, 4 February). *KFC Australia makes its drone delivery debut*. CMO. https://www.cmo.com.au/article/695011/kfc-australia-makes-its-drone-delivery-debut/

Campbell, D. (1948). Preliminary aerial distribution trials with superphosphate and seed mixtures. *New Zealand Journal of Science and Technology A*, *30*, 65–77.

Chan, K., Nirmal, U., & Cheaw, W. (2018). Progress on drone technology and their applications: A comprehensive review. *AIP Conference Proceedings*, *2030*(1), Article 020308. https://doi.org/10.1063/1.5066949

Chanthadavong, A. (2021, 27 January). *Victorian firefighters get a dedicated drone unit*. ZDNet. https://www.zdnet.com/article/victorian-firefighters-get-a-dedicated-drone-unit/

Chanthadavong, A. (2022, 18 May). *Swoop Aero gets green light from Australian aviation authority for drone centre*. ZDNet. https://www.zdnet.com/article/swoop-aero-gets-green-light-from-australian-aviation-authority-for-drone-centre/

Charles Darwin University. (2021). Drones to deliver health services. Retrieved 17 Sep 2022 from https://www.cdu.edu.au/news/drones-deliver-health-services

Charles Darwin University. (2022). *Rangers trial drones to track rare rock-wallaby*. https://www.cdu.edu.au/news/rangers-trial-drones-track-rare-rock-wallaby

Chauhan, S. K. (2019). Scholarly output on drone research: A bibliometric study. DESIDOC *Journal of Library & Information Technology*, *39*(2), 117–124. https://doi.org/10.14429/djlit.39.2.13970

Chirayath, V., & Earle, S. A. (2016). Drones that see through waves: Preliminary results from airborne fluid lensing for centimetre-scale aquatic conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*, 237–250. https://doi.org/10.1002/aqc.2654

Chowdhury, S. (2020, 3 July). Facemasks delivered to Mexican hospitals by drone to avoid human contact. *Hindustan Times*. https://www.hindustantimes.com/it-s-viral/facemasks-delivered-to-mexican-hospitals-by-drone-to-avoid-human-contact/story-zqqL6nHG4NNqjCvHTisJxJ.html

Ciobanu, E. (2022). Drones in firefighting. *Droneblog*. https://www.droneblog.com/drones-in-firefighting/

Civil Aviation Safety Authority. (2020). *CASR Part 101 Micro and excluded remotely piloted aircraft operations, Plain English guide September 2020*. Commonwealth of Australia https://www.casa.gov.au/sites/default/files/2021-08/part-101-micro-excluded-rpa-operations-plain-english-guide.pdf

Civil Aviation Safety Authority. (2022a, Mar 29). *AAUS: RPAS in Australian skies 2022 conference*. Commonwealth of Australia. https://www.casa.gov.au/aaus-rpas-australian-skies-2022-conference

Civil Aviation Safety Authority. (2022b). *Automated airspace authorisations trial*. Commonwealth of Australia. https://www.casa.gov.au/drones/industry-initiatives/automated-airspace-authorisations-trial

Civil Aviation Safety Authority. (2022c). *Guidelines for vertiport design: Draft Advisory Circular 139.V-01 v1.0*. Commonwealth of Australia. https://consultation.casa.gov.au/regulatory-program/draft-ac-139-v-01-v1-0/supporting_documents/Draft%20AC%20139.V01%20v1.0.PDF

Civil Aviation Safety Authority. (2022d). *RPAS and AAM strategic regulatory roadmap*. Commonwealth of Australia. https://www.casa.gov.au/sites/default/files/2022-06/the-rpas-and-aam-roadmap.pdf

Civil Aviation Safety Authority. (2022e). *Types of drones*. Commonwealth of Australia. https://www.casa.gov.au/drones/drone-rules/drone-safety-rules/types-drones#

Cliffe, A. D. (2019). Evaluating the introduction of unmanned aerial vehicles for teaching and learning in geoscience fieldwork education. *Journal of Geography in Higher Education*, *43*(4), 582–598. https://doi.org/10.1080/03098265.2019.1655718

Cohen, A. P., Shaheen, S. A., & Farrar, E. M. (2021). Urban air mobility: History, ecosystem, market potential, and challenges. *IEEE Transactions on Intelligent Transportation Systems*, *22*(9), 6074–6087. https://doi.org/10.1109/TITS.2021.3082767

Cokyasar, T. (2021). Optimization of battery swapping infrastructure for e-commerce drone delivery. *Computer Communications*, *168*, 146–154. https://doi.org/10.1016/j.comcom.2020.12.015

Colefax, A. P., Butcher, P. A., Pagendam, D. E., & Kelaher, B. P. (2020). Comparing distributions of white, bull, and tiger sharks near and away from the surf break using three tech-based methods. Ocean and Coastal Management, *198*, Article 105366. https://doi.org/10.1016/j.ocecoaman.2020.105366

CompTIA. (2019, June). *The drone market: Insights from customers and providers*. https://connect.comptia.org/content/research/drone-industry-trends-analysis

Consortiq. (2022). *A not-so-short history of unmanned aerial vehicles (UAV).* https://consortiq.com/uas-resources/short-history-unmanned-aerial-vehicles-uavs

Coyne, A. (2015, 31 August). *Fortescue deploys survey drones at Cloudbreak mine*. iTNews. https://www.itnews.com.au/news/fortescue-deploys-survey-drones-at-cloudbreak-mine-408550#:~:text=Fortescue%20Metals%20Group%20has%20deployed,and%20topographic%20surveys%20last%20year

CPB Contractors. (2021, 19 October). *Drone technology helps revolutionise how CPB Contractors works*. https://www.cpbcon.com.au/en/news-and-media/2021/drone-technology-helps-revolutionise-how-cpb-contractors-works

Crockford, T. (2017, 5 February). Virtual reality and drones having 'dramatic impact' on Queensland film industry. *Brisbane Times*. https://www.brisbanetimes.com.au/national/queensland/virtual-reality-and-drones-having-dramatic-impact-on-queensland-film-industry-20170205-gu5wng.html

Crozier, R. (2022, 16 August). *Transport for NSW flies drones for bridge inspections*. iTNews. https://www.itnews.com.au/news/transport-for-nsw-flies-drones-for-bridge-inspections-584025

Crumley, B. (2022a, 25 April). *Swoop Aero expands medical drone deliveries in Mozambique healthcare trials*. DroneDJ. https://dronedj.com/2022/04/25/swoop-aero-expands-medical-drone-deliveries-in-mozambique-healthcare-trials/

Crumley, B. (2022b, 6 May). *Vertical Aerospace to obtain concurrent UK and EU certification*. DroneDJ. https://dronedj.com/2022/05/06/vertical-aerospace-to-obtain-concurrent-uk-and-eu-certification/

DeBell, L., Anderson, K., Brazier, R. E., King, N., & Jones, L. (2015). Water resource management at catchment scales using lightweight UAVs: Current capabilities and future perspectives. *Journal of Unmanned Vehicle Systems*, *4*(1), 7–30. https://doi.org/10.1139/juvs-2015-0026

de Jager, W. (2022, 27 June). *Matternet announces urban drone delivery network in Switzerland*. DroneXL. https://dronexl.co/2022/06/27/matternet-urban-drone-delivery-network/#:~:text=Matternet%20plans%20to%20launch%20the,announced%20in%20the%20coming%20months.

Deloitte Access Economics. (2020). *Economic benefit analysis of drones in Australia, Final Report*. Department of Infrastructure, Regional Development and Communications. https://www.infrastructure.gov.au/sites/default/files/documents/economic-benefit-analysis-of-drones-to-australia-final-report.pdf

Department of Agriculture and Fisheries. (2021). *Drones: The flight of drones in farming*. State of Queensland. https://www.daf.qld.gov.au/agtech/be-inspired/future-trends/drones

Department of Infrastructure, Transport, Regional Development, Communications and the Arts. (2022a). *Drone delivery operations–Australia*. Commonwealth Government. https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/emerging-aviation-technologies/drone-delivery-operations-australia

Department of Infrastructure, Transport, Regional Development, Communications and the Arts. (2022b, 7 Nov). *Round One announcement*. Commonwealth Government. https://www.drones.gov.au/policies-and-programs/emerging-aviation-technology-partnerships-program/eatp-round-one-announcement

Department of Treasury and Finance. (2022a). *Advanced air mobility in Victoria*. State of Victoria. https://www.invest.vic.gov.au/__data/assets/pdf_file/0006/703077/AAM-Industry-Vision-Statement-2022.pdf

Department of Treasury and Finance. (2022b, 30 August). *Advanced air mobility*. State of Victoria. https://www.invest.vic.gov.au/opportunities/advanced-air-mobility#:~:text=Launched%20on%2030%20August%202022,of%20industries%20and%20critical%20functions.

Dorling, K., Heinrichs, J., Messier, G. G., & Magierowski, S. (2016). Vehicle routing problems for drone delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *47*(1), 70–85. https://doi.org/10.1109/TSMC.2016.2582745

Drone racing. (2022, Nov 8). In *Wikipedia*. https://en.wikipedia.org/wiki/Drone_racing

Duckett, C. (2021, 21 October). *Drones starting fires on purpose in Victoria*. ZDNet. https://www.zdnet.com/article/drones-starting-fires-on-purpose-in-victoria/

Duffy, J., Anderson, K., Shapiro, A., Spina Avino, F., DeBell, L., & Glover-Kapfer, P. (2020). Drone technologies for conservation. In *WWF Conservation Technology Series*, *1*(5), WWF.

Dukkanci, O., Kara, B. Y., & Bektaş, T. (2021). Minimizing energy and cost in range-limited drone deliveries with speed optimization. *Transportation Research Part C: Emerging Technologies*, *125*, Article 102985. https://doi.org/10.1016/j.trc.2021.102985

Elghaish, F., Matarneh, S., Talebi, S., Kagioglou, M., Hosseini, M. R., & Abrishami, S. (2021). Toward digitalization in the construction industry with immersive and drones technologies: A critical literature review. *Smart and Sustainable Built Environment*, *10*(3), 345–363. https://doi.org/10.1108/SASBE-06-2020-0077

Elsayed, M., & Mohamed, M. (2020). The impact of airspace regulations on unmanned aerial vehicles in last-mile operation. *Transportation Research Part D: Transport and Environment*, *87*, Article 102480. https://doi.org/10.1016/j.trd.2020.102480

Engineering, L. P. (2020). *Here's the history of drones in five minutes or less* [Infographic]. Lazen PE. https://www.lazenpe.com/post/the-history-of-drones-infographic

Ethan. (2022, 30 August). *NSW Fire and Rescue to utilise drones*. Droneverse. https://droneverse.com.au/index.php/2022/08/30/nsw-fire-and-rescue-to-utilise-drones/

eVTOL. (2022, Sept 7) In *Wikipedia*. https://en.wikipedia.org/wiki/EVTOL

Fassbender, J., Sanap, A. B., & Green, K. (2018). Improved productivity, efficiency and cost savings following implementation of drone technology in the surveying industry. In *ISARC*, *Proceedings of the International Symposium on Automation and Robotics in Construction* (Vol. 35, pp. 1–6). IAARC. https://doi.org/10.22260/ISARC2018/0115

Feist, J. (2019, 15 February). *Install your drone license plate: New FAA rule effective February 25, 2019*. Drone Rush. https://dronerush.com/display-faa-drone-registration-number-17175/

Figliozzi, M. A. (2020). Carbon emissions reductions in last mile and grocery deliveries utilizing air and ground autonomous vehicles. *Transportation Research Part D: Transport and Environment*, *85*, Article 102443. https://doi.org/10.1016/j.trd.2020.102443

Fortune Business Insights. (2022, 18 February). *Top 10 medical drone industry players in 2022*. https://www.fortunebusinessinsights.com/blog/top-10-medical-drone-industry-players-10634

Frankelius, P., Norrman, C., & Johansen, K. (2019). Agricultural innovation and the role of institutions: Lessons from the game of drones. *Journal of Agricultural and Environmental Ethics*, *32*(5), 681–707. https://doi.org/10.1007/s10806-017-9703-6

Gabani, P. R., Gala, U. B., Narwane, V. S., Raut, R. D., Govindarajan, U. H., & Narkhede, B. E. (2021). A viability study using conceptual models for last mile drone logistics operations in populated urban cities of India. *IET Collaborative Intelligent Manufacturing*, *3*(3), 262–272. https://doi.org/10.1049/cim2.12006

Gallacher, D. (2016). Drone applications for environmental management in urban spaces: A review. *International Journal of Sustainable Land Use and Urban Planning*, 3(4), 1–14. https://doi.org/10.24102/ijslup.v3i4.738

Gallan Herranz, A. (2017, 11 July). *A Colombian start-up is using drones to improve access to health care for people living in remote areas*. RESET.org. https://en.reset.org/saving-lives-drones-colombia-11062017/

Garsten, E. (2022, 30 March). FedEx teams up with Elroy Air for autonomous cargo drone delivery. *Forbes*. https://www.forbes.com/sites/edgarsten/2022/03/30/fedex-to-demo-elroy-air-autonomous-drones/?sh=a7109f42994c

Gibson, C. (2022, 26 August). *World first experiment using drones for wildlife health checks*. UniSA. https://www.unisa.edu.au/unisanews/2022/july/feature/

Gimesy, D. (2020, 11 February). Drones and thermal imaging: Saving koalas injured in the bushfires. *The Guardian*. https://www.theguardian.com/australia-news/gallery/2020/feb/11/drones-thermal-imaging-australia-koalas-bushfire-crisis

Global Data. (2022, 30 June). *Drone use rising in mines, with surveying and mapping the most common application*. Mining-Technology. https://www.mining-technology.com/comment/drone-use/

Global Drone Surveys. (2022). *Environmental impact assessments: Using UAV drones to support assessment data.* https://www.globaldronesurveys.com/environmental-impact-assessment

Global Market Insights. (2017). *Agricultural drones market worth over $1 billion by 2024*. https://www.gminsights.com/pressrelease/agricultural-drones-market

GlobeNewswire. (2022, 21 April). *Agriculture drones market projected to garner USD 22.10 billion with a CAGR of 29.3% by 2030: Report by Market Research Future (MRFR).* https://www.globenewswire.com/en/news-release/2022/04/21/2426640/0/en/Agriculture-Drones-Market-Projected-to-Garner-USD-22-10-Billion-with-a-CAGR-of-29-3-by-2030-Report-by-Market-Research-Future-MRFR.html

Goldman Sachs. (2016). *Drones, report for work*. https://www.goldmansachs.com/insights/technology-driving-innovation/drones/

Golizadeh, H., Hosseini, M. R., Edwards, D. J., Abrishami, S., Taghavi, N., & Banihashemi, S. (2019). Barriers to adoption of RPAs on construction projects: a task–technology fit perspective. *Construction Innovation*, *19*(2), 149–169. https://doi.org/10.1108/CI-09-2018-0074

Goodchild, A., & Toy, J. (2018). Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing CO2 emissions in the delivery service industry. *Transportation Research Part D: Transport and Environment*, *61*, 58–67. https://doi.org/10.1016/j.trd.2017.02.017

Goondiwindi Regional Council. (2022). *Goondiwindi region is first regional place in Australia to deliver rural medications by drones*. https://www.grc.qld.gov.au/news/article/486/goondiwindi-region-is-first-regional-place-in-australia-to-deliver-rural-medications-by-drone

Government Business. (2022). *The view from above: drones and public services. PSi*. https://governmentbusiness.co.uk/features/view-above-drones-and-public-services

Government of Western Australia. (2020, July 14). *Use of remotely piloted aircraft systems for public announcements*. https://www.police.wa.gov.au/About-Us/News/Remotely-Piloted-Aircraft-Systems-for-public-service-announcements

Goyal, R., Reiche, C., Fernando, C., & Cohen, A. (2021). Advanced air mobility: Demand analysis and market potential of the airport shuttle and air taxi markets. *Sustainability*, *13*(13), Article 7421. https://doi.org/10.3390/su13137421

Greenwood, W. W., Lynch, J. P., & Zekkos, D. (2019). Applications of UAVs in civil infrastructure. *Journal of Infrastructure Systems*, *25*(2). https://doi.org/10.1061/(ASCE)IS.1943-555X.0000464

Gupta, A., Afrin, T., Scully, E., & Yodo, N. (2021). Advances of UAVs toward future transportation: The state-of-the-art, challenges, and opportunities. *Future Transportation*, *1*(2), 326–350. https://doi.org/10.3390/futuretransp1020019

Gupta, S. G., Ghonge, D., & Jawandhiya, P. M. (2013). Review of unmanned aircraft system (UAS). *International Journal of Advanced Research in Computer Engineering & Technology*, *2*(4). https://doi.org/10.2139/ssrn.3451039

Hamylton, S. M. (2017). Mapping coral reef environments: A review of historical methods, recent advances and future opportunities. *Progress in Physical Geography*, *41*(6), 803–833. https://doi.org/10.1177/0309133317744998

Harvard, J., Hyvönen, M., & Wadbring, I. (2020). Journalism from above: Drones and the media in critical perspective. *Media and Communication*, *8*(3), 60–63. https://doi.org/10.17645/mac.v8i3.3442

Hassanalian, M., & Abdelkefi, A. (2017). Classifications, applications, and design challenges of drones: A review. *Progress in Aerospace Sciences*, *91*, 99–131. https://doi.org/10.1016/j.paerosci.2017.04.003

He, D., Chan, S., & Guizani, M. (2017). Drone-assisted public safety networks: The security aspect. *IEEE Communications Magazine*, *55*(8), 218–223. https://doi.org/10.1109/MCOM.2017.1600799CM

Head, E. (2021, 13 July). With Osaka Expo as a goal, Japan gets serious about electric air taxis. *Vertical Magazine*. https://verticalmag.com/features/japan-evtol-air-taxis-osaka-expo/

Hewson, G. (2021). *Queensland sunflower crop planted by drone could be first of its kind in the world*. ABC News. https://www.abc.net.au/news/2021-12-28/cambooya-sunflower-farm-planted-by-drone/100728166

Hill, B. P., DeCarme, D., Metcalfe, M., Griffin, C., Wiggins, S., Metts, C., Bastedo, B., D, M., Patterson, & Mendonca, N. L. (2020, 4 December). *UAM vision concept of operations (ConOps) UAM maturity level (UML) 4*. NASA Technical Reports Server. https://ntrs.nasa.gov/citations/20205011091

Hobba, B., Akinci, S., & Göktogan, A. H. (2021). Efficient herbicide spray pattern generation for site-specific weed management practices using semantic segmentation on UAV imagery. In *Proceedings of the Australian Robotics and Automation Association* (p.10).

Huang, H., Savkin, A. V., & Huang, C. (2020). Reliable path planning for drone delivery using a stochastic time-dependent public transportation network. *IEEE Transactions on Intelligent Transportation Systems*, *22*(8), 4941–4950. https://doi.org/10.1109/TITS.2020.2983491

Innovate Energy. (2021, 2 March). *Rio Tinto using drones, AR, and AI to improve mining safety*. https://innovateenergynow.com/resources/rio-tinto-using-drones-ar-and-ai-to-improve-mining-safety

Ip, P. (2022, 8 July). Drones in Hollywood: *How have drones changed the film & movie industry*. Adorama Camera, Inc. https://www.adorama.com/alc/drones-hollywood-film-movie-industry/

Iseli, C., & Lucieer, A. (2019). Tree species classification based on 3D spectral point clouds and orthomosaics acquired by snapshot hyperspectral UAS sensor. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*, *42*(2/W13). 379–384. https://doi.org/10.5194/isprs-archives-XLII-2-W13-379-2019

Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021). A review of applications and communication technologies for Internet of Things (IoT) and unmanned aerial vehicle (UAV) based sustainable smart farming. *Sustainability* (Switzerland), *13*(4), 1–20, Article 1821. https://doi.org/10.3390/su13041821

Jiménez López, J., & Mulero-Pázmány, M. (2019). Drones for conservation in protected areas: Present and future. *Drones*, *3*(1), 10. https://doi.org/10.3390/drones3010010

Johnson, A. M., Cunningham, C. J., Arnold, E., Rosamond, W. D., & Zègre-Hemsey, J. K. (2021). Impact of using drones in emergency medicine: What does the future hold? *Open Access Emergency Medicine*, *13*, 487-498. https://doi.org/10.2147/OAEM.S247020

Kamat, A., Shanker, S., & Barve, A. (2022). Assessing the factors affecting implementation of unmanned aerial vehicles in Indian humanitarian logistics: A g-DANP approach.

Journal of Modelling in Management. Advance online publication https://doi.org/10.1108/JM2-02-2021-0037

Katanich, D. (2022, 22 February). *Drones are planting sunflowers on this modern farm in Australia*. Euronews.green. https://www.euronews.com/green/2022/02/22/drones-are-planting-sunflowers-on-this-modern-farm-in-australia

Katwala, A. (2018, 6 July). The Thai cave rescue is relying on some totally ingenious tech hacks. *WIRED*. https://www.wired.co.uk/article/thai-cave-rescue-boys-news-tech

Kellermann, R., Biehle, T., & Fischer, L. (2020). Drones for parcel and passenger transportation: A literature review. *Transportation Research Interdisciplinary Perspectives*, *4*, Article 100088. https://doi.org/10.1016/j.trip.2019.100088

Khalid, M., Namian, M., & Massarra, C. (2021). The dark side of the drones: A review of emerging safety implications in construction. *EPiC Series in Built Environment*, *2*, 18–27. https://doi.org/10.29007/x3vt

Khan, M. N. H., & Neustaedter, C. (2019). *Exploring drones to assist firefighters during emergencies*. 1st International Workshop on Human-Drone Interaction [Conference Presentation]. Ecole Nationale de l'Aviation Civile [ENAC], May 2019, Glasgow, United Kingdom.

Kitjacharoenchai, P., Ventresca, M., Moshref-Javadi, M., Lee, S., Tanchoco, J. M., & Brunese, P. A. (2019). Multiple traveling salesman problem with drones: Mathematical model and heuristic approach. *Computers & Industrial Engineering*, *129*, 14–30. https://doi.org/10.1016/j.cie.2019.01.020

Kristensen, A. S., Ahsan, D., Mehmood, S., & Ahmed, S. (2017). Rescue emergency drone for fast response to medical emergencies due to traffic accidents. *International Journal of Health and Medical Engineering*, *11*(11), 637–641.

Kwan, C. (2021, 25 August). *Alphabet's Wing to pass 100,000 drone delivery milestone this week*. ZDNet. https://www.zdnet.com/article/alphabets-wing-to-pass-100000-drone-delivery-milestone-this-week/

Lal, S. (2021, 15 October). *Fireball-dropping drones part of new technology upgrades for NSW firefighters*. 9News. https://www.9news.com.au/national/nsw-bushfires-fireball-dropping-drones-part-of-new-technology-upgrades-for-firefighters/4493456c-6532-432f-9901-f281adeaca40

Lalrochunga, D., Parida, A., & Choudhury, S. (2020). Sustainability of UAVs in developing countries: Prospects and challenges. *Journal of Discrete Mathematical Sciences and Cryptography*, *23*(1), 237–248. https://doi.org/10.1080/09720529.2020.1721887

Lee, S., & Choi, Y. (2016). Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry. *Geosystem Engineering*, *19*(4), 197–204. https://doi.org/10.1080/12269328.2016.1162115

Li, Y., & Liu, C. (2019). Applications of multirotor drone technologies in construction management. *International Journal of Construction Management*, *19*(5), 401–412. https://doi.org/10.1080/15623599.2018.1452101

Li, Y., Yuan, X., Zhu, J., Huang, H., & Wu, M. (2020). Multiobjective scheduling of logistics UAVs based on variable neighborhood search. *Applied Sciences*, *10*(10), Article 3575. https://doi.org/10.3390/app10103575

Lum, C. W., Summers, A., Carpenter, B., Rodriguez, A., & Dunbabin, M. (2015). *Automatic wildfire detection and simulation using optical information from unmanned aerial systems* (No. 2015-01-2474). SAE Technical Paper. https://doi.org/10.4271/2015-01-2474

Macdonald, J. M., Robinson, C. J., Perry, J., Lee, M., Barrowei, R., Coleman, B., Markham, J., Barrowei, A., Markham, B., & Ford, H. (2021). Indigenous-led responsible innovation: Lessons from co-developed protocols to guide the use of drones to monitor a biocultural landscape in Kakadu National Park, Australia. *Journal of Responsible Innovation*, *8*(2), 300–319. https://doi.org/10.1080/23299460.2021.1964321

Mackenzie Valley Environmental Impact Review Board. (2007). Socio-economic impact assessment guidelines. https://reviewboard.ca/reference_material/socio_economic_impact_assessment

Macrina, G., Pugliese, L. D. P., Guerriero, F., & Laporte, G. (2020). Drone-aided routing: A literature review. *Transportation Research Part C: Emerging Technologies*, *120*, Article 102762. https://doi.org/10.1016/j.trc.2020.102762

Maghazei, O., & Netland, T. (2019). Drones in manufacturing: Exploring opportunities for research and practice. *Journal of Manufacturing Technology Management*, *31*(6), 1237–1259. https://doi.org/10.1108/JMTM-03-2019-0099

Magnani, M. (2022). *Making the global economy work for everyone: Lessons of sustainability from the tech revolution and the pandemic*. Springer. https://doi.org/10.1007/978-3-030-92084-5

Maharana, S. (2017). Commercial drones. *International Journal of Advances in Science, Engineering and Technology (IJASEAT)*, *5*(1), Spl. Iss-3, 96–101. https://doi.org/https://www.digitalxplore.org/up_proc/pdf/264-14863843671-6.pdf

Markowitz, E. M., Nisbet, M. C., Danylchuk, A. J., & Engelbourg, S. I. (2017). What's that buzzing noise? Public opinion on the use of drones for conservation science. *BioScience*, *67*(4), 382–385. https://doi.org/10.1093/biosci/bix003

Marshall, A., Turner, K., Richards, C., Foth, M., & Dezuanni, M. (2022). Critical factors of digital AgTech adoption on Australian farms: From digital to data divide. *Information Communication and Society*, *25*(6), 868–886. https://doi.org/10.1080/1369118X.2022.2056712

Martin, C. L., Curley, B., Wolfenden, K., Green, M., & Moltschaniwskyj, N. A. (2022). The social dimension to the New South Wales Shark Management Strategy, 2015–2020, Australia: Lessons learned. *Marine Policy*, *141*, Article 105079. https://doi.org/10.1016/j.marpol.2022.105079

Mazur, M., Wisniewski, A., & McMillan, J. (2016). *Clarity from above: PwC global report on the commercial applications of drone technology*. Drone Powered Solutions, PricewaterhouseCoopers.

Meola, A. (2021, 9 February). *Precision agriculture in 2021*: *The future of farming is using drones and sensors for efficient mapping and spraying*. Insider Inc. https://www.businessinsider.com/agricultural-drones-precision-mapping-spraying

Merkert, R., Beck, M. J., & Bushell, J. (2021). Will it fly? Adoption of the road pricing framework to manage drone use of airspace. *Transportation Research Part A: Policy and Practice*, *150*, 156–170. https://doi.org/10.1016/j.tra.2021.06.001

Merkert, R., & Bushell, J. (2020). Managing the drone revolution: A systematic literature review into the current use of airborne drones and future strategic directions for their effective control. *Journal of Air Transport Management*, *89*, Article 101929. https://doi.org/10.1016/j.jairtraman.2020.101929

Microdrones. (2017, 4 October). *Construction leader Strabag demonstrates microdrones UAV at German construction technology day*. https://www.microdrones.com/en/content/construction-leader-strabag-demonstrates-microdrones-uav-at-german-construction-technology-day/

Molloy, D., & Copestake, J. (2020, 30 April). *Drone-to-door medicines trial takes flight in Ireland*. BBC. https://www.bbc.com/news/technology-52206660

Moore, P. (2017, 30 November). *Bingham Canyon has 30 FAA-certified drone pilots running four to five flights a day*. International Mining. https://im-mining.com/2017/11/30/bingham-canyon-30-faa-certified-drone-pilots-running-four-five-flights-day/#:~:text=The%20ten%20drones%20used%20at,world's%20largest%20open%2Dpit%20mines

Moses, A. (2012, 11 September). Here comes the drone age. *The Age.* https://www.theage.com.au/technology/here-comes-the-drone-age-20120910-25o6p.html

Mualla, Y., Najjar, A., Daoud, A., Galland, S., Nicolle, C., & Shakshuki, E. (2019). Agent-based simulation of unmanned aerial vehicles in civilian applications: A systematic literature review and research directions. *Future Generation Computer Systems*, *100*, 344–364. https://doi.org/10.1016/j.future.2019.04.051

Mulero-Pázmány, M., Jenni-Eiermann, S., Strebel, N., Sattler, T., Negro, J. J., & Tablado, Z. (2017). Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. *PLoS ONE*, *12*(6), Article e0178448. https://doi.org/10.1371/journal.pone.0178448

Mullens, M. (2016). How drone and mapping technology revolutionised Tasmania's flood response. *National Emergency Response*, *29*(4), 4–5.

Nichols, N. (2022, Sep 7). *Institutional investors back AMSL Aero's hydrogen-powered Vertiia technology in $23m raise*. Business News Australia https://www.businessnewsaustralia.com/articles/institutional-investors-back-amsl-aero-s-hydrogen-powered-vertiia-technology-in--23m-raise.html

Nolan, A. P., Park, S., O'Connell, M., Fuentes, S., Ryu, D., & Chung, H. (2015). Automated detection and segmentation of vine rows using high resolution UAS imagery in a commercial vineyard. In T. Weber, M. McPhee, & R. Anderssen (Eds.), *Proceedings – 21st International Congress on Modelling and Simulation, MODSIM 2015* (pp. 1406–1412). Modelling and Simulation Society of Australia and New Zealand.

Nooralishahi, P., Ibarra-Castanedo, C., Deane, S., López, F., Pant, S., Genest, M., Avdelidis, N. P., & Maldague, X. P. (2021). Drone-based non-destructive inspection of industrial sites: A review and case studies. *Drones*, *5*(4), Article 106. https://doi.org/10.3390/drones5040106

Office of the Australian Information Commissioner. (2022). *Who has rights under the Privacy Act*? https://www.oaic.gov.au/privacy/the-privacy-act/rights-and-responsibilities#WhoHasResponsibilitiesUnderPrivacyAct

Olivares, P., & Gallo, S. (2022, 17 November). *Advanced air mobility: The future will arrive on drones*. Unmanned Publications. https://www.urbanairmobilitynews.com/commentary/advanced-air-mobility-the-future-will-arrive-on-drones/?utm_source=rss&utm_medium=rss&utm_campaign=advanced-air-mobility-the-future-will-arrive-on-drones

Oppenheimer. (2016, 18 February). *Drone industry report, Equity Research, Industry Update*.

Pantazis, C., & Pemberton, S. (2009). From the 'old' to the 'new' suspect community: Examining the impacts of recent UK counter-terrorist legislation. *The British Journal of Criminology*, *49*(5), 646–666. https://doi.org/10.1093/bjc/azp031

Park, J., Kim, S., & Suh, K. (2018). A comparative analysis of the environmental benefits of drone-based delivery services in urban and rural areas. *Sustainability*, 10(3), Article 888. https://doi.org/10.3390/su10030888

Park, S., Ryu, D., Fuentes, S., Chung, H., O'Connell, M., & Kim, J. (2021). Mapping very-high-resolution evapotranspiration from unmanned aerial vehicle (UAV) imagery. *ISPRS International Journal of Geo-Information*, *10*(4), Article 211. https://doi.org/10.3390/ijgi10040211

Pathology Awareness Australia. (2017). *Drones being used to transport lab samples in world-first*. https://knowpathology.com.au/drones-being-used-to-transport-lab-samples-in-world-first/

Persson, E. (2021). *A systematic literature review on drones' application in last-mile delivery* [Master's thesis, University of Gavle]. DiVA. https://www.diva-portal.org/smash/get/diva2:1577765/FULLTEXT01.pdf

Pfizer. (2021, 11 November). *Zipline, Pfizer and BioNTech collaboration paves the way for automated, on-demand delivery of first mRNA COVID-19 vaccines in Ghana* [Press release]. https://www.pfizer.com/news/press-release/press-release-detail/zipline-pfizer-and-biontech-collaboration-paves-way#:~:text=To%2Ddate%2C%20more%20than%20220%2C000,more%20as%20supply%20becomes%20available.

Plouffe, J. (2022, 11 July). *A new way to fly headed to Australia*. The Lead. https://theleadsouthaustralia.com.au/industries/business/a-new-way-to-fly-headed-to-australia/

Poikonen, S., Wang, X., & Golden, B. (2017). The vehicle routing problem with drones: Extended models and connections. *Networks*, *70*(1), 34–43. https://doi.org/10.1002/net.21746

Pope, D. (2022). *The business of Amazon's ethics*. DigitalCommons@SHU. https://digitalcommons.sacredheart.edu/cgi/viewcontent.cgi?article=1804&context=acadfest

Position Partners. (2022). *Drone surveying improving productivity, planning and management of mine sites*. https://www.positionpartners.com.au/position-partners/drones-for-mining/

Powell, J. (2019, 19 February). In roadbuilding and bridge inspections, drones cut time, costs and safety risks. Equipment World. https://www.equipmentworld.com/better-roads/article/14970683/drones-cut-time-costs-and-safety-risks-in-construction

Pozner, J. (2020, 18 June). A *comprehensive list of commercial drone use cases (128+ and growing).* Dronegenuity. https://www.dronegenuity.com/commercial-drone-use-cases-comprehensive-list/

Pradip, Gautham, B., Reddy, S., & Runkana, V. (2019). Future of mining, mineral processing and metal extraction industry. *Transactions of the Indian Institute of Metals*, *72*(8), 2159–2177. https://doi.org/10.1007/s12666-019-01790-1

Propeller Aero. (2020, 24 August). How Nevada Gold Mines uses drones to measure stockpiles on a massive scale. https://www.propelleraero.com/blog/how-nevada-gold-mines-uses-drones-to-measure-stockpiles-on-a-massive-scale/

Rachmawati, T. S. N., & Kim, S. (2022). Unmanned aerial vehicles (UAV) integration with digital technologies toward Construction 4.0: A systematic literature review. *Sustainability*, 14(9), Article 5708. https://doi.org/10.3390/su14095708

Raj, A., & Sah, B. (2019). Analyzing critical success factors for implementation of drones in the logistics sector using grey-DEMATEL based approach. *Computers and Industrial Engineering*, *138*, Article 106118. https://doi.org/10.1016/j.cie.2019.106118

Rao, B., Gopi, A. G., & Maione, R. (2016). The societal impact of commercial drones. *Technology in Society*, *45*, 83–90. https://doi.org/10.1016/j.techsoc.2016.02.009

Rebolo-Ifrán, N., Grilli, M. G., & Lambertucci, S. A. (2019). Drones as a threat to wildlife: YouTube complements science in providing evidence about their effect. *Environmental Conservation*, *46*(3), 205–210. https://doi.org/10.1017/S0376892919000080

Rejeb, A., Rejeb, K., Simske, S. J., & Treiblmaier, H. (2021a). Drones for supply chain management and logistics: A review and research agenda. *International Journal of Logistics Research and Applications*, 1–24. https://doi.org/10.1080/13675567.2021.1981273

Rejeb, A., Rejeb, K., Simske, S., & Treiblmaier, H. (2021b). Humanitarian drones: A review and research agenda. *Internet of Things*, *16*, Article 100434. https://doi.org/10.1016/j.iot.2021.100434

Roads Australia. (2022, 16 August). *Drone trial to revolutionise asset management*. https://roads.org.au/drone-trial-to-revolutionise-asset-management/

Robinson, J. M., Harrison, P. A., Mavoa, S., & Breed, M. F. (2022). Existing and emerging uses of drones in restoration ecology. *Methods in Ecology and Evolution*, *13*(9), 1899–1911. https://doi.org/https://doi.org/10.1111/2041-210X.13912

Royal Flying Doctor Service. (2019, 16 April). *Drones to overcome distance for the Royal Flying Doctor Service in Queensland*. https://www.flyingdoctor.org.au/qld/news/drones-overcome-distance-royal-flying-doctor-service-queensland/

Rudd, S., & Evans, D. (2022, 23 September). *Australia has relied on agricultural innovation to farm our dry land. We'll need more for the uncertain years ahead*. The Conversation Media Group. https://theconversation.com/australia-has-relied-on-agricultural-innovation-to-farm-our-dry-land-well-need-more-for-the-uncertain-years-ahead-188597

Ruder, S.-L. (2019). *A digital agricultural revolution: Ontario grain farmer perceptions of digital farming and Big Data* [Unpublished Master's thesis] University of Waterloo.

Ruiz-Vanoye, J. A., Barrera-Cámara, R. A., Díaz-Parra, O., Ramos-Fernández, J. C., Fuentes-Penna, A., Ochoa-Zezzatti, A., Hernández-Aguilar, J. A., & Campero-Jurado, I. (2022). Surveying smart farming for smart cities. In A. Abraham, S. Dash, J. J.P.C. Rodrigues, B. Acharya, & S. K. Pani (Eds.), *Intelligent Data-Centric Systems*, *AI, Edge and IoT-based Smart Agriculture* (pp. 241–262). Academic Press. https://doi.org/10.1016/B978-0-12-823694-9.00014-1.

Safonova, A., Guirado, E., Maglinets, Y., Alcaraz-Segura, D., & Tabik, S. (2021). Olive tree biovolume from UAV multi-resolution image segmentation with mask R-CNN. *Sensors*, *21*(5), Article 1617. https://doi.org/10.3390/s21051617

Sah, B., Gupta, R., & Bani-Hani, D. (2021). Analysis of barriers to implement drone logistics. *International Journal of Logistics Research and Applications*, *24*(6), 531–550. https://doi.org/10.1080/13675567.2020.1782862

Said, K. O., Onifade, M., Githiria, J. M., Abdulsalam, J., Bodunrin, M. O., Genc, B., Johnson, O., & Akande, J. M. (2021). On the application of drones: A progress report in mining operations. *International Journal of Mining, Reclamation and Environment*, *35*(4), 235–267. https://doi.org/10.1080/17480930.2020.1804653

Sakiyama, M., Miethe, T. D., Lieberman, J. D., Heen, M. S., & Tuttle, O. (2017). Big hover or big brother? Public attitudes about drone usage in domestic policing activities. *Security Journal*, *30*(4), 1027–1044. https://doi.org/10.1057/sj.2016.3

Samaras, S., Diamantidou, E., Ataloglou, D., Sakellariou, N., Vafeiadis, A., Magoulianitis, V., Lalas, A., Dimou, A., Zarpalas, D., & Votis, K. (2019). Deep learning on multi sensor data for counter UAV applications: A systematic review. *Sensors*, *19*(22), Article 4837. https://doi.org/10.3390/s19224837

Satish, S. (2021, 8 September). *Satellite VS drone imagery: Knowing the difference and effectiveness of SuperVision Earth's complementary synergy*. SuperVision Earth. https://medium.com/supervisionearth/satellite-vs-drone-imagery-knowing-the-difference-and-effectiveness-of-supervision-earths-90e98b78777c#:~:text=While%20drones%20often%20need%20to,back%20to%20the%20ground%20station

Schäffer, B., Pieren, R., Heutschi, K., Wunderli, J. M., & Becker, S. (2021). Drone noise emission characteristics and noise effects on humans: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(11), Article 5940. https://doi.org/10.3390/ijerph18115940

Schlesinger, L. (2022, 30 August). Rich Listers' land to host Australia's first 'vertiport'. *The Australian Financial Review.* https://www.afr.com/property/commercial/rich-listers-land-to-host-australia-s-first-vertiport-20220830-p5bdv2

Schmidt, B., & Vance, A. (2020, 26 March). *DJI won the drone wars, and now it's paying the price*. Bloomberg Businessweek. https://www.bloomberg.com/news/features/2020-03-26/dji-s-drone-supremacy-comes-at-a-price#xj4y7vzkg

Scott, J., & Scott, C. (2017, 4 January). *Drone delivery models for healthcare* [Paper presentation]. Proceedings of the 50th Hawaii International Conference on System Sciences, Hawaii, USA. https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/2d0a63d1-1c88-4bf2-ad90-74712b26c40d/content#:~:text=To%20our%20knowledge%2C%20this%20study%20is%20one%20of,regions.%20For%20a%20review%20of%20location%20decisions%20see.

Sengul-Jones, M. (2021, 23 August). *A guide to journalism's drone-powered future*. Global Investigative Journalism Network. https://gijn.org/2021/08/23/a-guide-to-journalisms-drone-powered-future/#:~:text=In%202011%2C%20The%20New%20York,attend%20%E2%80%94%20protests%20and%20environmental%20disasters.

Sexton, C. (2020). *Drones are becoming a threat to waterbirds*. Earth.com. https://www.earth.com/news/drones-are-a-growing-threat-to-waterbirds/

Shadiev, R., & Yi, S. (2022). A systematic review of UAV applications to education. *Interactive Learning Environments*, 1-30. https://doi.org/10.1080/10494820.2022.2028858

Shahmoradi, J., Talebi, E., Roghanchi, P., & Hassanalian, M. (2020). A comprehensive review of applications of drone technology in the mining industry. *Drones*, *4*(3), Article 34. https://doi.org/10.3390/drones4030034

Shavarani, S. M., Mosallaeipour, S., Golabi, M., & İzbirak, G. (2019). A congested capacitated multi-level fuzzy facility location problem: An efficient drone delivery system. *Computers & Operations Research*, 108, 57–68. https://doi.org/10.1016/j.cor.2019.04.001

She, R., & Ouyang, Y. (2021). Efficiency of UAV-based last-mile delivery under congestion in low-altitude air. *Transportation Research Part C: Emerging Technologies*, 122, Article 102878. https://doi.org/10.1016/j.trc.2020.102878

Shendryk, Y., Sofonia, J., Garrard, R., Rist, Y., Skocaj, D., & Thorburn, P. (2020). Fine-scale prediction of biomass and leaf nitrogen content in sugarcane using UAV LiDAR and multispectral imaging. *International Journal of Applied Earth Observation and Geoinformation*, *92*, Article 102177. https://doi.org/10.1016/j.jag.2020.102177

Singh, I. (2022a, 7 November). *FAA grants nationwide waiver to Percepto for automated, BVLOS drone missions*. DroneDJ. https://dronedj.com/2022/11/07/faa-waiver-bvlos-automated-drones/

Singh, I. (2022b). *Swiss Post to hand over drone delivery operations to California's Matternet*. DroneDJ. https://dronedj.com/2022/06/01/swiss-post-drone-delivery-matternet/

Singhal, G., Bansod, B., & Mathew, L. (2018). Unmanned aerial vehicle classification, applications and challenges: A review. *Preprints*, Article 2018110601. https://doi.org/10.20944/preprints201811.0601.v1.

Skynews.com.au. (2022, 30 May). *Vivid hosts largest drone show in Southern Hemisphere*. Australian New Channel. https://www.skynews.com.au/business/tech-and-innovation/vivid-hosts-largest-drone-show-in-southern-hemisphere/video/0935c547ebca2940b4e43ce70d554554

Smart AKIS. (2016). *What is smart farming?* https://www.smart-akis.com/index.php/network/what-is-smart-farming/

Smith, A., Dickinson, J. E., Marsden, G., Cherrett, T., Oakey, A., & Grote, M. (2022). Public acceptance of the use of drones for logistics: The state of play and moving towards more informed debate. *Technology in Society*, *68*, Article 101883. https://doi.org/10.1016/j.techsoc.2022.101883

Snouffer, E. (2022, 13 April). Six places where drones are delivering medicines. *Nature Medicine*, *28*, 874–875. https://doi.org/10.1038/d41591-022-00053-9

Sood, A., Sharma, R. K., & Bhardwaj, A. K. (2021). Artificial intelligence research in agriculture: A review. *Online Information Review*. *46*(6), 1054–1075. https://doi.org/10.1108/OIR-10-2020-0448

Sookram, N., Ramsewak, D., & Singh, S. (2021). The conceptualization of an unmanned aerial system (UAS) ship–shore delivery service for the maritime industry of Trinidad. *Drones*, *5*(3), Article 76. https://doi.org/10.3390/drones5030076

Spires, J. (2019, 21 August). *Mining giant BHP saves an estimated $5 million per year using drones*. DroneDJ. https://dronedj.com/2019/08/01/bhp-saves-5-million-using-drones/

Spires, J. (2020, 19 August). *Drones to help Aussie farmers reduce chemical, water usage*. DroneDJ. https://dronedj.com/2020/08/19/drones-to-help-aussie-farmers-reduce-chemical-water-usage/

Spires, J. (2021, 23 February). *Mining giant Rio Tinto purchases more drones, smart glasses*. DroneDJ. https://dronedj.com/2021/02/23/mining-giant-rio-tinto-purchases-more-drones-smart-glasses/

Spires, J. (2022, 16 August). *Sphere Drones works with TfNSW to automate Sydney Harbour Bridge inspections*. Sphere Drones. https://spheredrones.com.au/blogs/case-studies/skydio-tfnsw-automate-bridge-inspections-australia

Statista. (2017). *Drone & robot delivery: Trends – development – comparisons*. https://www.statista.com/study/44364/drone-and-robot-delivery-trends---development-comparisons/

Stewart, P. (2016). Drone danger: Remedies for damage by civilian remotely piloted aircraft to persons or property on the ground in Australia. *Torts Law Journal*, *23*(3), 290–319. https://search.informit.org/doi/10.3316/agispt.20170916

Stolaroff, J. K., Samaras, C., O'Neill, E. R., Lubers, A., Mitchell, A. S., & Ceperley, D. (2018). Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery. *Nature Communications*, *9*(1), 1–13. https://doi.org/10.1038/s41467-017-02411-5

Straits Research. (2022, Jun 21). *Commercial drone market*. https://straitsresearch.com/report/commercial-drone-market

sUAS News. (2021, 14 October). *The adoption of drone technology helps ArcelorMittal to accelerate Its transformation and innovate in industrial inspections and maintenance processes*. https://www.suasnews.com/2021/10/the-adoption-of-drone-technology-helps-arcelormittal-to-accelerate-its-transformation-and-innovate-in-industrial-inspections-and-maintenance-processes/

Subramaniam, E., Joseph, N., Rose, A., & Bil, C. (2012). Design of a fire-fighting unmanned air vehicle. In *50th AIAA aerospace sciences meeting including the New Horizons Forum and Aerospace Exposition*. https://doi.org/10.2514/6.2012-1039

Sunshine Coast Regional Council. (2020, 13 May). *Council takes asset management to new heights with drone program*. https://www.sunshinecoast.qld.gov.au/Council/News-Centre/Drone-technology-130520

Surf Life Saving NSW. (2022). *Australian UAV service*. https://www.surflifesaving.com.au/about-us/australian-uav-service/

Swain, S. (2022, 21 November). *Drones worth $100k plunge into river as 'technical issues' hit Perth Christmas event*. Nine Digital Network. https://www.9news.com.au/national/perth-drone-show-fall-into-swan-river/6ed2b4c4-1525-49c3-8ca2-a0852b8dedbf

Tey, Y. S., & Brindal, M. (2022). A meta-analysis of factors driving the adoption of precision agriculture. *Precision Agriculture*, *23*(2), 353–372. https://doi.org/10.1007/s11119-021-09840-9

Thorn, A. (2021, 12 May). *Surf Life Saving QLD invests in inflatable-dropping drone firm*. Australian Aviation. https://australianaviation.com.au/2021/05/surf-life-saving-qld-invests-in-inflatable-dropping-drone-firm/

Thurling, D., Harvey, R., & Buller, N. (1985). Aerial photography of field experiments using remotely-piloted aircraft. In *British Crop Protection Conference – Weeds: Proceedings of a conference held at Brighton Metropole, England, November 18-21* (pp. 18–21). BCPC Publications.

Towner, A. V., Kock, A. A., Stopforth, C., Hurwitz, D., & Elwen, S. H. (2022). Direct observation of killer whales predating on white sharks and evidence of a flight response. *Ecology*, *104*(1), Article e3875. https://doi.org/10.1002/ecy.3875

Trabado, C. (2022, 14 July). *Air taxis on the Urban Air Mobility horizon*. AERTEC. https://aertecsolutions.com/en/2021/03/01/air-taxis-on-the-urban-air-mobility-horizon/

Tsiamis, N., Efthymiou, L., & Tsagarakis, K. P. (2019). A comparative analysis of the legislation evolution for drone use in OECD countries. *Drones*, *3*(4), Article 75. https://doi.org/10.3390/drones3040075

Unmanned Airspace. (2021, 7 December). *Successful U-Space trial completed in Germany's first sandbox in Hamburg, tests U-Space services*. https://www.unmannedairspace.info/latest-news-and-information/successful-u-space-trial-completed-in-germanys-first-sandbox-in-hamburg/

Unmanned Airspace. (2022, 4 July). *Industry welcomes publication of Australia's Civil Aviation Safety Authority AAM, RPAS roadmap*. https://www.unmannedairspace.info/latest-news-and-information/industry-welcomes-publication-of-australias-civil-aviation-safety-authority-aam-rpas-roadmap/

Unmanned Systems Technology. (2022). *eVTOL drones*. https://www.unmannedsystemstechnology.com/expo/evtol-drones/#:~:text=Within%20the%20context%20of%20drones,unmanned%20aerial%20vehicle)%20with%20VTOL

Urban Air Mobility. (2022, 4 October). *Kencoa reported to have completed first test flight of 'air taxi' in South Korea*. https://www.urbanairmobilitynews.com/air-taxis/kencoa-reported-to-have-completed-first-test-flight-of-air-taxi-in-south-korea/

US Army UAS Center of Excellence. (2010). *US Army unmanned aircraft systems roadmap: 2010–2035*. https://irp.fas.org/program/collect/uas-army.pdf

US Department of Transportation. (2022, 18 October). *US FAA, Japanese Agree to Partner on Advanced Air Mobility Certification, Operations*. https://www.faa.gov/newsroom/us-faa-japanese-agree-partner-advanced-air-mobility-certification-operations

Vanderhorst, H. R., Suresh, S., & Renukappa, S. (2019). Systematic literature research of the current implementation of unmanned aerial system (UAS) in the construction industry. *International Journal of Innovative Technology and Exploring Engineering*, *8*(11S), 416–428. https://doi.org/10.35940/ijitee.K1073.09811S19

Wendt, K., König, A., & Naser, F. (2022). Development of a modular model city for unmanned aircraft vehicle experiments–A visionary concept. In *AIAA Aviation 2022 Forum*. https://doi.org/10.2514/6.2022-3230

Winter, V. (2022, 6 October). *Drone footage captures orca whales chasing, stalking and eating great white sharks*. ABC News. https://www.abc.net.au/news/2022-10-06/orca-whales-filmed-chasing-and-eating-great-white-sharks/101506952

Wisk Aero. (2022, 8 June). *Wisk Aero Brings advanced air mobility to Australia through partnership with Queensland Local Government*. https://wisk.aero/news/press-release/australia-mou/

World Wildlife Fund. (2020, 2 December). *Exploring tree planting drones to make Australia green again!* https://www.wwf.org.au/news/blogs/exploring-tree-planting-drones-to-make-australia-green-again#gs.eze9ls

Wright, D., & Finn, R. (2016). Making drones more acceptable with privacy impact assessments. In Custers, B. (Ed.) *The future of drone use* (pp. 325–351). Information Technology and Law Series (Vol. 27). TMC Asser Press. https://doi.org/10.1007/978-94-6265-132-6_17

Yawson, G. E., & Frimpong-Wiafe, B. (2018). The socio-economic benefits and impact study on the application of drones, sensor technology and intelligent systems in commercial-scale agricultural establishment in Africa. *International Journal of Agriculture and Economic Development*, *6*(2), 18–36.

Yaxley, K. J., Joiner, K. F., & Abbass, H. (2021). Drone approach parameters leading to lower stress sheep flocking and movement: sky shepherding. *Scientific Reports*, *11*(1), 1–9. https://doi.org/10.1038/s41598-021-87453-y

Yebra, M., Barnes, N., Bryant, C., Cary, G. J., Durrani, S., Lee, J.-U., Lindenmayer, D., Mahony, R., Prinsley, R., & Ryan, P. (2021). An integrated system to protect Australia from catastrophic bushfires. *The Australian Journal of Emergency Management*, *36*(4), 20–22.

Yong, C. (2022, 16 February). Air taxi services in Sentosa and Marina Bay by 2024; flights to Malaysia and Indonesia to follow. *The Straits Times*. https://www.straitstimes.com/singapore/transport/air-taxi-services-in-sentosa-and-marina-bay-by-2024-flights-to-malaysia-and-indonesia-to-follow

Yoo, H. D., & Chankov, S. M. (2018). Drone-delivery using autonomous mobility: An innovative approach to future last-mile delivery problems. In *2018 IEEE international conference on industrial engineering and engineering management* (pp. 1216–1220), IEEE. https://doi.org/10.1109/IEEM.2018.8607829.

Yoo, W., Yu, E., & Jung, J. (2018). Drone delivery: Factors affecting the public's attitude and intention to adopt. *Telematics and Informatics*, *35*(6), 1687–1700. https://doi.org/10.1016/j.tele.2018.04.014

Zerlenga, O., Cirillo, V., & Iaderosa, R. (2021). Once upon a time there were fireworks. The new nocturnal drones light shows. *IMG Journal*, *3*(4), 402–425. https://doi.org/10.6092/issn.2724-2463/12628

Zheng, S., Wang, Z., & Wachenheim, C. J. (2018). Technology adoption among farmers in Jilin Province, China: The case of aerial pesticide application. *China Agricultural Economic Review*. *11*(1), 206–216. https://doi.org/10.1108/CAER-11-2017-0216

Zhou, S., & Gheisari, M. (2018). Unmanned aerial system applications in construction: A systematic review. *Construction Innovation*, *18*(4), 453–468. https://doi.org/10.1108/CI-02-2018-0010

Zuo, A., Wheeler, S. A., & Sun, H. (2021). Flying over the farm: Understanding drone adoption by Australian irrigators. *Precision Agriculture*, *22*(6), 1973–1991. https://doi.org/10.1007/s11119-021-09821-y

SECTION C: Consumer Survey

Stage II: Quantitative Survey to understand community- and demographic-specific concerns

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C.1 Methodology, Approach and Technical Framework

To capture the Australian population's perceptions, opinions and preferences related to drone technology and services, and answer the research objectives, an online survey was developed and fielded that had three major components, as follows:

- A general familiarity and knowledge component with questions about how familiar respondents are with drone technology; whether they were aware in which industries drones are being used in Australia; whether they had used a drone and, if yes, the purpose for which they had used it; their level of proficiency in using it; and, last, whether they owned one.
- A component on a small-scale uncrewed aerial vehicle (UAV), commonly known as a drone. First, this component provided a brief definition of drones, their various types and sizes and some use case examples. In this component, respondents were asked whether they were willing to purchase a small-scale drone and, if yes, the purpose for which they would use it. Furthermore, in this section, we developed a best/worst task and asked respondents to rank 41 different drone use cases that they believe provide the most value to (a) their community and (b) society at large. Respondents were also asked to rank their level of acceptance for these 41 use cases. Moreover, in this component, we used a discrete choice experiment (DCE) followed by a series of questions regarding the use of drone delivery services, in order to understand Australian preferences, attitudes, perceptions and concerns related to drone delivery services as opposed to traditional delivery services.
- Large-sized advanced air mobility (AAM) component. This component focused on the eVTOL service (i.e. flying cars) for transporting passengers as an alternative mode of transport. This component also began with a brief definition. Respondents were asked to indicate whether they were willing to travel using flying cars and, if yes, the acceptable range. Furthermore, they were asked to provide detailed information regarding their recent intracity and intercity trips (e.g. metropolitan–regional and regional–regional). Then, two DCEs, designed to elicit respondents' preferences and willingness to use eVTOL services in the future to make a similar trip as their reported recent trip, were conducted. In the concluding section of this component, respondents were asked to respond to a series of Likert-scale questions and express their beliefs, attitudes and perceptions towards the flying car technology and services.

Questions about respondents' socio-demographic characteristics were asked at the end of the survey. In the following section, we explain the sample data collected for this study and provide a detailed analysis of respondents' answers for each of the three components.

C.2 Data

Data for our analysis were from a sample of Australians aged 18 years and above. In all, 1,002 respondents were drawn from a major national market research company. After data cleansing, data on 1,000 respondents remained for analysis. The survey was tested and piloted in September 2022 and later administered online in October 2022 using a web-based interface. The average completion time of the survey was 24:20 minutes. Respondents were recruited to represent the Australian population demographically by age and gender as well as geographically by the proportion of the population by state. Differences between our sample and the Australian population were controlled for through reweighting in our subsequent analysis. Iterative proportional fitting was used to impute the joint probability distributions across our sample and the Australian population according to age and income. For each individual in the sample, the weighting factor was calculated by taking the ratio of the probability of observing the individual's demographic characteristics in the target population to the corresponding probability for the sample. For the distribution of each of the variables against the latest statistics in the Australian Bureau of Statistics, please see Appendix C-1. The weighted sample size for this study was 995. For information about respondent's demographic characteristics please refer to Appendix C-8. Figure C.1 provides an overview of the sample distribution across Australia, with respondents positioned at their postal code centroid.

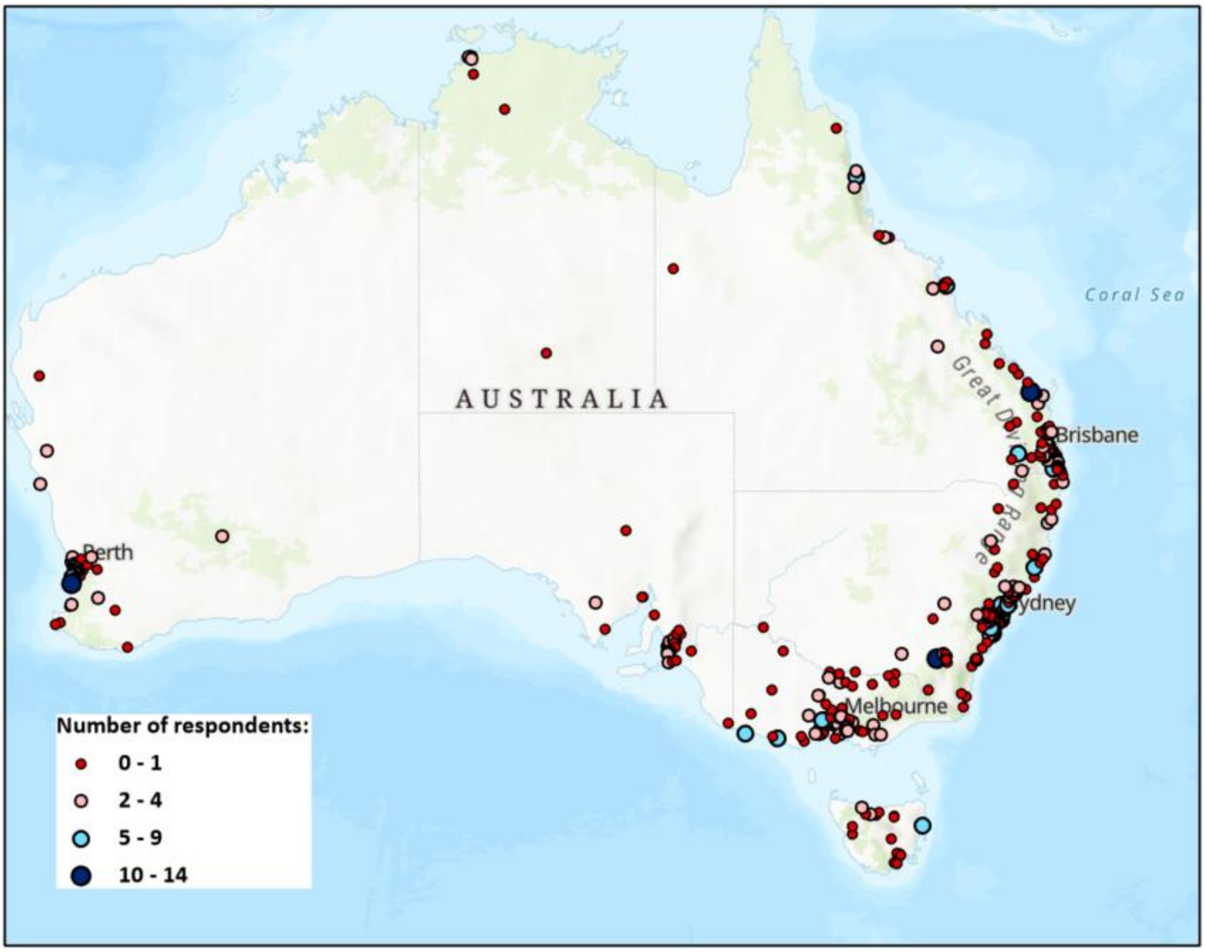


Figure C.1: Sample distribution over Australia shown at the postal code centroid

C.3 Descriptive Analysis

The questionnaire consisted of three major parts (a copy of the survey can be found in Appendix C-2). In subsequent sections, a detailed descriptive analysis of each part is presented.

C.3.1 General familiarity with, and knowledge of, drone technology

In all, 84% of the sample indicated that they have some familiarity with drone technology, whereas 7.8% are very familiar (Figure C.2). Only 16% specified they are not familiar at all.

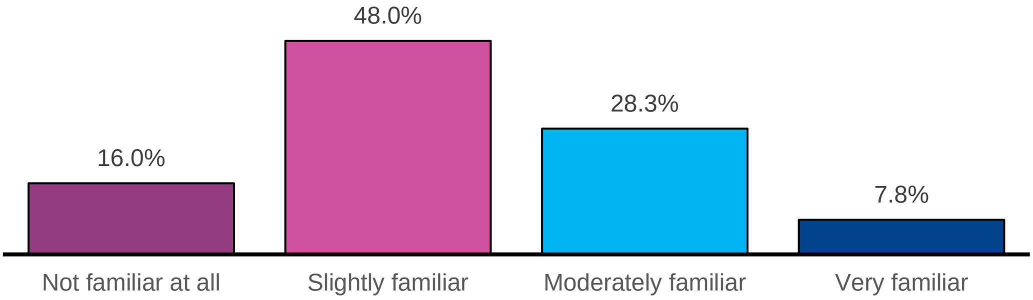


Figure C.2: Level of familiarity with drone technology

Table C.1 shows the split for the level of familiarity by population segment, which reveals that high-income younger males are more familiar with drone technology than are the other respondents. The chi-square test results support this finding about the differences between the various cohorts.

Table C.1: Level of familiarity with drone technology by population segment

		How Familiar Are You with Drone Technology?				Total (%)
		Not at all familiar (%)	Slightly familiar (%)	Moderately familiar (%)	Very familiar (%)	
Gender	Male	6.9	23.1	18.0	5.6	53.6
	Female	9.0	24.9	10.2	2.2	46.4
	Total	16.0	48.0	28.2	7.8	100.0
Age category	18–24	1.2	4.8	2.5	1.1	9.6
	25–34	3.1	6.9	5.7	2.8	18.6
	35–44	1.7	7.3	7.4	1.4	17.9
	45–54	2.1	8.4	4.6	1.5	16.7
	55–64	2.7	8.0	3.5	0.7	15.0
	65 +	5.1	12.4	4.4	0.3	22.3
	Total	16.0	48.0	28.2	7.8	100.0
Income category (A$ per year)	Low income (up to 52,000)	5.6	11.4	7.0	1.9	26.0
	Mid-income (52,000–104,000)	4.7	14.9	6.9	2.0	28.6
	High income (more than 104,000)	5.6	21.7	14.3	3.8	45.5
	Total	16.0	48.0	28.3	7.7	100.0

Figure C.3 shows that of the 84% who mentioned they are familiar with drone technology, 72.9% mentioned they have seen other people flying drones and 62.3% have read and heard about them in the media. Less than 3% have received a delivery using drones.

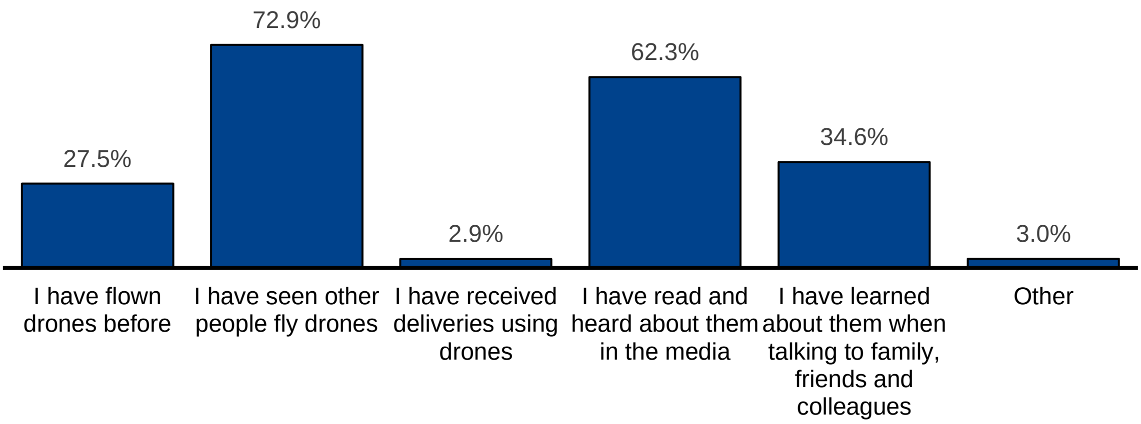


Figure C.3: Ways of becoming familiar with drone technology

Male respondents have used drones more than female respondents have (66% v. 34%). The majority belonged to the 25–34 years age category (36.6%) and 26.8% were from the 45–54 years age category. Furthermore, 58.5% were from the high-income category, and the industry sector in which most respondents were employed was the construction industry (24%), followed by mining (16%) and accommodation and food services (11%). Figure C.4 shows that among the 84% of respondents who indicated they have some familiarity with drones, 35.3% have used drones but mostly for recreation (74.7%). Less than 14% reported they have used drones for work purposes.

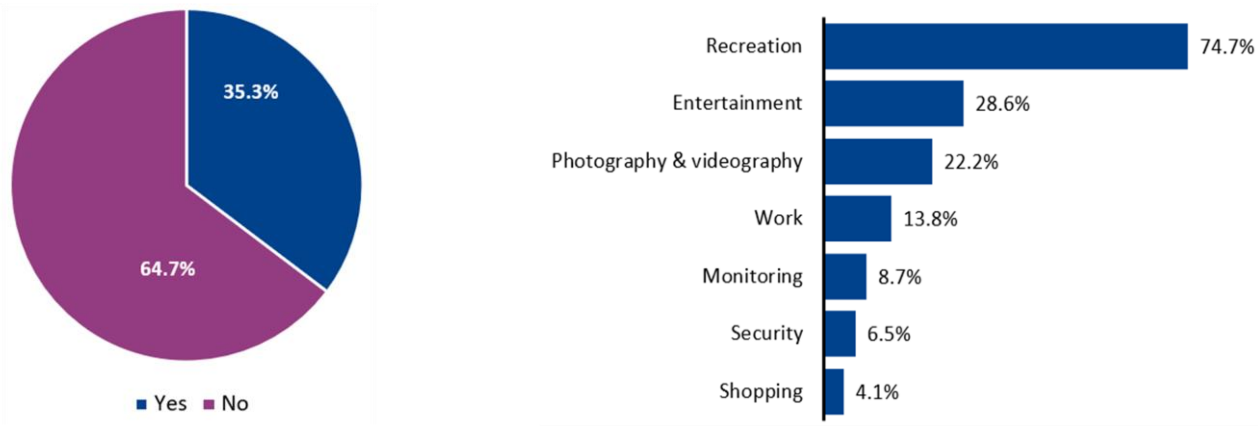


Figure C.4: Respondents' user experience with drone technology and its purpose

Only 4% of the 836 respondents have used a drone more than five times a week and nearly 60% have used drones less than once a week (Figure C.5, left graph). The majority were at the early stages of learning how to use drones, and only 5% indicated their level of proficiency in using drones as 'advanced' or 'expert' (Figure C.5, right graph). Last, 18.5% of the total sample indicated that they currently own a drone.

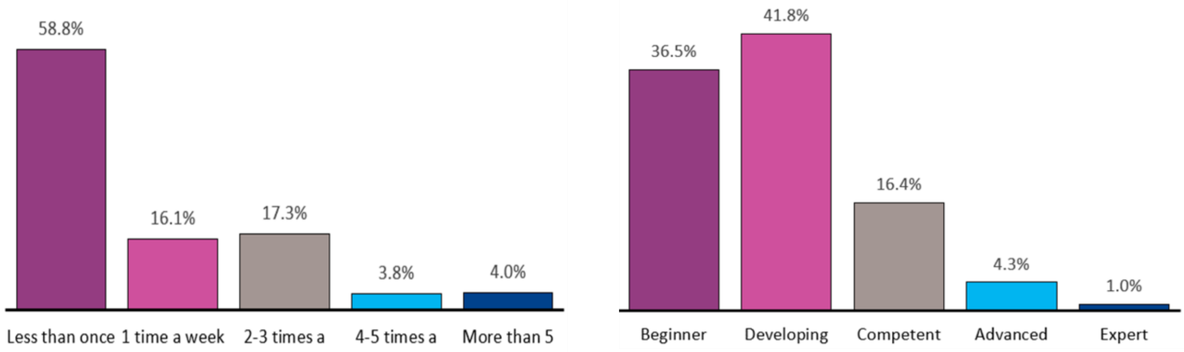


Figure C.5: Frequency of use and level of proficiency in using drones

In order to comprehend respondents' awareness in detail, they were asked to indicate the industries in Australia that currently use drones. Figure C.6 shows that they are well aware of drone use in different sectors, such as agriculture, mining, transport and construction, in Australia. Only 13.4% indicated they are unaware about the industries that currently use drone technology.

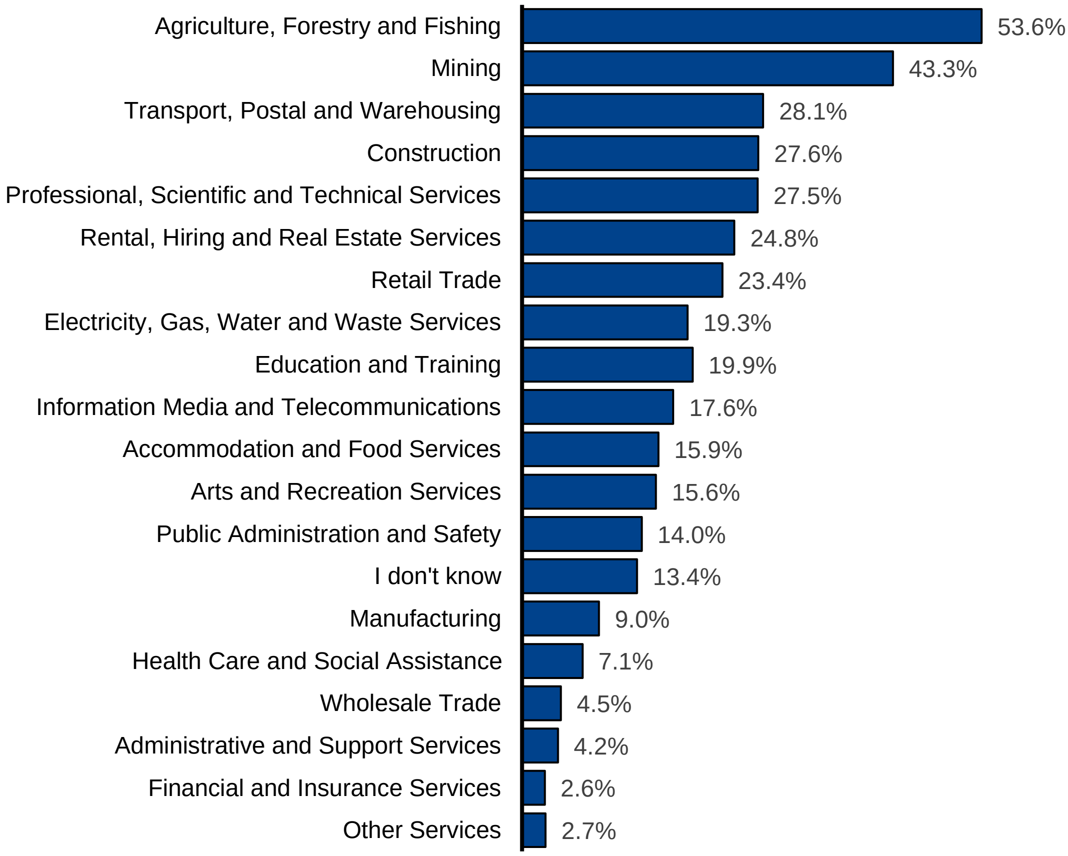
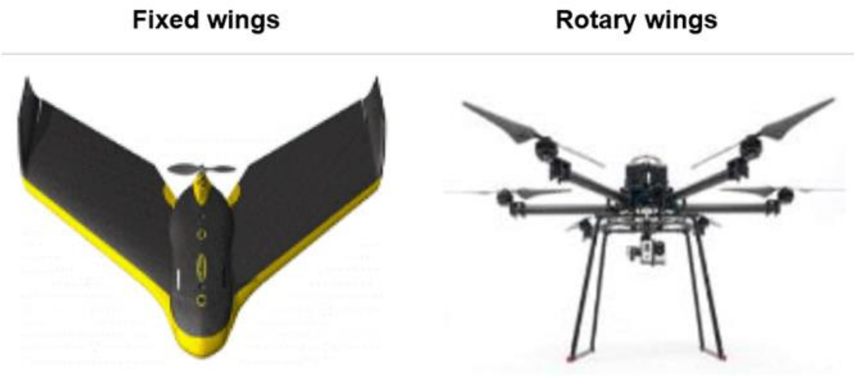


Figure C.6: Respondents' knowledge of industries in Australia that are currently using drones

C.3.2 Small-scale uncrewed aerial vehicle

In this section of the survey, to ensure all respondents are familiar with what a UAV is, the following description and image were provided at the beginning of this section.

> An uncrewed aerial vehicle (UAV), commonly known as a drone, is an aircraft without any human pilot or crew on board. Drones can vary in size. Small-sized drones measuring 0.15–1.20 metres in wingspan or footprint are already commercially available, and are increasingly being used for photography, remote sensing, surveillance and other related activities. Below are examples of rotary wing and fixed-wing small-sized drones:



Then, the respondents were informed that the term ‘drone’ would be used, instead of ‘UAV’, in the remainder of the survey. They were asked whether they are interested in purchasing a small-sized drone, such as the examples in the image shown to them, and if so, the purpose for which they would use it. The chart on the left in Figure C.7 shows that almost one in three Australians (33.5%) were not at all interested in purchasing a drone.

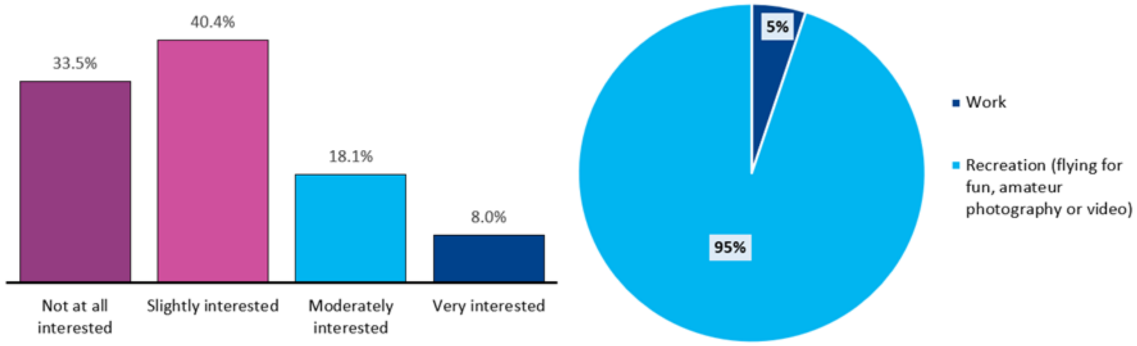


Figure C.7: Level of interest in purchasing a UAV and potential purpose of use

Table C.2 indicates that the respondents not at all interested in purchasing a drone are more likely older female adults with a high income. In contrast, 26.1% mentioned that they are moderately or very interested in purchasing a drone. These respondents are also high-income earners but male adults in their 30s and 40s. Interestingly, 95% of these respondents reported that they will purchase a drone for recreation purposes. Only 5% mentioned they will use it for work, and the examples specified were to use it in the agriculture industry, to deliver food, to take photos, for real estate, for construction site inspections, to teach students more about drones and to be used for their YouTube videos.

Table C.2: Level of interest in purchasing a drone by population segment

		How Interested Are You in Purchasing a Small-sized Drone?				Total (%)
		Not at all interested (%)	Slightly interested (%)	Moderately interested (%)	Very interested (%)	
Gender	Male	15.0	20.0	11.3	4.7	51.0
	Female	18.6	20.4	6.8	3.2	49.0
	Total	33.5	40.5	18.1	7.9	100.0
Age category	18–24	2.1	4.1	2.0	1.0	9.1
	25–34	4.7	5.7	3.3	1.8	15.5
	35–44	3.2	7.0	3.3	3.0	16.5
	45–54	4.8	8.4	3.2	0.7	17.1
	55–64	6.2	5.8	3.4	1.0	16.4
	65 +	12.6	9.6	2.8	0.4	25.4
	Total	33.5	40.5	18.1	7.9	100.0
Income category (A$ per year)	Low income (up to 52,000)	9.9	10.0	6.0	2.2	28.1
	Mid-income (52,000–104,000)	7.5	13.8	4.6	3.0	28.9
	High income (more than 104,000)	16.2	16.6	7.4	2.8	43.0
	Total	33.5	40.4	18.0	8.0	100.0

C.3.2.1 Appeal of different drone use cases

Following a thorough literature review, 41 different drone use cases were selected from eight different sectors, as shown in Table C.3. The best/worst scaling method was used to ascertain respondents' opinions on which use case is:

- valued the most for their community;
- valued the most for society at large; and
- more acceptable to the respondents if, and when, it is deployed in practice.

The best/worst scaling method is used to understand how multiple items in a list (e.g. different drone use cases) are ranked by a target population (e.g. the general Australian public) in terms of specific features (e.g. value to community). Similar rankings can be obtained through other methods as well, such as questions that ask respondents to rate each use case on a fixed Likert scale. However, category rating scales do not force respondents to compare different items with each other, and they offer less information than the best/worst scaling method. For example, if one person rates most items as '7' on a scale of 1–10, one does not know the relative ordering between these items. In comparison, best/worst scales provide a more robust, accurate ranking of individuals' relative preferences for different items by forcing them to compare different items. For a detailed technical description of the best/worst scaling method, see Appendix C-3.

An experimental design was used to systematically randomise the presentation of different subsets of use cases across different best/worst tasks. The task was repeated five times for each respondent. An example task is presented in Figure C.8. Data from the tasks were used in conjunction with other demographic information collected as part of the survey to estimate a logit model. Logit models are commonly used to model outcomes to categorical variables, such as the most or least preferred item from a list of items (in contrast to linear regression models, which are commonly used to model outcomes to continuous variables). Here, we summarise the key findings from our analysis.

We first estimated a logit model for each of the three aforementioned ranking questions. Figure C.9 presents the order of the most important drone use case for society and for the community and of those the respondents were most willingly to accept for commercial use, normalised on a scale of 0–100. As the figure shows, the use of drones in the emergency services and disaster recovery sector was ranked as the top three most valued use cases. The respondents ranked 'search and rescue' as the most valued use case for society at large, 'emergency response coordination' as the most valued use case for their community and 'emergency delivery' as the most acceptable use case to be deployed in practice. 'Advertising and Marketing' in the media and communications sector was ranked the least valued drone use case followed by marketing in urban planning, real estate architecture and engineering sector, in all three ranking decisions.

Table C.3: List of drone use cases

Sectors	Use Case Example
Emergency services & disaster recovery	1. Emergency delivery (medicine, equipment, supplies): Drones could deliver medical supplies including cold chain vaccines and blood to meet emergency medical situations much faster than by road. This would be essential in regional areas where medical facilities can be hours away by road, but also in the city and its suburbs particularly through peak hour traffic. 2. Emergency response coordination (situational awareness): Drones could be sent to an emergency like a fire, accident or drowning, much faster and not only provide visuals but also assess the situation using various sensors and even provide assistance, such as delivering defibrillators and life vests. 3. Disaster Management—prevention monitoring: Drones with multiple sensors could be used to monitor fire prone areas and flood situations more routinely and tirelessly than conventionally done. 4. Disaster Management—relief operations and post-disaster assessment: drones could be used to rescue people trapped by floodwaters with life rafts, water food supplies and rescue people trapped by bushfires. 5. Search and rescue: drones could be used to search and rescue people lost in dense bushland.
Security services	6. Crime scene investigation: drones could be used by the police to quickly map and assess crime scenes, including searching for evidence using multispectral and even ground penetrating sensors. 7. Criminal surveillance and tracking: drones could be used for aerial surveillance and tracking of criminal activities. 8. Police response coordination: drones can speed up road traffic accident reconstruction for the evidence-gathering process – taking less than 30 minutes for a job that usually takes three or four hours. This means that roads can be reopened faster and cuts down on officer on-scene times. 9. Security surveillance: drones could be deployed in large facilities to provide scheduled patrols day and night, in rain and snow. In protecting secure facilities, drones can automatically respond to alerts, be airborne

	in 30 seconds, transmit live video feeds, land, recharge, communicate and report maintenance needs – all by itself. 10. Crowd control and events management: drones could be deployed to scout key areas or suspects and obtain situational awareness, which would help with deployment tactics, particularly in monitoring crowd behaviour and movement. Drones could help investigate suspects who could be armed – while maintaining a safe distance.
Agriculture, aquaculture, silviculture and viticulture	11. Livestock monitoring and herding: drones can be very useful in real time continuous livestock monitoring (looking out for ailing ones, etc.) which is critically important to prevent devastating diseases. Drones are already complementing dogs in herding roles. 12. Pasture monitoring: drones can monitor pastures in terms of maintenance, production and viability for maintaining herds and flocks of livestock, identify heavily grazed areas and thickets of thistles which may cause harm to animals and move the flock should this be required. 13. Drones to prevent rustling: drones can deter rustlers by spotting thefts in progress, capturing images of culprits and their vehicles and accessories. 14. Water and asset management: drones can assess watering spots and monitor potential drought conditions. 15. Aerial surveying and planning: with drone photogrammetry, drones can help farmers and agronomists create highly accurate maps and 3D models of the area, wide open areas and tight spaces alike to make better plans. 16. Pest and disease detection and treatment: fitted with different types of cameras and sensors drones can provide farmers invaluable data to take timely action on issues such as pests or other unwanted visitors, crop yield, weather, and other agricultural contingencies for healthier produce efficiently. 17. Crop and yield management: drones can allow farmers to better plan their seed planting patterns as well as the harvesting, conduct soil analysis, and stay up to date with how their plants are growing. 18. Stock management: drones can efficiently monitor and keep stock of inventory of all kinds of agricultural produce.
Environmental management	19. Environmental hazard assessment: Drones can be easily deployed to access hard-to-reach areas for acquiring data during emergencies that is unsafe or impossible for people to carry out. They also provide first responders during emergency cases with opportunities to save time, money and, most importantly, lives. 20. Environmental impact assessment and compliance: drones can now capture relevant updated imagery and data over wide or specific areas of terrain with accurate repeatability, and where necessary fly very low to capture detailed and accurate data. Drones can help with supervision and compliance with environment protection regulations. 21. Invasive species and pest control: Drones can radio-track multiple invasive animals simultaneously and track their movements across difficult landscapes where invasive species thrive, such as vast wetlands and rugged mountain ranges. Drones can be used in novel ways for pest control beyond the application of pesticides such as using bio controls (e.g., natural enemies of pests). 22. Scientific research: equipped with necessary instruments, aerial drones provide a new means to conduct scientific research of all kinds; from prolonged observations from very high altitudes to close observations of extreme conditions such as volcanic activity, from close and intimate transformative experiments such as pollination of plants in remote areas to less invasive tracking and capturing invaluable images and data of elusive animals and their behaviour.

	23. Wildlife and habitat monitoring and protection: Drones can collect real time data on flora and fauna to protect and preserve wildlife and their habitat. Drones can provide timely and cost-effective interventions, particularly in law enforcement against poaching, illegal logging, etc.
Urban planning, real estate architecture & engineering	24. Construction and management: Drones can be used on site in civil engineering projects such as construction of buildings and infrastructure projects like dams & bridges. Drones facilitate better planning, analysing, designing and supervision by engineers, architects, surveyors etc. with accurate and up-to-date data. 25. Environmental design (architecture, engineering, landscape architecture, urban design): modern drones equipped with sophisticated cameras and sensors have the aerial dexterity that can give urban designers and architects imagery in nearly infinite number of angles, scales and elevations, in real time, that has been previously elusive. 26. Mapping (archaeology, resource, topography, …): drones can be used to produce highly accurate orthomosaics to 3D models to traditional contour and terrains maps faster 27. Marketing: drones can produce highly impressive imagery of projects that can be key to successful marketing of the projects.
Media & communications	28. Advertising and marketing: drones with sophisticated cameras used for movies can also produce impressive imagery to put a gloss on advertising and marketing collateral. 29. Entertainment (film, television, internet, …): drones can continue to provide increasingly sophisticated images from hitherto impossible angles and positions for television and movie productions. 30. Investigative journalism: drones can be an effective tool in showing sites of events and the scope or scale. 31. News photography and videography: drone journalism can enhance the overall quality of news by being faster on the scene and providing real-time images while improving the safety of journalists and cameramen who often have to put themselves in harm's way for a better view.
Business & commerce	32. Documentation (accident reporting, building verification, site status, …): drones can assist with expeditious documentation of various reports such as building inspection, site inspections, crash scene inspections, etc. 33. Exploration (water, oil, gas, mineral, …): drones equipped with highly sophisticated instruments can be used for exploration of resources like oil, gas minerals and even for life forms. 34. Inspection (infrastructure, structural industrial, …): using increasingly complex suite of sensors and telemetry, drones are used in many types inspection works such as on ships, bridges, buildings and other infrastructure, in a safe, consistent and reliable way. 35. Pick-up and delivery services: drone based delivery companies like Wing which already have active operations in Australia can deliver your orders of food, grocery or medicines faster and possibly for less than standard deliveries. 36. Passenger transport: drones to ferry passengers or flying taxis could soon be an attractive alternative available for intraurban and regional travel for up to 4 passengers with companies like Wisk.
Recreation & entertainment	37. Group activities and events: professional and recreational drones are being used increasingly for capturing and live streaming events like weddings, birthdays, parades and carnivals. 38. Hobby (do it yourself and kit building): modern drones owe much to hobbyists who contributed to its growth, and the hobby drones sector is reaping rewards with more models with greater range and sophistication.

	39. Personal photography and videography: for private photography and videography, mini drones can be used to take amazing images from otherwise inaccessible positions and angles. 40. Remote control flying: remote controlled aircrafts or planes have been growing as a hobby and in recent times multi-rotor drones have also gained traction. 41. Drones swarm light display: drones can complement traditional fireworks used for major events like New Year celebrations, with spectacular light displays with increasing sophistication and artistry and, more importantly, in a safer and reusable way.

In order to identify segments in the population that differ in terms of their most valued use case ranking in this study, we estimated a latent class choice model (LCCM). LCCMs are choice models that can help identify distinct segments in the population that differ systematically in terms of their preferences, and they help explain how these differences correlate with demographic and geographic characteristics. Please see Appendix C-4 for a detailed technical description about the model. Since a similar ranking of use cases was observed between the three ranking decisions for this section, we only considered respondents' ranking for the most valued use case for their community. Using behavioural interpretation and statistical measures of fit, namely, the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) as listed in Table C.4, a two-class (or two-segment) model was selected as the preferred model specification.

Table C.4: Summary statistics for LCCMs with varying numbers of classes

Classes	Number of Parameters	Model Loglikelihood	R-squared	Adjusted R-squared	AIC	BIC
One Class	41	-12,945	0.136	0.133	25,972	26,173
Two Class	**100**	**-12,278**	**0.180**	**0.174**	**24,757**	**25,248**
Three Class	159	-12,171	0.187	0.177	24,660	25,441

Figure C.10 shows the ranking scores for each segment. Figure C.11 summarises the two-class segmentation results for the different sectors and shows the average ranking score for the use cases presented in that sector. In both classes, emergency response coordination was ranked as the most valued drone use case for the community, and in general value, use cases related to emergency services & disaster recovery were ranked the highest. On average, Class 1 ranked use cases related to the 'environmental management sector' as the second most valued sector, 'security services' as the third most valued sector and the 'media and communication' sector as the least valued sector. In contrast, Class 2 ranked 'security services' as the second most valued sector, 'environmental management sector' as the third most valued sector and the 'recreation and entertainment' sector as the least valued sector. Overall, 41% of the sample are more likely to belong to Class 1 and 58% are likely to belong to Class 2. Those in Class 1 are most likely educated male adults with an average age of 40 years and income of A$79,000 per year. These respondents have most likely either flown a drone in the past or have received a delivery using drones. They have been reported to be more frequent users of drones and have a higher level of proficiency in using drones. They are most likely interested in purchasing a small-scale drone. Relative to the respondents in Class 2, they are more supportive of the use of small-scale drones for commercial applications and are less concerned about the potential impact of small-scale drone technologies. In contrast, the Class 2 respondents constitute 58% of the sample and are more likely to be higher-income-earning females belonging to couple households with no kids and an average age of 50 years. Compared with those in Class 1, respondents belonging to this class have read and heard about drones in the media more often and have learned about them when talking with their family and friends. Table C.5 provides a high-level summary of the two segments.

Table C.5: High-level summary of segments, or classes

	Class 1	Class 2
Sample share	41%	58%
Use case preferences	Higher preferences for business & commerce; urban planning, real estate, architecture & engineering; recreation & entertainment; and media & communications sectors.	Higher preferences for emergency & security services as well as drone use in environmental management, and in agriculture, aquaculture, silviculture and viticulture sector.
Demographic characteristics	Male, young (40), educated, average income A$79,000	Female, older (50), couple family with no children, average income A$93,000
Attitudes	**Level of familiarity:** Have flown drones before Have received deliveries using drones **Drone ownership and use:** More frequent user Higher level of proficiency in using drones More likely willing to purchasing a small-sized drone **Support and acceptance:** Overall, more supportive of use of small-scale drones for commercial applications, and less concerned about the potential impact of small-scale drone technologies	**Level of familiarity:** Have read and heard about drones in the media more Have learned about them when talking to family

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Set 1 of 5

Please select among the five listed potential use cases for drone technologies, the use case you are **most** and **least** likely to ***support***.

I am **most** likely to support this use case	Offers **most** value to society at large	Offers **most** value to me and my community	**Use cases**	Offers **least** value to me and my community	Offers **least** value to society at large	I am **least** likely to support this use case
○	●	●	**Pick-up & delivery services:** Drone based delivery companies like wing which already have active operations in Australia can deliver your orders of food, grocery or medicines faster and possibly for less than standard deliveries.			●
●			**Disaster Management - prevention monitoring:** Drones with multiple sensors could be used to monitor fire prone areas and flood situations more routinely and tirelessly than conventionally done.		●	○
○			**Livestock monitoring and herding:** Drones can be very useful in real time continuous livestock monitoring (looking out for ailing ones etc.) which is critically important to prevent devastating diseases. Drones are already complementing dogs in herding roles.	●		○
○			**Security surveillance:** Drones could be deployed in large facilities to provide scheduled patrols day and night, in rain and snow. In protecting secure facilities, drones can automatically respond to alerts, be airborne in 30 seconds, transmit live video feeds, land, recharge, communicate and report maintenance needs – all by itself.			○
○			**Investigative journalism:** Drones can be an effective tool in showing sites of events and the scope or scale.			○

Figure C.8: Example of drone use case best/worst ranking task

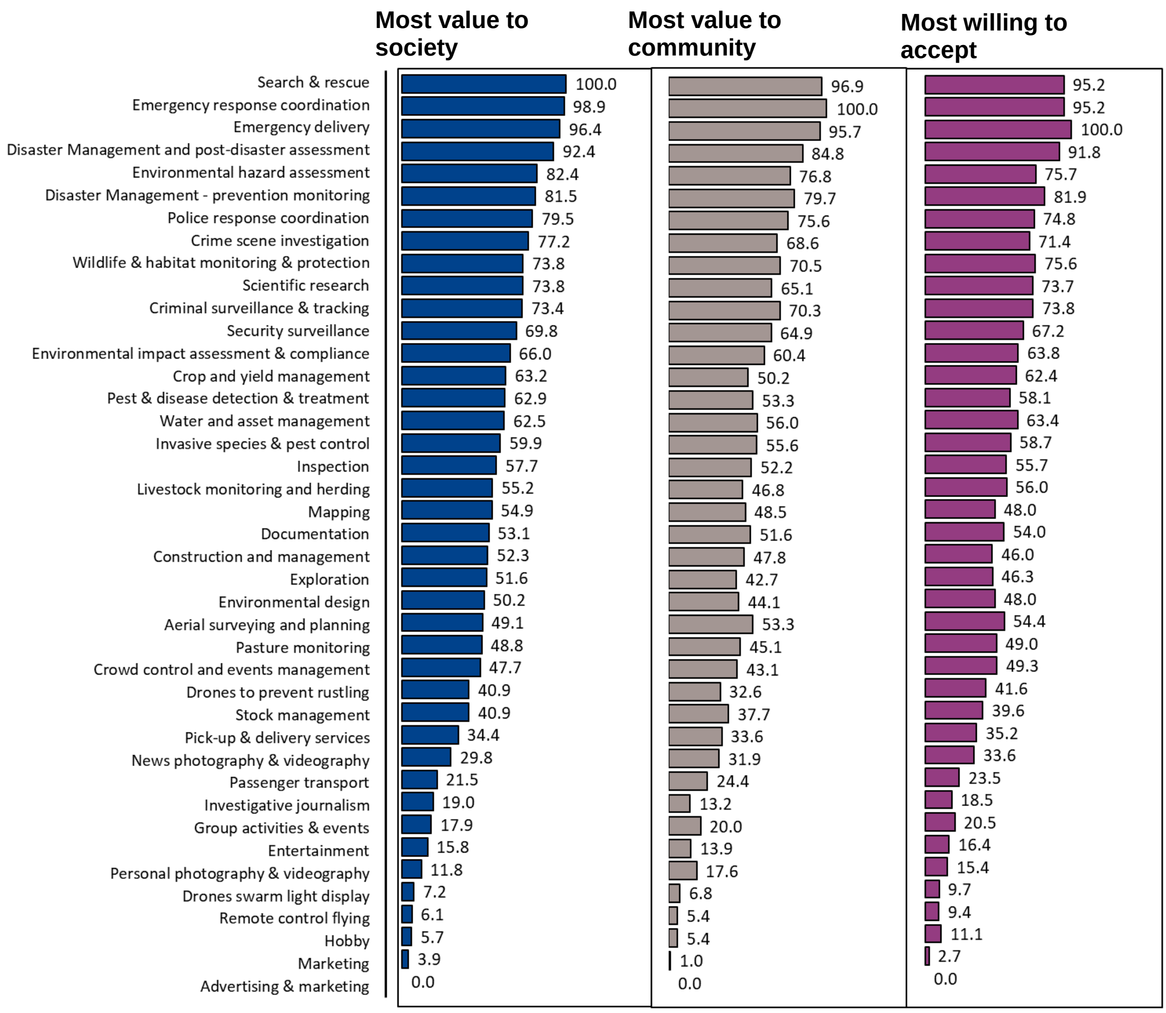


Figure C.9: Order of importance of different drone use cases

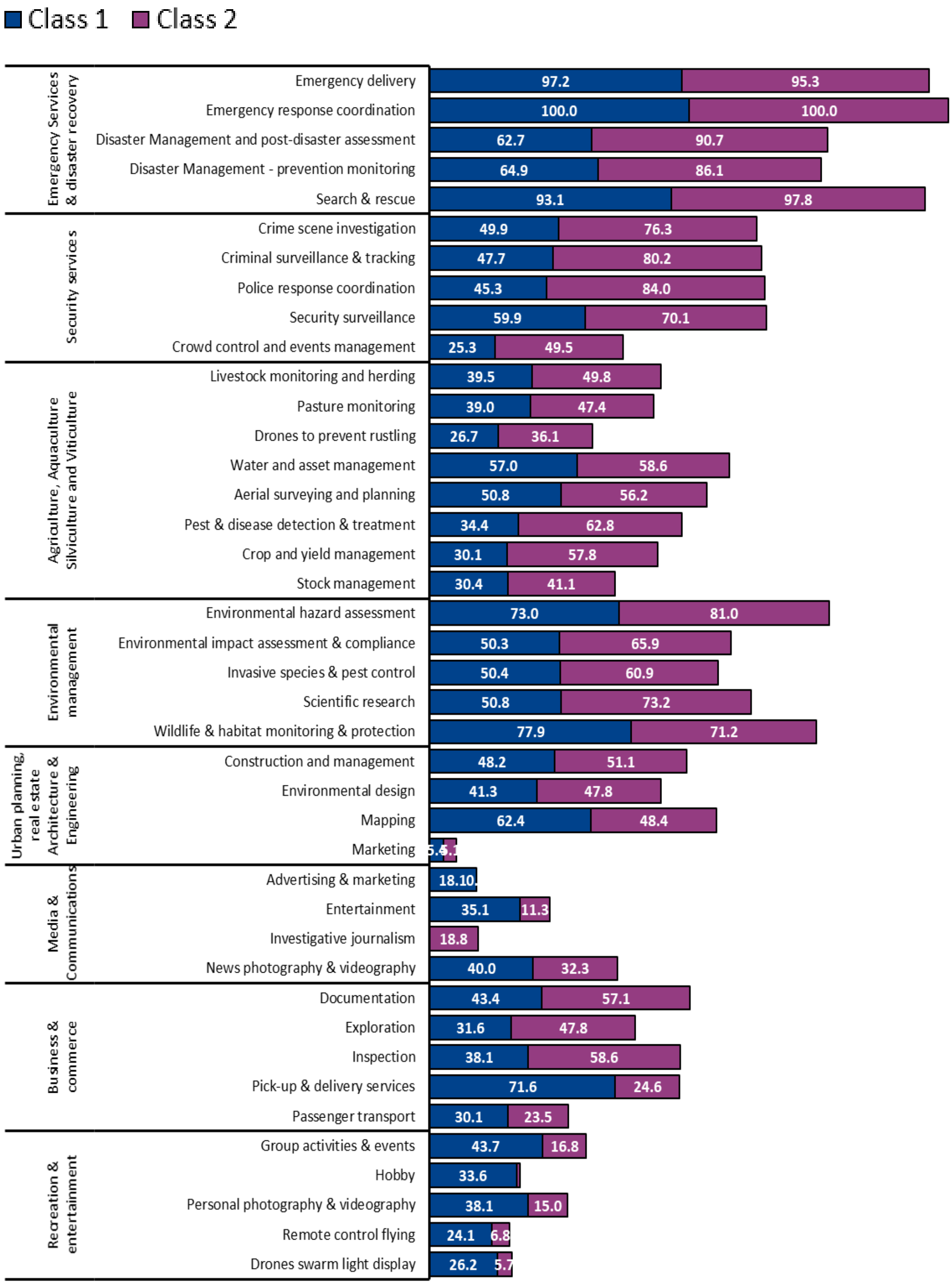


Figure C.10: Two-class segmentation results for most valued drone use case in the community

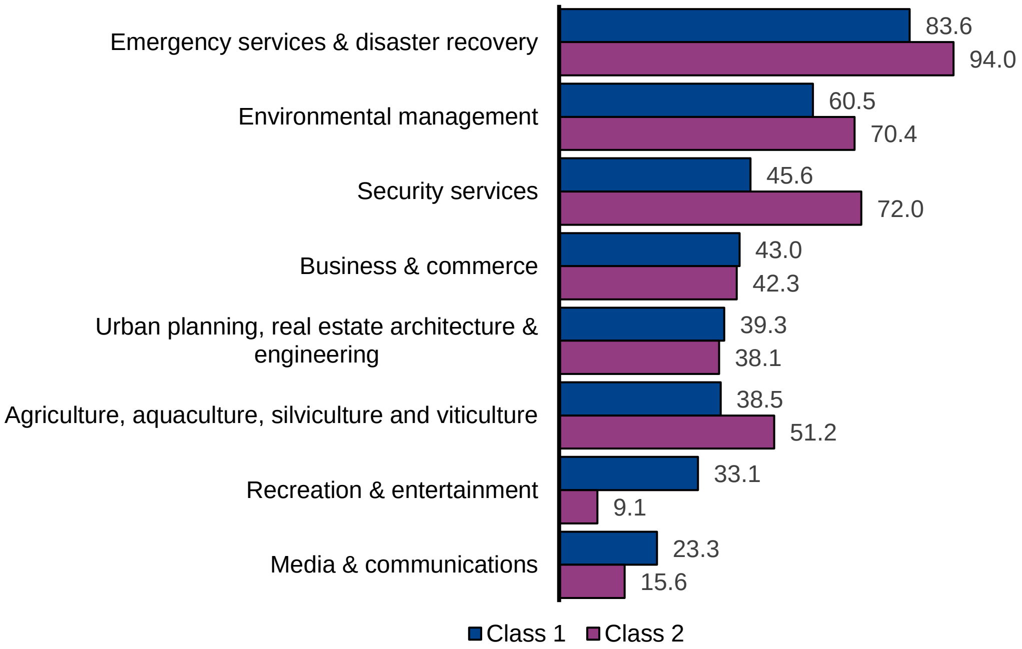


Figure C.11: Summarising two-class segmentation results for most valued drone use case in the community by sector

C.3.2.2 Preference for drone delivery services

In this section, we reveal insights into Australian preferences towards the delivery of small items, such as groceries, medicines and food, via drones. These drone-based services could be expanded to provide an alternative to existing postal, mail and other delivery services. Respondents were required to indicate their level of interest in drone delivery services. Figure C.12 presents that just over half or 50% of them have some level of desire to use drones for delivery and 25.9% have no desire to use this service. Table C.6shows the level of interest in drone delivery services of different segments of the population. Although no significant gender-based differences were found, younger adults earning more income show greater interest in using drones for delivery services.

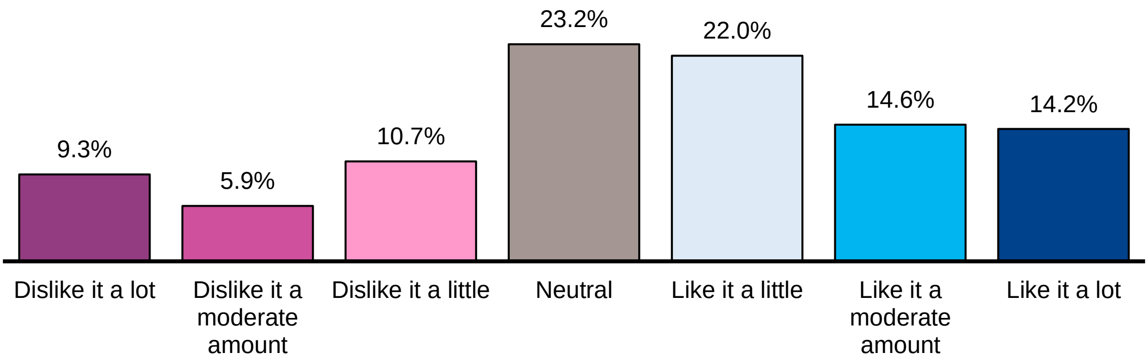


Figure C.12: Level of interest in drone delivery services

Table C 6: Level of interest towards drone delivery services by different segments of the population

		How Much Do You Like or Dislike the Idea of Drone Delivery Services?							**Total (%)**
		Dislike it a lot (%)	Dislike it a moderate amount (%)	Dislike it a little (%)	Neutral (%)	Like it a little (%)	Like it a moderate amount (%)	Like it a lot (%)	
Gender	Male	4.7	3.2	6.0	12.7	11.7	7.7	7.5	53.6
	Female	4.6	2.7	4.6	10.6	10.5	6.8	6.6	46.4
	Total	9.3	5.9	10.7	23.2	22.1	14.6	14.2	100.0
Age category	18–24	0.4	0.5	0.5	2.2	2.8	1.6	1.6	9.7
	25–34	1.1	0.4	0.8	4.0	5.4	3.2	3.5	18.5
	35–44	0.4	1.1	1.5	4.1	4.8	3.5	2.3	17.8
	45–54	1.3	1.5	2.8	2.3	4.4	2.0	2.2	16.6
	55–64	1.6	1.5	1.4	4.3	2.6	1.6	1.8	14.9
	65 +	4.4	0.9	3.7	6.1	1.9	2.6	2.8	22.5
	Total	9.3	5.9	10.8	23.1	22.0	14.6	14.3	100.0
Income category	Low income (up to A$52,000 per year)	2.8	1.2	2.7	7.1	5.6	3.0	3.4	**26.0**
	Mid-income (A$52,000–104,000 per year)	1.8	2.0	2.2	6.7	6.9	5.4	3.4	**28.6**
	High income (more than A$104,000 per year)	4.7	2.7	5.7	9.4	9.5	6.1	7.3	**45.5**
	Total	9.4	5.9	10.7	23.2	22.0	14.6	14.2	100.0

Although the responses to the previous question show that these Australian respondents are somewhat interested in drone delivery services in general, Figure C.13 shows that they are somewhat split in whether they will use this service themselves, with 51.6% mentioning 'likely' and 48.3% mentioning 'unlikely'.

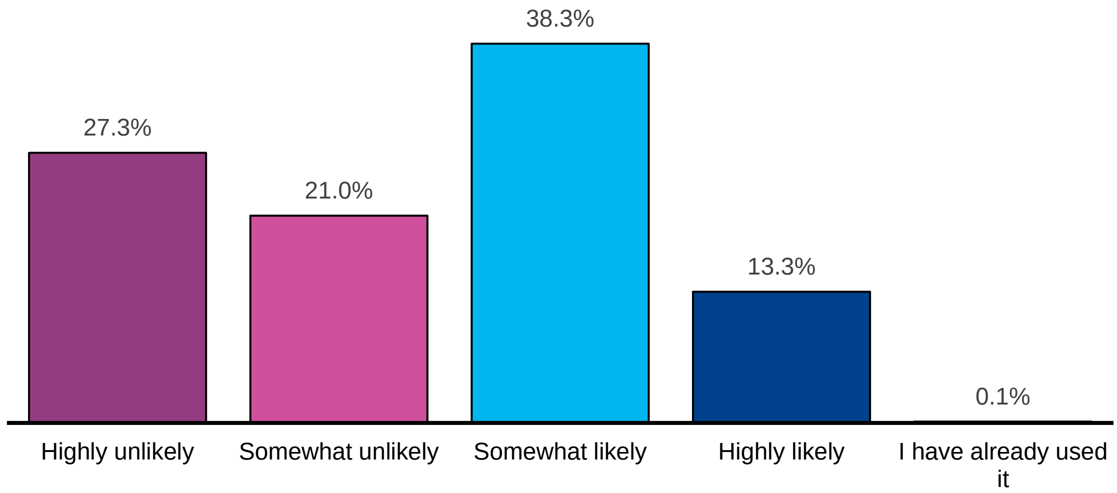


Figure C.13: Level of interest in using drone delivery services

Of the 51.6% that reported they are likely to use drones for themselves, over half of the sample indicated they will use the service once a fortnight or more frequently (see Figure C.14). For example, 7.4% mentioned they will use it more than once a week and 23% reported they will use it at least once a week. Almost one in three said they are more likely to use the service once a month when it becomes available.

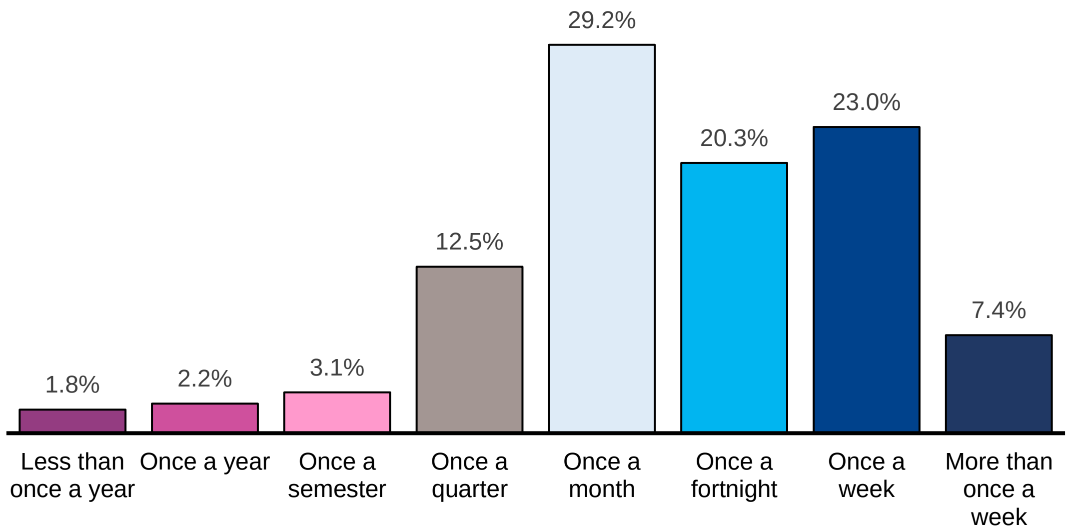


Figure C.14: Likely frequency of drone delivery service use if it becomes available

In order to examine Australians' preferences towards drone delivery services as against the traditional ways of delivery, a DCE was designed and developed to understand more about the respondents' willingness to use a drone delivery service to receive different items. The delivery items used in this experiment were letters, food, medicine and other goods. Subsequently, the respondents were presented with scenarios, such as the example shown in Figure C.15, in which a delivery item is specified and the respondents are asked to select from the delivery options given. In all scenarios, respondents were shown a delivery option using drones as well as the traditional delivery option (e.g. Australian Post). Each option was provided with specific delivery details, such as delivery time, tracking option, service reliability, the chance of damage and delivery cost, and the respondent had to select the most preferred delivery option for the given item. Each respondent was presented with eight different scenarios. The attributes of the alternatives were varied systematically across scenarios, according to the potential range of values listed in Table C.8, using a statistically robust experiment design.

Data from the hypothetical scenarios were used in conjunction with other demographic information collected as part of the survey to estimate LCCMs of consumer preferences regarding the use of drone delivery services. We describe the general LCCM framework in Appendix C-4 (Latent Class Choice Models). As mentioned previously, LCCMs are especially useful to identify segments in the population that differ in terms of their preferences, and to explain these differences in terms of underlying demographic and geographic characteristics. Here, we summarise the key findings from our analysis. Note that the model presented in this section was estimated independently of previous models. Consequently, the classes identified here differ from the classes identified previously.

Numerous models and sub-models were estimated. The utility specification and the number of classes were varied in determining the final model. Using behavioural interpretation and statistical measures of fit, namely the BIC and the AIC as listed in Table C.7, a four-class model was selected as the preferred model, which shows four distinct segments, or classes, in our sample population that differ in terms of their preferences for drone delivery services and their demographic characteristics. The classes have been ordered in terms of increasing enthusiasm for drone delivery services. These descriptions are summarised in Table C.9. Over the following paragraphs, we discuss some of the key findings.

First, we find that roughly 67.5% of the population (Classes 1, 2 and 3) prefer traditional delivery over drone delivery. Class 1 has the strongest adverse opinion against drone delivery services. Ceteris paribus, drone delivery services need to be on average A$25 dollar cheaper for respondents in Class 1 to use drone delivery services. For Class 2, this value drops to $4.5. Class 3 are indifferent towards different delivery methods.

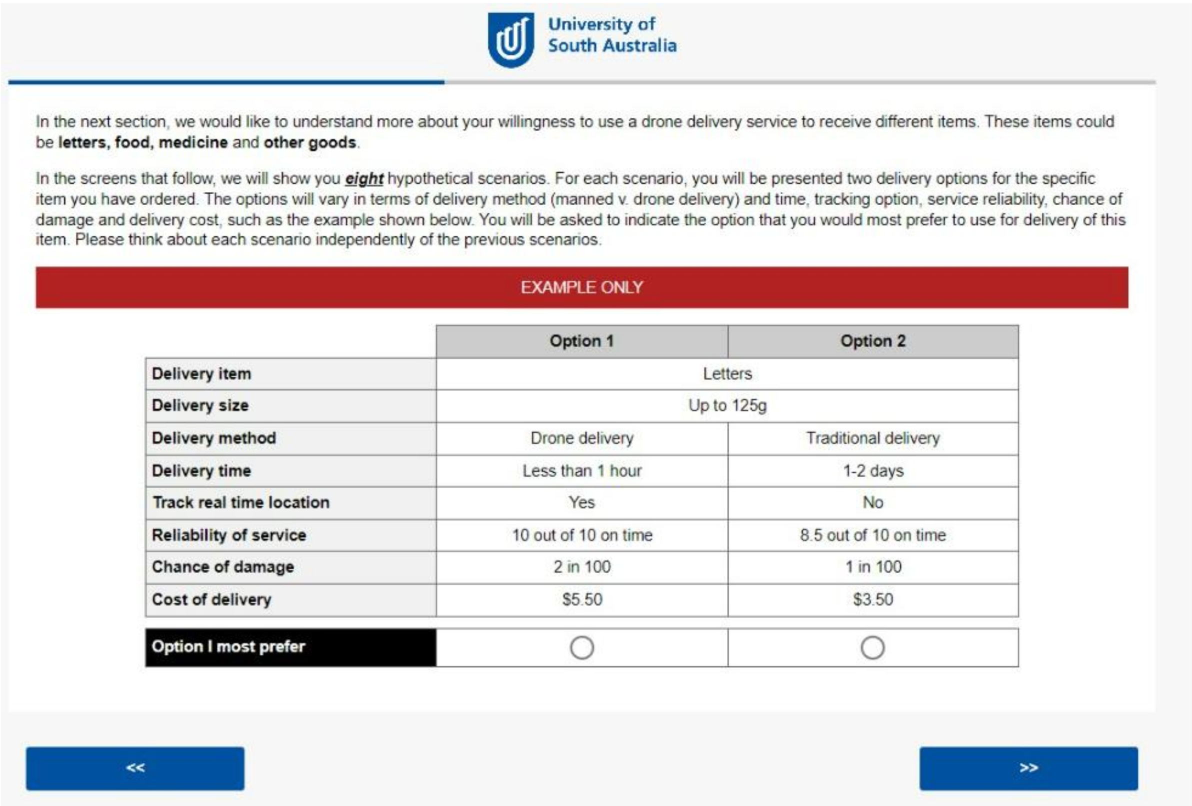
Second, we find that 63.5% of the population who are more enthusiastic about drone delivery are less likely to use this service to receive takeaway food delivery. Furthermore, respondents from Class 2 (26.2%) have a higher preference for receiving other goods using drone delivery. Third, one in three prefer receiving lighter items using drone delivery and the majority are indifferent towards the delivery size range specified for each item (see Table C.8 for delivery size range).

Fourth, they are willing to pay the most to receive their takeaway food delivery quicker compared with other items explored in this task. The willingness to pay (WTP) ranges from A$10.4 per hour for Class 4 to A$3.3 for Class 3. Class 2 respondents are willing to pay A$4.2 per hour to receive medicine deliveries faster. Respondents' WTP to receive letters and other goods faster ranges from 25 cents per day to A$1.2. Fifth, 26.2% prefer the option to be able to track the delivery in real time. However, almost nine out of 10 prefer a delivery service that is more reliable. Two out of three show strong sensitivity to any possibility of the delivery item being damaged on the way.

Respondents in Classes 1 and 2 are more likely to be female with the difference that Class 1 respondents are older and earn a lower income than Class 2 respondents. Respondents belonging to Classes 3 and 4 are more likely to be male with the difference that Class 3 respondents are slightly older and have a higher income than Class 4 respondents.

Table C.7: Summary statistics for LCCMs with varying numbers of classes

No. of Classes	AIC	BIC
Two	8355.951	8473.737
Three	8023.131	8229.257
Four	**7908.707**	**8163.91**
Five	7812.828	8180.91
Six	7752.085	8218.322



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In the next section, we would like to understand more about your willingness to use a drone delivery service to receive different items. These items could be **letters, food, medicine** and **other goods**.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented two delivery options for the specific item you have ordered. The options will vary in terms of delivery method (manned v. drone delivery) and time, tracking option, service reliability, chance of damage and delivery cost, such as the example shown below. You will be asked to indicate the option that you would most prefer to use for delivery of this item. Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

	Option 1	Option 2
Delivery item	Letters	
Delivery size	Up to 125g	
Delivery method	Drone delivery	Traditional delivery
Delivery time	Less than 1 hour	1-2 days
Track real time location	Yes	No
Reliability of service	10 out of 10 on time	8.5 out of 10 on time
Chance of damage	2 in 100	1 in 100
Cost of delivery	$5.50	$3.50
Option I most prefer	○	○

<< >>

Figure C.15: Example stated preference scenario to elicit consumer preferences for drone delivery service

Table C.8: Attributes and the values they can take across different stated preference scenarios

Attributes	**Level**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Delivery item	Letters	Other Goods	Food (takeaway)	Medicine				
Delivery method	In-person	Drone						
Delivery size								
Letters	Up to 125 gm	Over 125 gm to 250 gm	Over 250 gm to 500 gm	Over 500 gm to1 kg				
Food/Medicine/Goods	Less than 1 kg	1–2 kg	2–5 kg	5–10 kg				
Delivery time								
Letters/Goods	60 minutes or less	Same day	1–2 business days (BDs)	3–5 BDs	6–8 BDs	10–14 BDs		
Food/Medicine (minutes)	10	20	30	60	90	120		
Track real-time location	Yes	No						
Reliability of service	7.5/10 on time	8/10 on time	8.5/ 10 on time	9/10 on time	9.5/10 on time	10/10 on time		
Chance of damage	1 in 100	2 in 100	5 in 100	10 in 100				
Cost of delivery (in-person; in A$)								
Letters	1.50	3.50	5.50	7.50	9.50	11.50	13.50	15.50
Food/Medicine	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00
Goods	2.50	5.00	10.00	15.00	20.00	25.00	30.00	35.00
Cost of delivery (drones) as a percentage of in-person delivery	40%	60%	80%	100%	120%	140%		

Table C.9: High-level summary of different market segments, or classes

	Drone Delivery Sceptics	**Class 2**	**Class 3**	**Drone Delivery Enthusiasts**
Sample share	**10.3%**	**26.2%**	**31%**	**32.5%**
Preference for delivery method	Preferred delivery using traditional method. Willing to use drone delivery service if it is on average A$25 cheaper.	Preferred delivery using traditional method. Willing to use drone delivery service if it is on average A$4.5 cheaper.	Indifferent between different delivery methods.	Preferred delivery with drone.
Preference for delivery items	Indifferent between different items	Higher preference for delivery of other goods using drones	Lower preference for food delivery using drones	
Preference for delivery size	Indifferent between delivery size when using drones			Prefer lighter items to be delivered with drones
Preference for delivery time (per hour: ph)	Indifferent between delivery time explored in this study	WTP A$5.5 ph for food WTP A$0.04 ph for letter WTP A$4.2 ph for medicine	WTP A$3.3 ph for food WTP A$0.01 ph for letter & other goods	WTP A$10.4 ph for food WTP A$0.05 ph for other goods
Preference for tracking real-time location	Indifferent towards tracking real-time location	Prefer the option of tracking real-time location	Indifferent towards tracking real-time location	
Preference for reliability of service	Indifferent towards reliability range explored in this study	Prefer services with higher reliability		
Preference for chance of damage	Indifferent towards the chance of damage explored in this study		Very sensitive to any increase in chance of damage	
Demographic characteristics	Female	Female	Male	Male
	Average age: 57 years	Average age: 44 years	Average age: 49 years	Average age: 43 years
	Household income: A$72,000	Household income: A$82,000	Household income: A$94,000	Household income: A$89,000
	Not in the labour force	Less likely to be couple family with children	More likely to be couple family with children	

C.3.2.3 Beliefs, attitudes and perceptions towards small-scale drone technology and services

In the concluding section of this component, respondents were presented with several Likert-scale questions to express their beliefs, attitudes and perceptions about small-scale drone technology and services. Figure C.16 presents their level of support towards the use of small-scale drones for commercial applications. Overall, almost 63% indicated they support the use of these drones for cases where such use offers value. Significantly, almost 80% reported that they support the use of drones for specialised use cases where these offer high value. Interestingly 8% strongly agree they do not want to see drones commercially deployed in practice at all. Table C.10 provides further information on the different segments of the population who responded to this question. No significant gender or income difference is seen in the response to not wanting to see drones to be commercially deployed in practice at all; however, Australians aged 55 years and above have a higher presence than the other age categories.

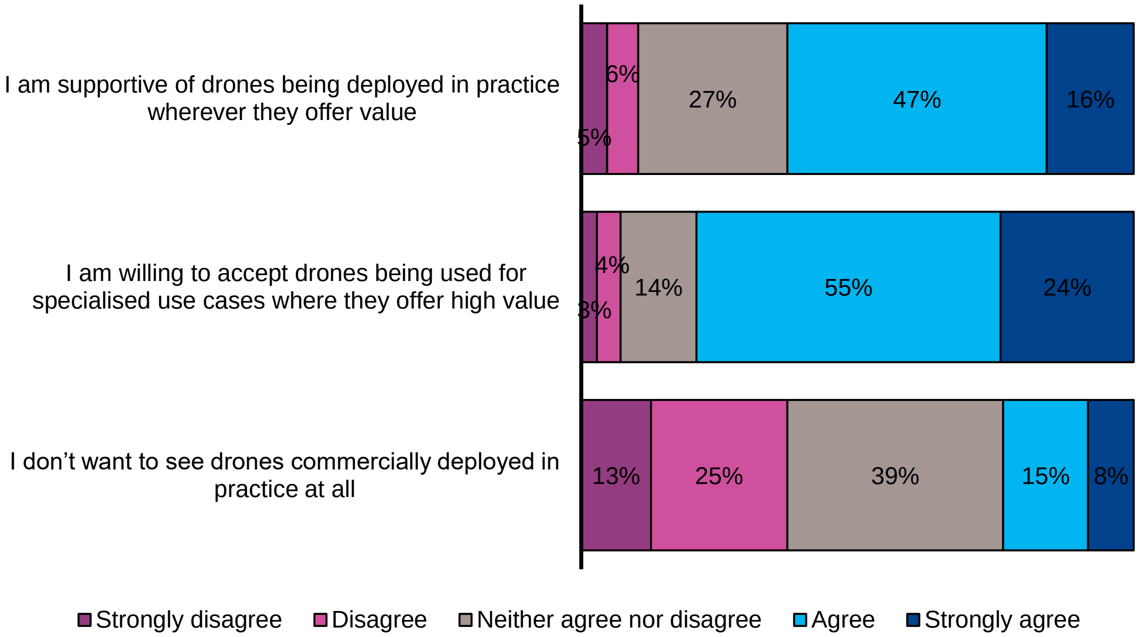


Figure C.16: Level of support towards small-scale drones being used for commercial applications

Table C.10: Lack of support for commercial deployment of drones in practice, by population segment

		I Don't Want to See Drones Commercially Deployed in Practice at All					
		Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)	Total (%)
Gender	Male	8.9	12.4	19.3	8.6	4.3	53.6
	Female	3.7	12.2	19.8	6.7	4.0	46.4
	Total	12.6	24.7	39.0	15.3	8.3	100.0
Age category	18–24	0.8	2.1	5.1	1.2	0.3	9.6
	25–34	2.0	4.7	7.0	3.4	1.3	18.5
	35–44	1.5	4.8	7.1	3.8	0.6	17.9
	45–54	2.2	4.3	5.7	3.1	1.2	16.6
	55–64	2.2	4.5	4.6	1.7	1.9	15.0
	65 +	3.9	4.1	9.4	2.1	2.9	22.4
	Total	12.7	24.6	39.0	15.4	8.2	100.0
Income category (A$ per year)	Low income (up to 52,000)	2.4	4.8	11.7	4.2	2.8	26.0
	Mid-income (52,000–104,000)	2.5	8.0	10.6	4.9	2.5	28.6
	High income (more than 104,000)	7.6	11.8	16.7	6.2	3.0	45.4
	Total	12.6	24.7	39.1	15.4	8.3	100.0

Overall, almost 13% expressed that they are extremely concerned about small-scale drones being used by the general public and 15.6% indicated they have no concern at all. Table C.11 shows that those aged 65 years and above form a significant proportion of extremely concerned people, whereas those aged 25–34 years belonging to the high-income category comprise the largest proportion of people who are not at all concerned about the likely use of small-scale drones by the general public.

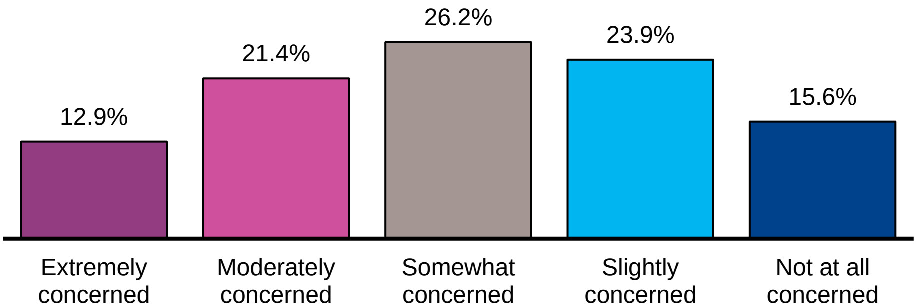


Figure C.17: Level of concern towards the use of small-scale drones by the general public

Table C.11: Level of concern regarding the use of small-scale drones by the general public, by population segment

		How Concerned Are You about the Use of Small-scale Drones by the General Public?					Total (%)
		Extremely concerned (%)	Moderately concerned (%)	Somewhat concerned (%)	Slightly concerned (%)	Not at all concerned (%)	
Gender	Male	6.9	12.7	12.9	12.9	8.2	53.5
	Female	6.0	8.7	13.4	11.0	7.3	46.5
	Total	13.0	21.4	26.2	23.9	15.6	100.0
Age category	18–24	0.4	1.4	2.9	2.5	2.3	9.5
	25–34	1.1	3.0	6.2	4.7	3.5	18.6
	35–44	1.1	4.7	5.3	5.0	1.7	17.9
	45–54	2.6	4.4	3.4	3.3	2.8	16.6
	55–64	3.0	3.8	2.7	3.1	2.2	14.9
	65 +	4.7	4.0	5.5	5.1	3.1	22.5
	Total	13.0	21.4	26.1	23.8	15.7	100.0
Income category (A$ per year)	Low income (up to 52,000)	4.4	6.4	5.2	5.7	4.1	25.9
	Mid-income (52,000–104,000)	4.3	5.7	7.0	7.1	4.3	28.5
	High income (more than 104,000)	4.2	9.2	14.0	11.0	7.1	45.5
	Total	13.0	21.4	26.2	23.8	15.6	100.0

Figure C.18 reveals that among the potential effects of small-scale drones explored in this study, the respondents reported that 'invasion of privacy', 'disturbance to wildlife' and 'safety risks to the general public' are the most concerning factors and that 'noise pollution', 'disturbance to cultural sites' and 'reduce the beauty of the sky' are the least concerning factors.

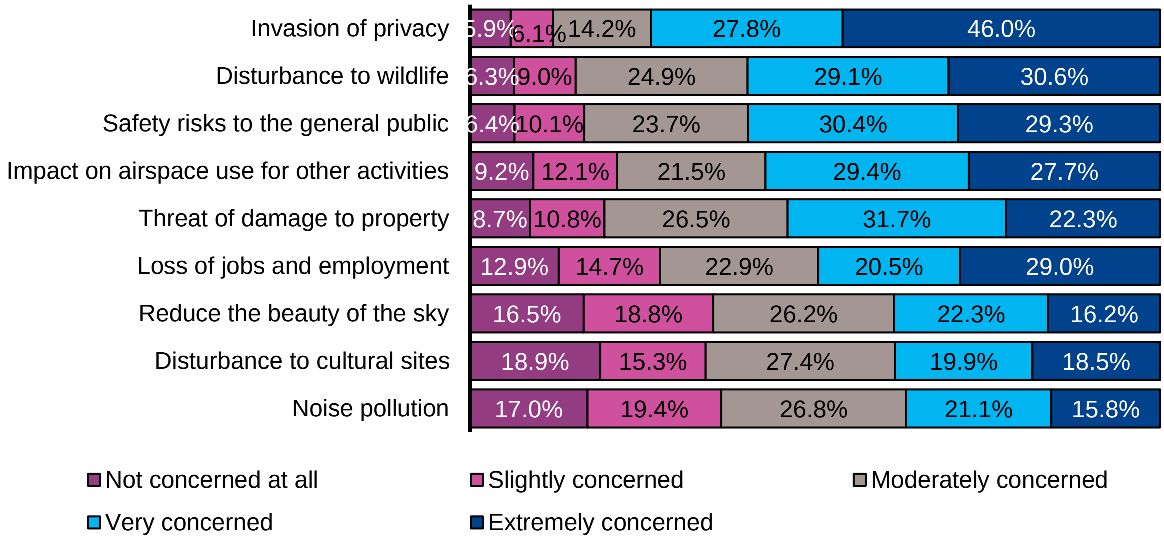


Figure C.18: Level of concern regarding different potential effects of small-scale drones

Last, Figure C.19 and Figure C.20 respectively present respondents' answers to open-ended questions regarding the relative benefits and challenges of increased uptake of small-scale drones for their community. As the figures show, keywords such as 'delivery', 'quicker', 'faster' and 'emergency' were mentioned the most as some of the likely benefits, whereas 'privacy', 'noise', 'invasion', 'safety' and 'jobs' were among those mentioned more frequently in their responses about the key challenges.

Figure C.19: Word cloud presentation of respondents' answers about key benefits of increased uptake of small-scale drones for their community

Figure C.20: Word cloud presentation of respondents' answers about key challenges of increased uptake of small-scale drones for their community

C.3.3 Large-scale uncrewed aerial vehicle

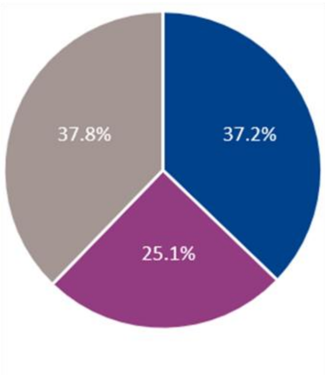
This component was designed and developed to ascertain Australians' perceptions regarding their community's uptake and willingness to use eVTOL services for travelling within and in between cities and regional areas. As for the previous components, respondents were first presented with a definition of the eVOTL service and an image of an eVOTL, as follows:

> An electric vertical take-off and landing (eVTOL) aircraft is a variety of VTOL (vertical take-off and landing) aircraft that uses electric power to hover, take off and land vertically. Large-sized drones of the size of commercial helicopters and aircraft, such as those shown below, are currently under research and development for transporting passengers and goods in the future (i.e. flying cars).

Respondents were informed that hereafter the term 'flying cars' will be used instead of 'eVTOL' in all the questions in this component.

In this section, respondents were first asked whether they are willing to use flying cars for travelling in the future. Only one in four mentioned 'No', 37.2% indicated they would be happy to use this service once it becomes commercially available and 37.8% were unsure at this stage.

Figure C.21 shows the breakdown of the responses as well as a word cloud that presents frequently used keywords to express the reason for their unwillingness to use flying cars for travelling. As shown in the figure, keywords such as ‘dangerous’, ‘safety’ and ‘trust’ were mentioned the most. Table C.12 shows the key demographics of the respondents to the options in this question. The results of a Pearson’s chi-square test show significant differences in all the demographic characteristics. For example, male respondents said ‘Yes’ the most, as did respondents aged 25–34 years and those belonging to the high-income category. In contrast, more of those aged 65 years and above said ‘No’.



a) *b)*

Figure C.21: a) Australians’ willingness to use flying cars for travelling in the future, and b) if unwilling, the reason

Table C.12: Australians' willingness to use flying cars for travelling in the future, by population segment

		Would You Be Willing to Use Flying Cars for Travelling in the Future?			**Total (%)**
		Yes (%)	No (%)	Unsure (%)	
Gender	Male	23.5	13.7	16.4	53.5
	Female	13.7	11.4	21.4	46.5
	Total	37.1	25.1	37.8	100.0
Age category	18–24	4.0	1.3	4.3	9.6
	25–34	9.5	2.2	6.8	18.6
	35–44	7.1	4.1	6.6	17.9
	45–54	5.1	4.5	6.9	16.6
	55–64	4.0	4.5	6.4	15.0
	65 +	7.4	8.4	6.5	22.4
	Total	37.2	25.1	37.7	100.0
Income category (A$ per year)	Low income (up to 52,000)	8.0	7.7	10.2	25.9
	Mid-income (52,000–104,000)	11.6	5.6	11.5	28.6
	High income (more than 104,000)	17.6	11.7	16.2	45.4
	Total	37.2	25.0	37.8	100.0

In all, 37.2% of the population reported they are willing to use flying cars for travelling and received a follow-up question about the distance they are willing to travel using flying car services. Figure C.22 reports the maximum distance they are willing to travel. Most of the respondents (28%) indicated they are happy to travel 200 km or more using this new transport mode. Only 4% indicated that they are willing to travel up to 25 km. Figure C.23 shows respondents' willingness to purchase a flying car once it becomes available—24.6% said 'Yes' and 38.5% said 'No'.

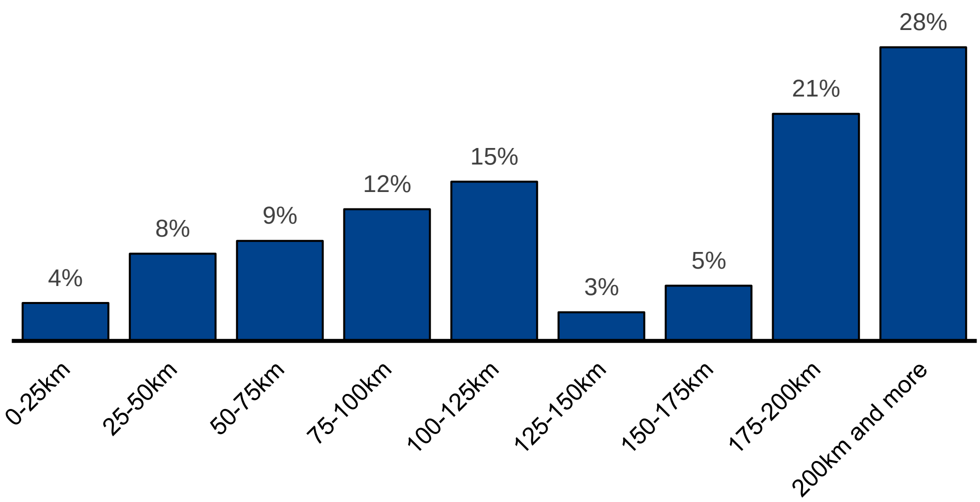


Figure C.22: Maximum distance Australians are willing to travel using flying cars

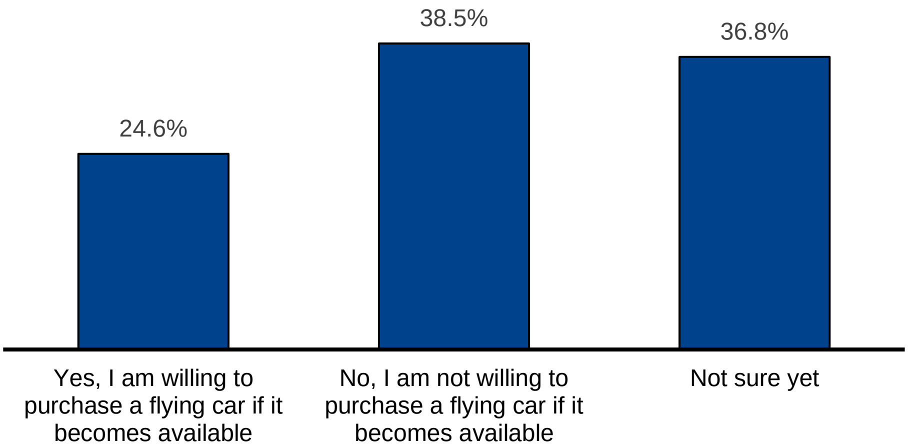


Figure C.23: Australians' willingness to purchase a flying car if it becomes commercially available

Table C.13: Australian willingness to purchase a flying car if it becomes commercially available, by population segment

		Are You Willing to Purchase a Flying Car if It Becomes Available?			**Total (%)**
		Yes (%)	No (%)	Unsure (%)	
Gender	Male	15.9	19.7	18.0	53.6
	Female	8.8	18.8	18.8	46.4
	Total	24.6	38.5	36.8	100.0
Age category	18–24	2.2	2.9	4.4	9.6
	25–34	6.6	4.7	7.2	18.6
	35–44	6.0	5.4	6.3	17.8
	45–54	4.1	6.6	5.8	16.6
	55–64	2.0	6.8	6.1	15.0
	65 +	3.6	12.0	6.8	22.4
	Total	24.6	38.5	36.8	100.0
Income category (A$ per year)	Low income (up to 52,000)	5.8	9.4	10.8	26.0
	Mid-income (52,000–104,000)	8.6	10.2	9.9	28.6
	High income (more than 104,000)	10.3	19.0	16.2	45.5
	Total	24.6	38.5	36.8	100.0

C.3.3.1 Intracity travel DCE

In this section of the survey, we developed two DCEs to understand respondents' willingness to use drones for intracity and intercity travel (e.g. a trip to the capital city, regional city or remote areas). We began with intracity travel. Respondents were asked to provide details about their mobility (see Appendix C-5) and a recent trip they had made within their city. Table C.14 provides a summary of the trips reported, and Appendix C-6 provides a detailed descriptive analysis of the information provided. More than 62% of the reported trips were made between 6 and 9 am and the majority stated the trip was for work purposes. The most used mode (78.4%) of transport for this trip was a car, and on average, 1.6 passengers (including the respondent) travelled on this trip. The average travel time for the private mode (i.e. car, motorcycle and electric scooter) and public mode (bus, train, tram, ferry and taxi/Uber) was 27 and 26 minutes, respectively. On average, respondents had travelled longer distances using the private mode, and interestingly reported higher costs per passenger. The access and egress time when using the private mode was significantly lower than that for the public mode, and respondents using the private mode reported higher reliability scores for the mode they used, than did those who used the public mode.

Table C.14: Summary of recent intracity travel

	Private Mode	Public Mode
Average in-vehicle travel time	27 minutes	26 minutes
Average distance travelled	21 km	18 km
Average trip cost per passenger	A$12.80	A$11
Average access time	1 minute	11.6 minutes
Average egress time	1.2 minutes	11.2 minutes
Mode reliability	9.5 out of 10	8.5 out of 10
Time of the day	6 to 9 am (62.4%)	
Travel purpose	Work (35.4%)	
Average number of travellers	1.6	
Travel mode	Car (78.4%)	

Later, respondents were asked to consider the same recent intracity trip they had made, including all passengers who had accompanied them for this journey, and were shown eight hypothetical scenarios. For each scenario, they were presented with the option of making the same trip using a drone passenger transport service. All the relevant information, such as travel times, costs and reliability, such as the example shown in Figure C.24, were given for this alternative. The reported details of their recent trip were also provided as Option 2. For each scenario, respondents were required to indicate the option that they would most prefer to use for this trip. The attributes of the alternatives were varied systematically across scenarios, on the basis of the potential range of values listed in Table C.15, using a statistically robust experiment design.

Data from the hypothetical scenarios were used in conjunction with other demographic information collected as part of the survey to estimate the LCCMs of consumer willingness to use flying cars for the same recent intracity travel they made. As mentioned before, the general LCCM framework is described in Appendix C-4. Here, we summarise the key findings from our analysis.

Table C.15: Attributes and the values they can take across different stated preference scenarios

Attribute	Level							
	1	2	3	4	5	6	7	8
In-vehicle travel time (as % of their reported travel time)	40%	50%	60%	70%	80%	90%	110%	120%
Access time (as % of in-vehicle travel time in same alternative)	5%	10%	15%	20%	25%	30%	35%	40%
Egress time (as % of in-vehicle travel time in same alternative)	5%	10%	15%	20%	25%	30%	35%	40%
Travel cost (as % of their reported travel cost)	60%	80%	100%	120%	140%	180%	200%	
Reliability of service	Less than 8 out of 10 on time	8 out of 10 on time	8.5 out of 10 on time	9 out of 10 on time	9.5 out of 10 on time	10 out of 10 on time		

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In this section of the survey, we would like to understand your willingness to use drones for intra-city travel. We would like you to consider the same recent **Work** trip you made at **6:05 AM** including all passengers that accompanied you for this journey as you mentioned in the previous question.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented the option of making the same trip using a drone passenger transport service, defined in terms of travel times, costs, reliability, etc., such as the example shown below. We have also provided the same details for your current mode of transport for this recent trip. For each scenario, you will be asked to indicate the option that you would most prefer to use for this trip.

Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	39 minutes	55 minutes
Access time (Time spent walking from starting point to drone pick-up point)	8 minutes	55 minutes
Egress time (Time spent walking from drone drop-off point to final destination)	8 minutes	5 minutes
Travel cost (per passenger)	$4.00	$5.00
Reliability of service	8 out of 10 on time	8.5 out of 10 on time
Option I most prefer	○	○

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Figure C.24: Example stated preference scenario to elicit consumer preferences for travelling using flying cars for intracity travel

Numerous models and sub-models were estimated. The utility specification and the number of classes were varied in determining the final model. Using behavioural interpretation and statistical measures of fit, namely the BIC and the AIC as listed in Table C.16, a five-class model was selected as the preferred model. This model shows five distinct segments, or classes, in our sample population that differ in terms of their preferences to use flying cars for intracity travel and their demographic characteristics. The classes have been ordered in terms of increasing enthusiasm for using flying car services. These descriptions are summarised in

Table C.17. In the following paragraphs, we discuss some of the key findings. Note that the model presented in this section was estimated independently of previous and following models. Consequently, the classes identified here differ from those identified elsewhere.

Table C.16: Summary statistics for LCCMs with varying numbers of classes

No. of Classes	AIC	BIC
Two	6675.682	6748.841
Three	6043.035	6189.354
Four	5712.877	5937.232
Five	**5614.144**	**5848.254**
Six	5606.044	5874.295

First, 27.1% of the respondents (Class 1) reported that they are unwilling to use flying cars. They are more likely to be highly car-oriented and to be older females with low earnings relative to other classes. This class has the largest proportion of respondents living in regional cities and remote areas compared with other classes. Second, the model predicts that 27% of the population is willing to shift to using flying cars for their intracity travels. They are less likely to be car-oriented and more likely younger male adults living in metropolitan areas. Third, the average in-vehicle value of time (VOT) is A$31.9, and the average VOT for access and egress is A$15.3.

Table C.17: High-level summary of different market segments, or classes

	Class 1: Non-users	**Class 2**	**Class 3**	**Class 4**	**Class 5: Enthusiastic users**
Sample share (%)	27.1	22.6	19.6	14.7	16.1
Mode share (%)	• Car: 79.6 • Motorcycle: 0.4 • Bus: 8.2 • Train: 8.3 • Tram: 2.1 • Taxi/Uber: 1.4 • Drone: 0.0	• Car: 70.2 • Motorcycle: 0.1 • Bus: 4.5 • Train: 6.4 • Tram: 0.9 • Taxi/Uber: 0.8 • Drone: 17.2	• Car: 54.6 • Motorcycle: 0.5 • Bus: 8.6 • Train: 8.7 • Tram: 2.8 • Taxi/Uber: 0.8 • Drone: 24	• Car: 37.1 • Motorcycle: 0.0 • Bus: 2.2 • Train: 1.1 • Tram: 0.1 • Taxi/Uber: 0.7 • Drone: 58.8	• Car: 30.5 • Motorcycle: 1.6 • Bus: 2.6 • Train: 1.8 • Tram: 0.7 • Taxi/Uber: 0 • Drone: 62.8
Preference for travel time	-	VOT: A$7.8	VOT: A$1.5	VOT: A$51.7	VOT: A$136.1
Preference for access or egress time	-	VOT: A$9.8	VOT: A$3	VOT: A$87.2	-
Preference for reliability of service	-	Prefer services with higher reliability			-
Demographic characteristics	• Dominant gender: Female • Average age: 51 years • Household income: A$82,500 • Location: Have the highest proportion of Australians living in regional and remote areas	• Dominant gender: Female • Average age: 49 years • Household income: $87,200	• Dominant gender: Male • Average age: 49 years • Household income: A$91,600 • Location: Most likely living in metropolitan areas	• Dominant gender: Male • Average age: 44 years • Household income: A$97,800	• Dominant gender: Male • Average age: 38 years • Household income: A$81,200 • Location: Most likely living in metropolitan areas

C.3.3.2 Intercity travel DCE

In this section, respondents were first asked about their frequency of intercity travel. Anyone who had reported that they were living in a capital city was first asked if they had made any trips recently to regional and remote areas in Australia. Of the 1,000 respondents, 67% were currently living in the capital city. Figure C.25 shows that 16.5% mentioned that they had never travelled to regional or remote areas in Australia. These people were asked a follow-up question regarding whether they had made any trips to other capital cities. Interestingly, almost 66% reported that they had also not travelled to any other capital city. Conversely, 33% of respondents living in regional or remote areas were first asked whether they had recently travelled to capital cities. Figure C.25 shows that 26.7% had never travelled to a capital city; hence, in a follow-up question, they were asked whether they had travelled to any other regional and remote area in Australia recently, to which almost 42% replied that they had not. This analysis revealed that in all, almost 15% of the sample had not engaged in intercity travel recently and had bypassed the intercity travel section.

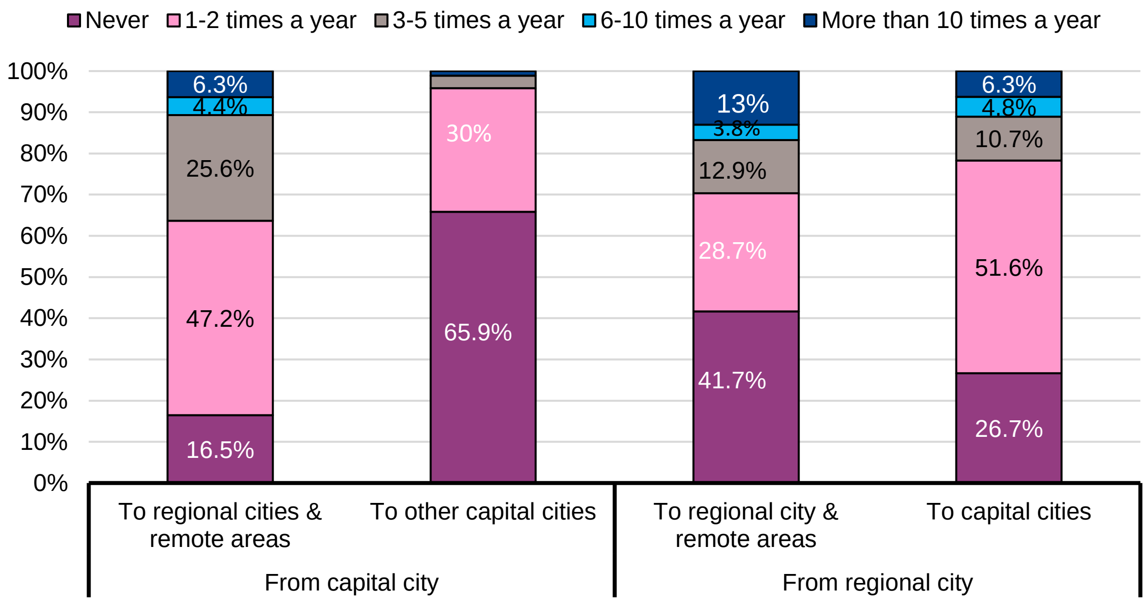


Figure C.25: Frequency of intercity travel

Then, the remaining 85% of the sample population were asked to provide details of a recent trip they had made from their city to a capital city or a regional or remote area. Table C.18 provides a summary of the trips reported, and Appendix C-7 provides a detailed descriptive analysis of the information provided. Almost 65% of the reported trips were made between 6 and 9 am. The majority stated they had travelled to visit family and friends. The most used mode (76.9%) for this trip was a car, and on average 2.3 passengers (including the respondent) travelled on this journey. The average travel time for both the private mode (i.e. car, motorcycle and electric scooter) and the public mode (i.e. bus, train, tram, ferry and taxi/Uber) was 207 minutes and 172 minutes, respectively. On average, respondents had travelled longer distances using the public mode and reported they had paid higher fees per passenger. The access and egress time when using the private mode was significantly lower than when using the public mode. Respondents who had used the private mode reported higher reliability scores for the mode they used, than did those who had used the public mode.

Table C.18: Intercity recent travel summary

	Private	**Public**
Average in-vehicle travel time	207 minutes	172 minutes
Average distance travelled	295 km	857 km
Average trip cost per passenger	A$63.70	A$239
Average access time	1.2 minute	34 minutes
Average egress time	2.4 minutes	50.6 minutes
Mode reliability	9.5 out of 10	8.5 out of 10

Time of the day	6 to 9 am (64.6%)
Travel purpose	Visiting family & friends (39.9%)
Average number of travellers	2.3
Travel mode	Car (76.9%)

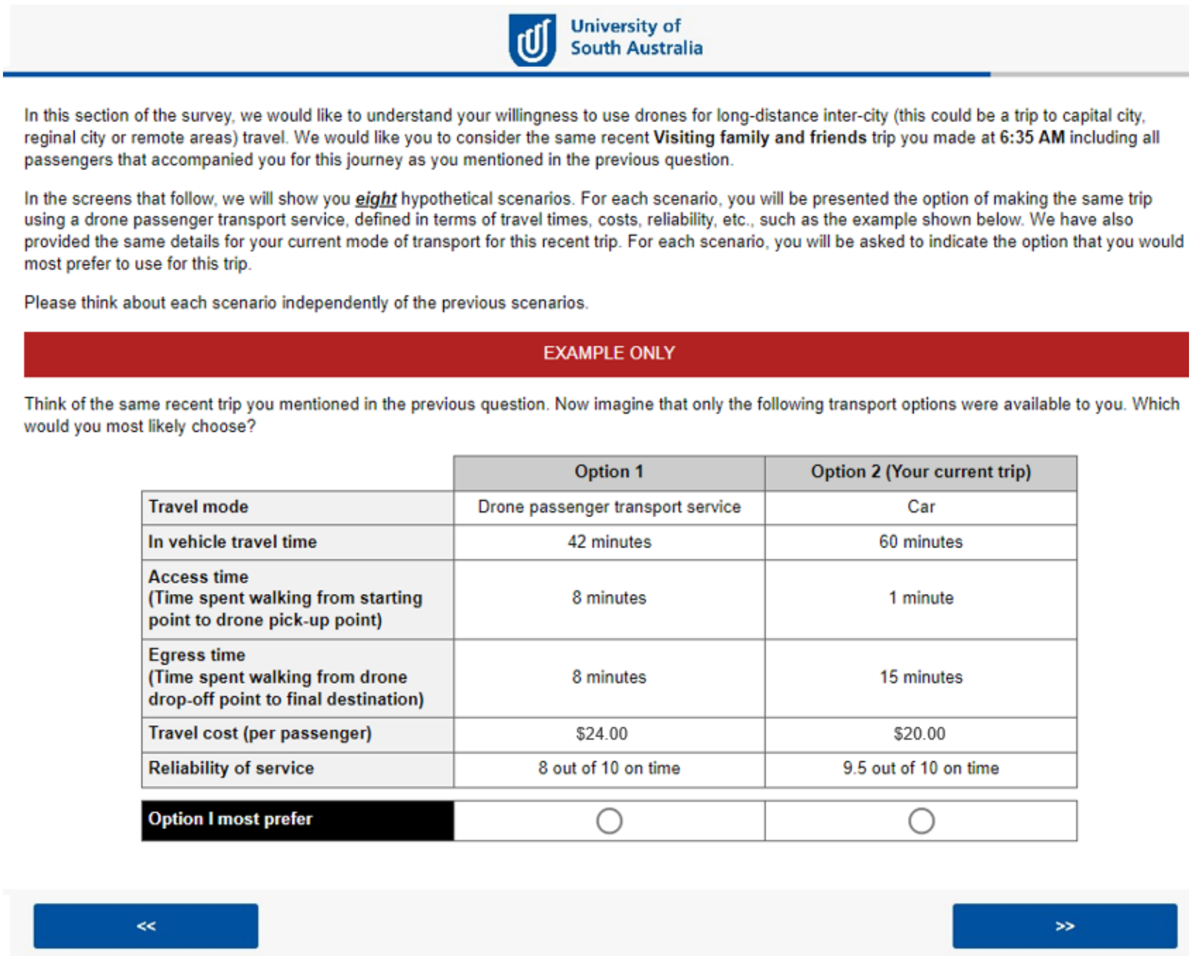
In the next stage, respondents were asked to consider the same recent intercity journey they had made, including all passengers who accompanied them for this journey, and were shown eight hypothetical scenarios. For each scenario, respondents were presented with the option of making the same trip using a drone passenger transport service. All the relevant information such as travel times, costs and reliability, as in the example shown in Figure C.26 were given for this alternative. The reported details of their recent trip were also provided as Option 2. For each scenario, respondents were required to indicate the option that they would most prefer to use for this trip. The attributes of the alternatives were varied systematically across scenarios, on the basis of the potential range of values listed in Table C.15, using a statistically robust experiment design.

Data from the hypothetical scenarios were used in conjunction with other demographic information collected as part of the survey to estimate the LCCMs of respondents' willingness to use flying cars for the same recent intercity travel they had made. As mentioned before, the general LCCM framework is described in Appendix C-4. Here, we summarise the key findings from our analysis. Note that the model presented in this section was estimated independently of previous models. Consequently, the classes identified here differ from the classes identified previously.

Numerous models and sub-models were estimated. The utility specification and the number of classes were varied in determining the final model. Using behavioural interpretation and statistical measures of fit, namely, the BIC and the AIC as listed in Table C.19, a five-class model was selected as the preferred model. This model shows five distinct segments, or classes, of our sample population that differ in terms of their preferences to use flying cars for intercity travel and their demographic characteristics. The classes have been ordered in terms of increasing enthusiasm for using flying car services. These descriptions are summarised in Table C.20. In the following paragraphs, we discuss some of the key findings.

Table C.19: Summary statistics for LCCMs with varying numbers of classes

No. of Classes	AIC	BIC
Two	6094.57	6170.513
Three	5680.437	5808.59
Four	5402.459	5611.301
Five	**5338.733**	**5552.321**
Six	5285.215	5626.956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In this section of the survey, we would like to understand your willingness to use drones for long-distance inter-city (this could be a trip to capital city, regional city or remote areas) travel. We would like you to consider the same recent **Visiting family and friends** trip you made at **6:35 AM** including all passengers that accompanied you for this journey as you mentioned in the previous question.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented the option of making the same trip using a drone passenger transport service, defined in terms of travel times, costs, reliability, etc., such as the example shown below. We have also provided the same details for your current mode of transport for this recent trip. For each scenario, you will be asked to indicate the option that you would most prefer to use for this trip.

Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	42 minutes	60 minutes
Access time (Time spent walking from starting point to drone pick-up point)	8 minutes	1 minute
Egress time (Time spent walking from drone drop-off point to final destination)	8 minutes	15 minutes
Travel cost (per passenger)	$24.00	$20.00
Reliability of service	8 out of 10 on time	9.5 out of 10 on time
Option I most prefer	○	○

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Figure C.26: Example stated preference scenario to elicit consumer preferences for travelling on flying cars for intercity travel

Similarly to the intracity travel results, we found that 28.1% of the respondents (Class 1) are unwilling to use flying cars for intercity travel. They are likely to be highly car-oriented and to be older females with an average household income of A$90,000. Second, the model predicts that 27.5% of the population is willing to shift to using flying cars for their intercity travels. These people are less likely to be car-oriented and more likely younger adults living in metropolitan areas. Third, the average in-vehicle VOT is $29.3, and the average VOT for access and egress is $23.6.

Table C.20: High-level summary of different market segments, or classes

	Class 1: Non-users	Class 2	Class 3	Class 4	Class 5: Enthusiastic users
Sample share (%)	28.1	25.3	10.8	10.7	25.1
Mode share (%)	• Car: 78.9% • Motorcycle: 0.3% • Bus: 1.6% • Train: 8.3% • Tram: 0.4% • Aeroplane: 10.5% • Drone: 0.0%	• Car: 68.2% • Motorcycle: 0.1% • Bus: 0.0% • Train: 2.8% • Tram: 0.1% • Aeroplane: 8.2% • Drone: 20.6%	• Car: 46.6% • Motorcycle: 0.7% • Bus: 2.0% • Train: 7.1% • Tram: 0.8% • Aeroplane: 3.9% • Drone: 38.8%	• Car: 40.4% • Motorcycle: 1.0% • Bus: 0.9% • Train: 5.9% • Tram: 0.0% • Aeroplane: 5.2% • Drone: 46.5%	• Car: 38.5% • Motorcycle: 0.1% • Bus: 1.0% • Train: 3.1% • Tram: 0.4% • Aeroplane: 4.6% • Drone: 52.2%
Preference for travel time	-	VOT: A$203.9	-	VOT: A$74.6	-
Preference for access or egress time	-	-	VOT: A$35.4	VOT: A$220	-
Preference for reliability of service	-	Prefer services with higher reliability	-	-	Prefer services with higher reliability
Demographic characteristics	• Dominant gender: Female • Average age: 52 years • Household income: A$90,600	• Dominant gender: Female • Average age: 49 years • Household income: A$93,800	• Dominant gender: Male • Average age: 45 years • Household income: A$83,300 • Number of vehicles: have the lowest number of vehicles in the household.	• Dominant gender: Female • Average age: 45 years • Household income: A$101,200 • Location: 70% of the sample are most likely living in metropolitan areas	• Dominant gender: Male • Average age: 38 years • Household income: A$90,700 • Location: 71% of the sample are most likely living in metropolitan areas

C.3.3.3 Beliefs, attitudes and perceptions towards large-scale uncrewed aerial vehicle

To understand Australians' beliefs, attitudes and perceptions towards large-scale UAVs (i.e. flying cars), respondents were asked to answer a series of Likert-type questions to indicate their agreement with each statement. Figure C.27 highlights that almost 1 in 2 Australians agree that flying cars will reduce their travel time and increase mobility for people with driving impairments or restrictions and are concerned about learning and operating/using a flying car. The lowest agreement was on ‘relocate to a remote area’, ‘relocate further away from the city centre’ and ‘using flying cars for daily travel’. Table C.21 and Table C.22 show the demographic breakdown of responses for both relocation statements with the lowest agreement among the respondents. In both cases, male respondents aged 65 years and above who belong to a high-income household, have a full-time job and live in a metropolitan area are very reluctant to move further away from the city centre or to a regional or remote area. Last, 31.7% showed interest to be trained and to work in the drone industry.

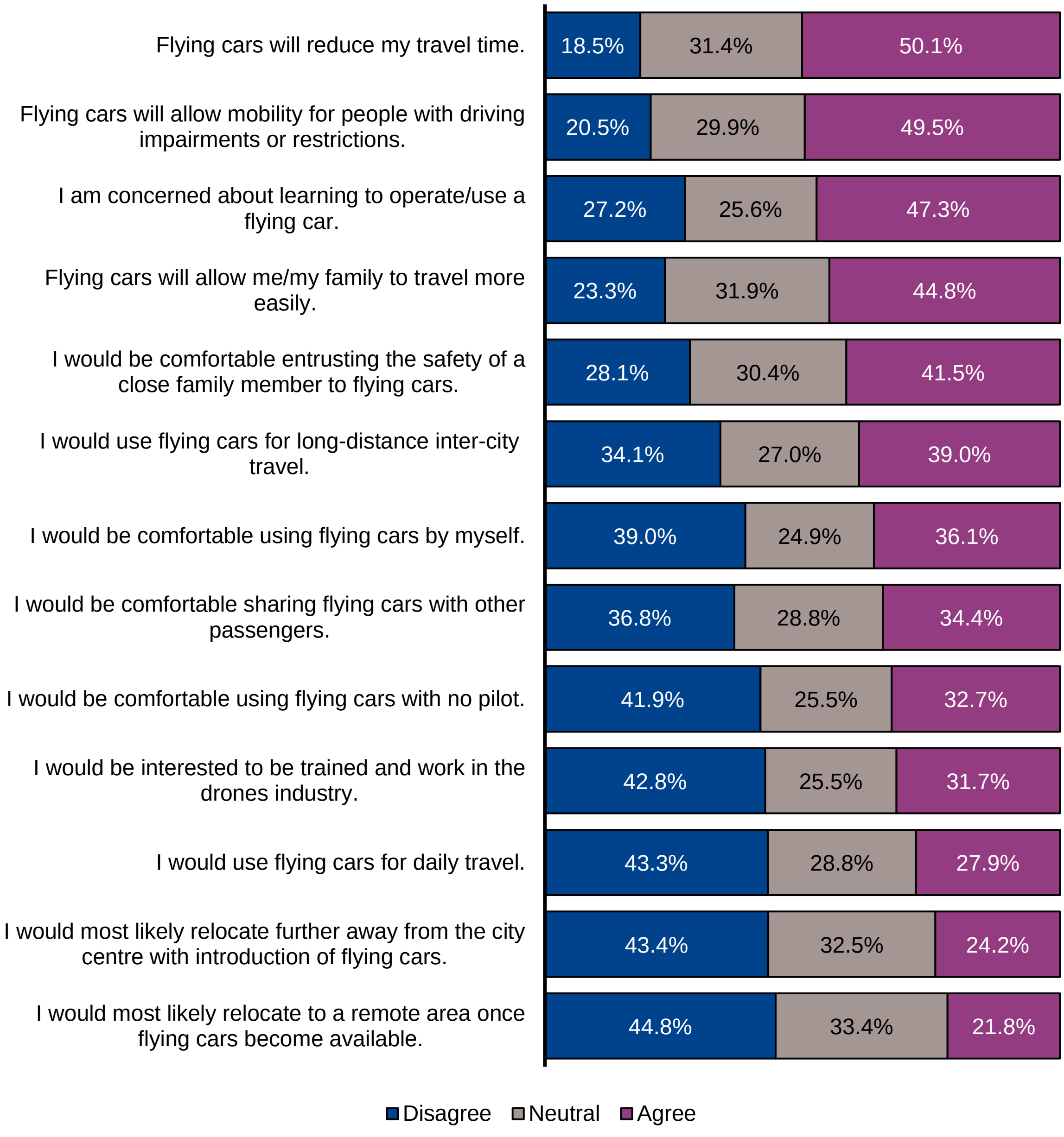


Figure C.27: Australians’ agreement to statements related to flying cars

Table C.21: Respondents' agreement to relocating further away from the city centre by demographic characteristics

		I Would Most Likely Relocate Further Away from the City Centre					Total (%)
		Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)	
Gender	Male	13.8	10.6	14.2	11.7	3.3	53.6
	Female	6.3	12.7	18.3	6.4	2.7	46.4
	Total	20.1	23.3	32.4	18.2	6.0	100.0
Age category	18–24	0.7	2.2	4.2	2.0	0.5	9.6
	25–34	1.2	3.4	6.3	5.8	1.7	18.5
	35–44	2.4	4.7	6.1	3.6	1.0	17.9
	45–54	2.0	5.1	5.4	3.1	0.9	16.6
	55–64	4.5	1.9	5.3	2.0	1.2	15.0
	65 +	9.2	5.8	5.0	1.7	0.6	22.4
	Total	20.1	23.2	32.5	18.3	5.9	100.0
Income category (A$ per year)	Low income (up to 52,000)	4.4	5.7	10.4	4.0	1.4	26.0
	Mid-income (52,000–104,000)	3.9	6.4	9.8	6.0	2.4	28.6
	High income (more than 104,000)	11.7	11.1	12.2	8.1	2.2	45.4
	Total	20.1	23.3	32.5	18.2	6.0	100.0
Employment status	Employed full time	8.6	9.5	13.5	11.7	2.9	46.2
	Employed part time	2.2	4.5	7.6	2.9	1.4	18.7
	Unemployed	0.7	0.9	1.6	1.0	0.2	4.4

	Not in the labour force: Stay-at-home parent or caregiver	0.6	2.3	3.7	0.9	0.6	8.1
	Not in the labour force: Full-time student	0.2	0.1	0.4	0.2	0.0	0.9
	Not in the labour force: Retired	7.2	5.3	4.1	1.1	0.7	18.5
	Not in the labour force: Other	0.5	0.5	1.6	0.4	0.1	3.1
	Total	20.1	23.2	32.6	18.2	5.9	100.0
Residential location	Metropolitan	12.6	15.0	21.7	13.9	4.2	67.3
	Regional	7.5	8.3	10.8	4.3	1.7	32.7
	Total	20.1	23.3	32.5	18.2	5.9	100.0

Table C.22: Respondents' agreement to relocating to a remote area by demographic characteristics

		I would most likely relocate to a remote area					**Total (%)**
		Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)	
Gender	Male	15.2	8.7	15.8	11.0	3.0	53.7
	Female	8.2	12.7	17.6	6.1	1.7	46.3
	Total	23.4	21.4	33.4	17.1	4.7	100.0
Age category	18–24	1.6	1.6	4.7	1.4	0.2	9.5
	25–34	1.2	4.1	6.9	5.2	1.1	18.6
	35–44	2.9	4.7	5.8	3.5	0.9	17.9
	45–54	2.8	4.7	5.4	2.8	0.9	16.6
	55–64	4.1	1.7	5.5	2.6	1.0	14.9
	65 +	10.7	4.6	5.0	1.4	0.7	22.5
	Total	23.4	21.5	33.4	17.0	4.8	100.0
Income category (A$ per year)	Low income (up to 52,000)	4.9	5.7	9.6	4.4	1.3	26.0
	Mid-income (52,000–104,000)	4.6	6.3	9.9	5.3	2.4	28.6
	High income (more than 104,000)	13.9	9.4	14.0	7.2	1.0	45.5
	Total	23.4	21.4	33.4	17.0	4.7	100.0
Employment status	Employed full time	9.8	8.8	14.9	10.7	2.1	46.3
	Employed part time	3.5	3.7	7.4	2.9	0.9	18.5
	Unemployed	0.5	1.2	1.6	1.0	0.2	4.5
	Not in the labour force: Stay-at-home parent or caregiver	0.9	2.6	3.0	1.0	0.7	8.2
	Not in the labour force: Full-time student	0.2	0.1	0.4	0.2	0.0	0.9
	Not in the labour force: Retired	7.9	4.5	4.3	0.9	0.7	18.4
	Not in the labour force: Other	0.5	0.4	1.8	0.3	0.1	3.1
	Total	23.4	21.4	33.5	17.0	4.7	100.0
Residential location	Metropolitan	14.4	14.6	21.9	12.9	3.4	67.2
	Regional	9.0	6.8	11.5	4.2	1.3	32.8
	Total	23.3	21.4	33.4	17.1	4.7	100.0

Last, Table C.21 and Table C.22 respectively present respondents' answers to open-ended questions regarding the relative benefits and challenges of increased flying car uptake for their community. As the figures show, keywords such as 'less', 'travel', 'time' and 'traffic' were mentioned the most as some of the benefits, whereas 'safety', 'noise' and 'accident' were mentioned more frequently in their response about key challenges.

Figure C.28: Word cloud presentation of respondents' answers about key benefits of increased flying car uptake for their community

Figure C.29: Word cloud presentation of respondents' answers about key challenges of increased flying car uptake for their community

C.4 Summary

To understand public attitudes and perceptions regarding drone technology, we conducted an online nationwide survey of 1,000 Australians aged 18 years and above in October 2022. In general, we find high levels of familiarity with drone technology. Roughly 84% of the sample reported they are at least slightly familiar with the technology, 28% reported they have flown a drone themselves at least once and 26% indicated moderate to strong interest in purchasing a drone. Young men were most likely to report high levels of familiarity and experience, and a greater desire for drone ownership.

Next, survey respondents were asked to assess different drone technology use cases in terms of value to their community and society at large. They perceived the greatest value of the technology for emergency services and disaster recovery, such as to assist with search and rescue operations and emergency response coordination and to provide emergency deliveries. Security services, with applications in police response coordination, crime scene investigation and criminal surveillance and tracking, were rated second. Environmental management, with applications in environmental hazard assessment, wildlife and habitat monitoring and protection, and scientific research, was rated third. Agriculture, with use cases such as crop and yield management, pest and disease detection and treatment, and water and asset management, was rated fifth. Respondents did not perceive as much value in applications of drone technologies to other industries, such as marketing, entertainment and recreation.

In general, 63% of our sample indicated they are supportive of drones being deployed in practice wherever such deployment offers value, 79% indicated they are willing to accept drone use for specialised use cases where drones offer high value and only 23% indicated that they do not want to see drones being commercially deployed in practice at all. From the list of potential effects of small-scale drones explored in the survey, respondents reported being most concerned about ‘invasion of privacy’, ‘disturbance to wildlife’ and ‘safety risks to the general public’, and perhaps surprisingly, being least concerned about ‘noise pollution’, ‘disturbance to cultural sites’ and ‘reduce the beauty of the sky’. Note though that as drone uptake increases over time, some of these concerns might become more salient as people gain more experiences with the technology.

Roughly half our sample indicated some desire to use drones for delivery, while a quarter indicated no desire to use such a service. Trust in the service varied across the sample—37% expressed some scepticism, such that a drone delivery service would need to be A$5–A$25 cheaper than a traditional delivery service for them to use it. Further, 31% expressed indifference between drone and traditional delivery services, and 33% indicated a preference for drone delivery services. Young men from high-income households are most likely to use these services.

Last, survey respondents were asked about their willingness to use large-scale drones, or flying cars, for intracity and intercity travel. Roughly 30–35% of the sample indicated they are willing to use flying cars, and 25% indicated they would purchase a flying car when it becomes available. In general, respondents indicate that they are much more likely to use flying cars for long-distance intercity travel than short-distance intracity travel. However, most are still sceptical of the technology and wary of entrusting their safety to an unmanned aerial vehicle at this point for any type of travel.

References

Baumgartner, H., & Steenkamp, J.-B. E. (2001). Response styles in marketing research: A cross-national investigation. Journal of Marketing Research, 38(2), 143–156. https://doi.org/10.1509/jmkr.38.2.143.18840

Ben-Akiva, M. E., Lerman, S. R., & Lerman, S. R. (1985). Discrete choice analysis: theory and application to travel demand (Vol. 9). *MIT press*.

Bierlaire, M. (2020). A short introduction to PandasBiogeme. *A short introduction to PandasBiogeme.*

Finn, A., & Louviere, J. J. (1992). Determining the appropriate response to evidence of public concern: The case of food safety. *Journal of Public Policy & Marketing*, *11*(2), 12-25. https://doi.org/10.1177/074391569201100202

Flynn, T. N. (2010). Valuing citizen and patient preferences in health: Recent developments in three types of best–worst scaling. *Expert Review of Pharmacoeconomics & Outcomes Research*, *10*(3), 259–267. https://doi.org/10.1586/erp.10.29

Helson, H. (1964). *Adaptation-level theory: An experimental and systematic approach to behavior*. Harper & Row.

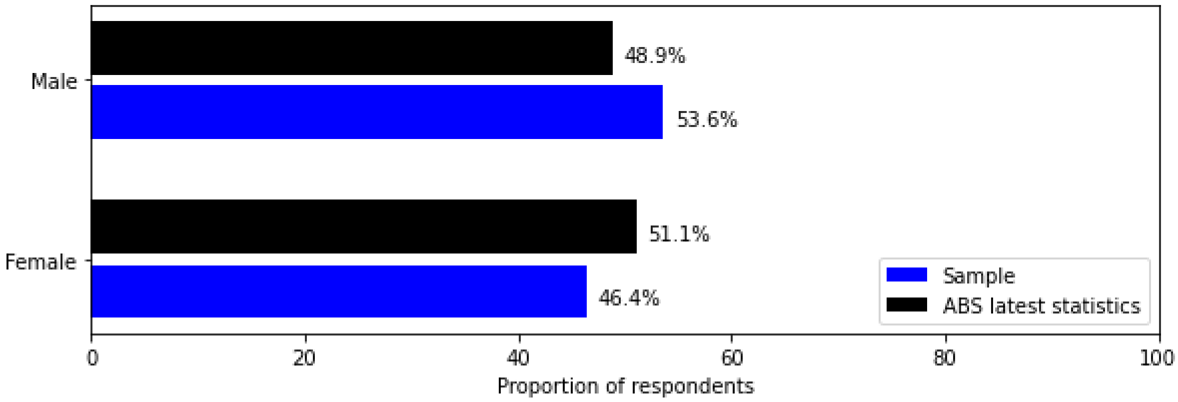
Kamakura, W. A., & Russell, G. J. (1989). A probabilistic choice model for market segmentation and elasticity structure. *Journal of marketing research*, 26(4), 379-390.

Lee, J. A., Soutar, G. N., & Louviere, J. (2007). Measuring values using best-worst scaling: The LOV example. *Psychology & Marketing*, *24*(12), 1043–1058. https://doi.org/10.1002/mar.20197

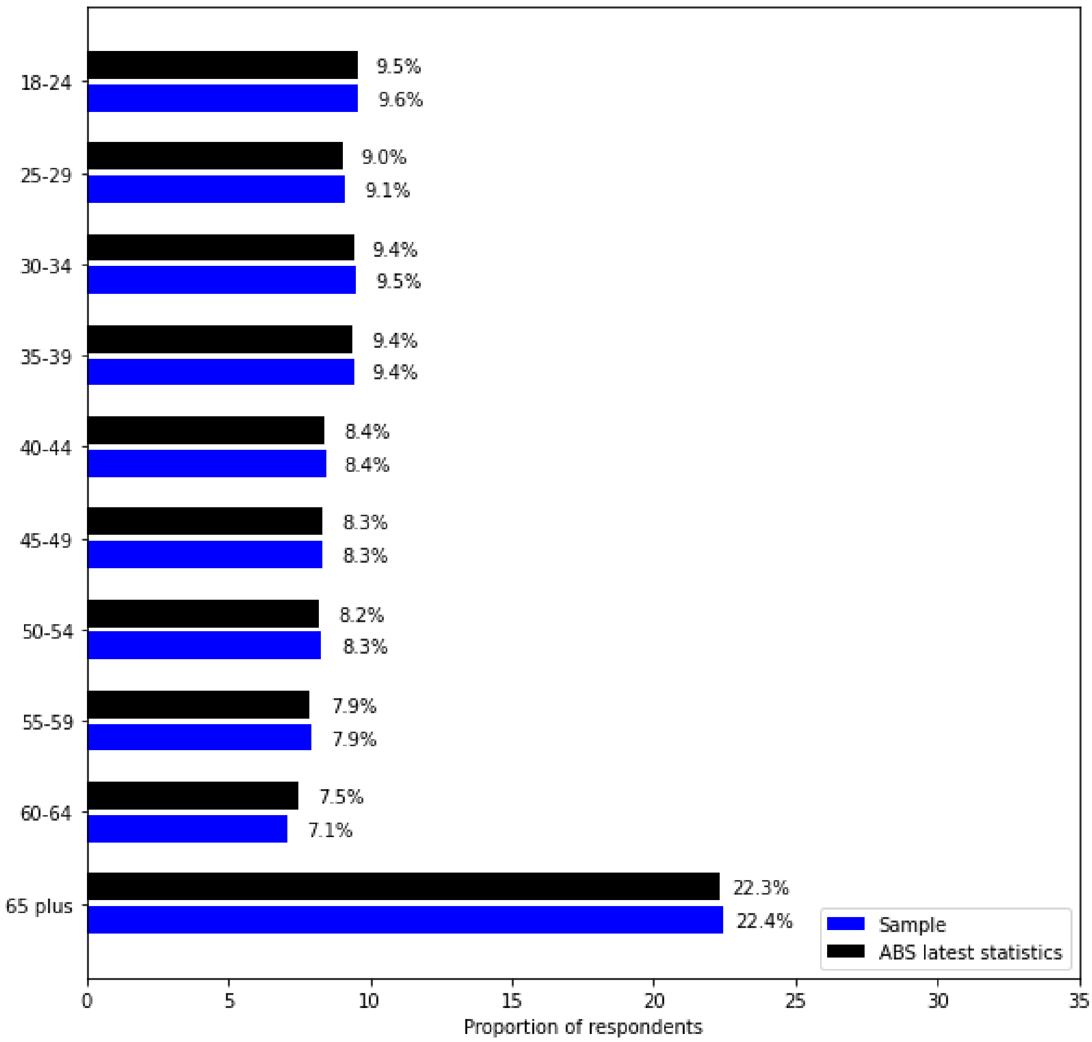
Marley, A. A., & Louviere, J. J. (2005). Some probabilistic models of best, worst, and best–worst choices. *Journal of mathematical psychology*, 49(6), 464-480.

Appendix C-1: Weighting Sample Population to Represent Australian Population

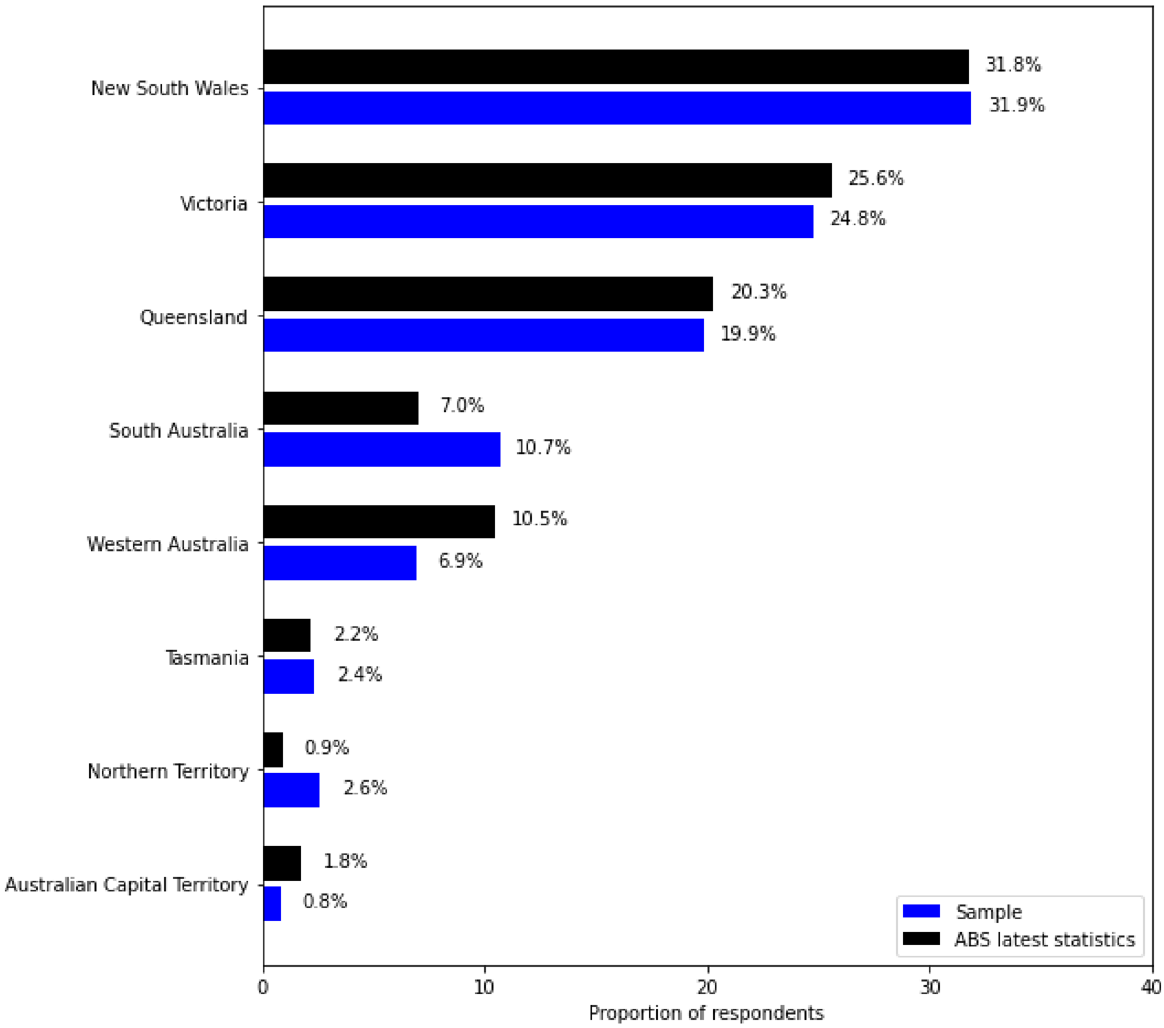
Gender:



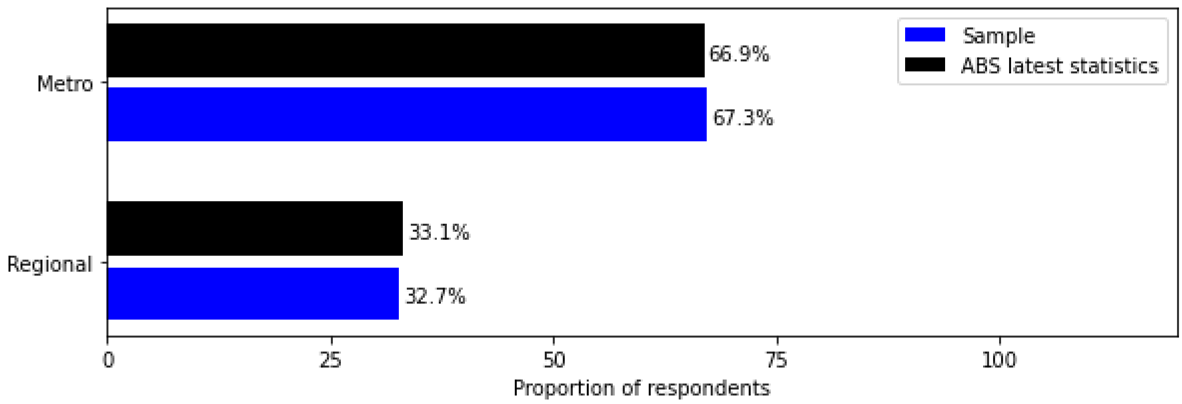
Age:



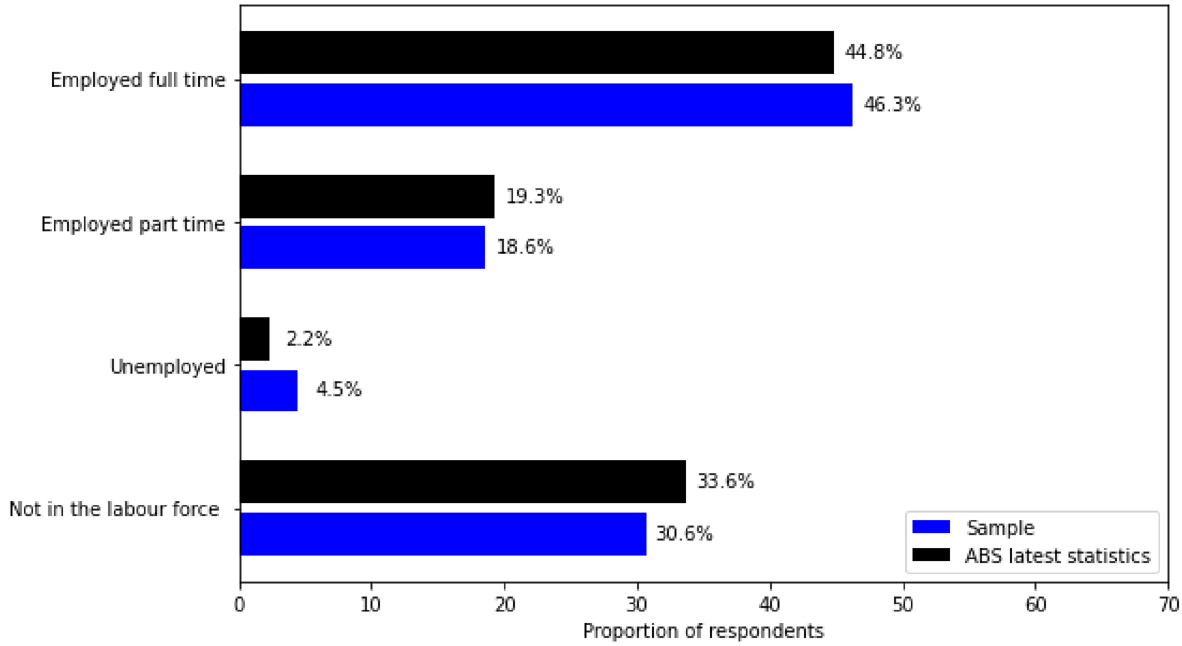
State:



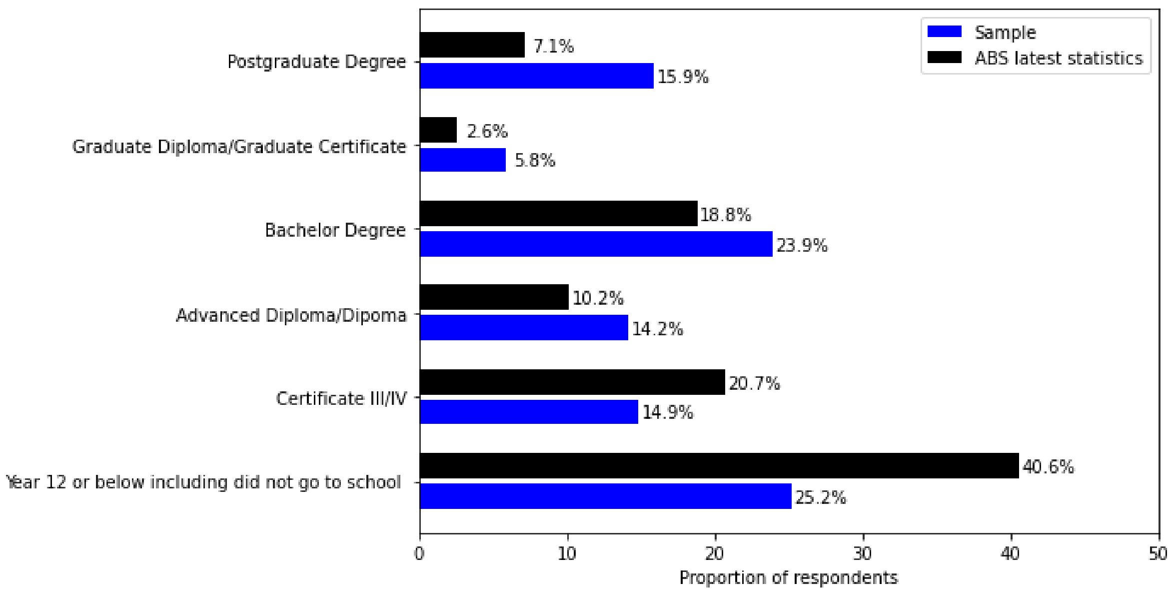
Metropolitan v. Regional



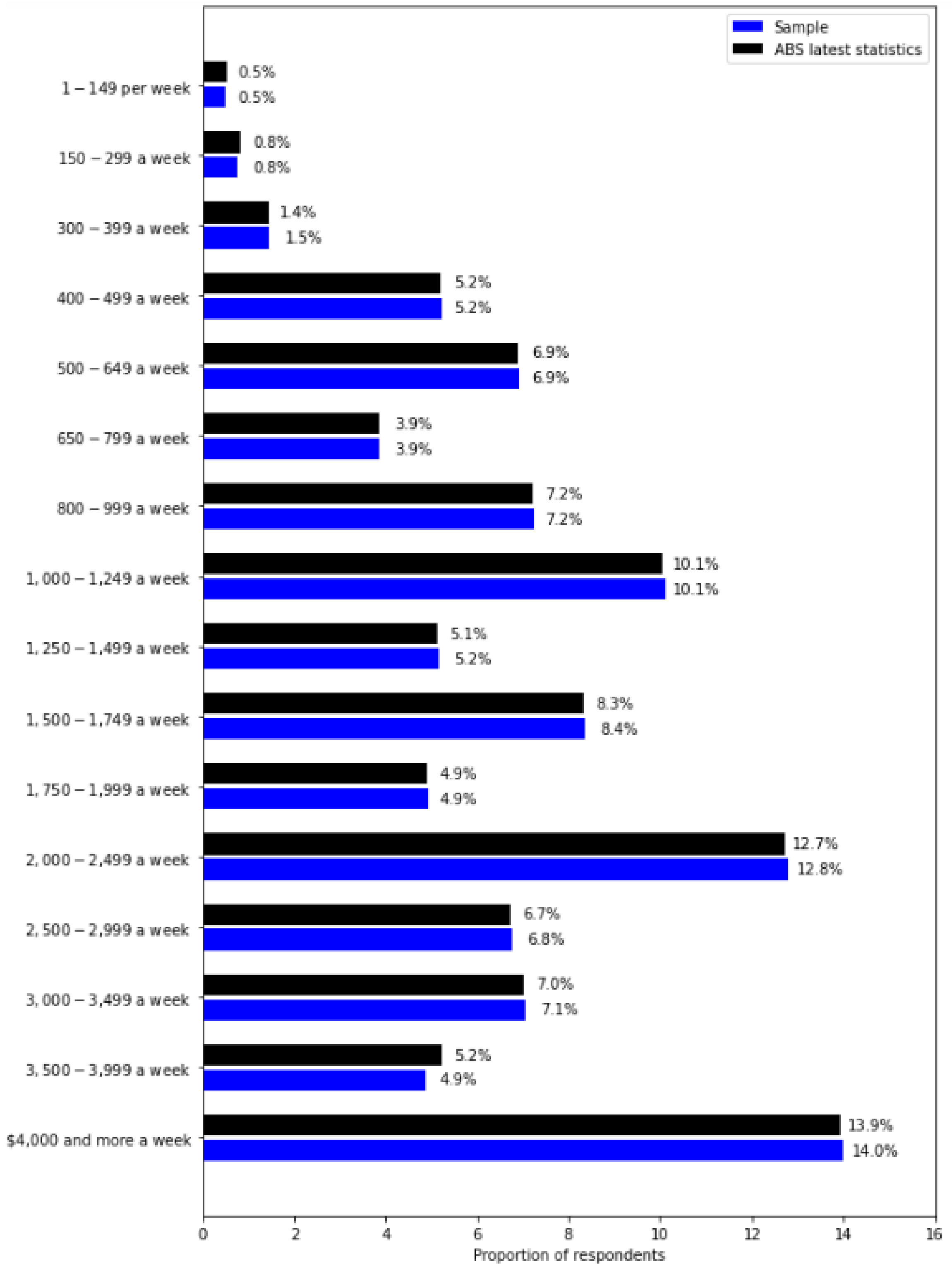
Employment:



Education:



Income:


Sample
ABS latest statistics
1 – 149 per week
150 – 299 a week
300 – 399 a week
400 – 499 a week
500 – 649 a week
650 – 799 a week
800 – 999 a week
1, 000 – 1,249 a week
1, 250 – 1,499 a week
1, 500 – 1,749 a week
1, 750 – 1,999 a week
2, 000 – 2,499 a week
2, 500 – 2,999 a week
3, 000 – 3,499 a week
3, 500 – 3,999 a week
$4,000 and more a week
0.5%
0.5%
0.8%
0.8%
1.4%
1.5%
5.2%
5.2%
6.9%
6.9%
3.9%
3.9%
7.2%
7.2%
10.1%
10.1%
5.1%
5.2%
8.3%
8.4%
4.9%
4.9%
12.7%
12.8%
6.7%
6.8%
7.0%
7.1%
5.2%
4.9%
13.9%
14.0%
0
2
4
6
8
10
12
14
16
Proportion of respondents

Appendix C-2: Survey of Australians' Preferences, Beliefs and Perceptions Related to Drone Technology & Related Services

Dear Respondent,

We thank you in advance for choosing to take part in this study. This study is being conducted by researchers from the University of South Australia with support from the Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA) and the iMOVE CRC.

What is the survey about?

This research will examine the demographic and geographic determinants of increased drone uptake for different communities and sub-populations.

Why do we need this information?

The use of drones and advanced air mobility technology is gaining momentum every day as more businesses realise the potential to improve practices across a wide range of industrial and consumer operations. However, there are many who still question the effectiveness of the technology, and have raised concerns around impacts on privacy, security and safety. The market and non-market benefits and challenges of drones may not be the same across all sectors, use cases and geographies. This survey will help us better understand community attitudes and perceptions towards the same.

What do we want you to do?

- Your level of familiarity and knowledge about drone technology and related services,
- Your attitude towards drone use in different industries,
- Your preferences for drone delivery and air travel,
- Your demographic information.

Please take as much time as you need to answer the questions. Most questions only require you to tick a box.

Please DO NOT USE the "back" and "forward" buttons in your browser. Please use the buttons at the bottom of each screen.

The survey will take about 25 minutes in total.

Note that this survey is for academic research purposes only and does not form part of any promotional activity. Your responses will be completely anonymous and only used together with those of other study participants. No identifying details will be disclosed to any third party and your anonymity will be protected. All information collected as part of this study will be retained for five years in a secured computer server at UniSA Business.

Your participation is voluntary. You are free to stop your participation at any point and withdraw from the survey at any time during the questionnaire. Please note that refusal to participate or withdrawal of your consent or discontinued participation in the study will result in loss of any payments or benefits to which you may be entitled to for participating in this survey.

This project has been approved by the UniSA Business Negligible Risk Ethics Committee 020-2022. If you have any ethical concerns about the project or questions about your rights as a participant, please contact BIS-Research@unisa.edu.au or 61 8 8302 0245.

If you have questions pertaining to your rights as a research participant, or you want further information concerning this study, you may contact Associate Professor Akshay Vij (Akshay.Vij@unisa.edu.au) or Dr. Ali Ardeshiri (Ali.Ardeshiri@unisa.edu.au) at the University of South Australia.

Consent

In submitting this form, I confirm that:

- The nature and purpose of the research project has been explained to me, and I understand and agree to take part.
- I understand the purpose of the research project and my involvement in it.
- I understand that my participation in this research project is voluntary.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I understand that while information gained during the study will be published, I will not be identified and my personal results will remain confidential, unless required by law.

Please click below to give your informed consent in this survey:

○ I CONSENT to participate in this survey

○ I do NOT CONSENT to participate in this survey

What is your year of birth?

How do you identify yourself?

- ◯ Male
- ◯ Female
- ◯ Neither
- ◯ Intersex
- ◯ Non-binary
- ◯ Prefer not to say

Please enter in your home postcode:

Postcode:

Which one of the following categories best describes your annual total household gross income (before tax)?

Please select your answer

How familiar are you with drone technology?

- ◯ Not familiar at all
- ◯ Slightly familiar
- ◯ Moderately familiar
- ◯ Very familiar

How familiar are you with drone technology?

- ( ) Not familiar at all
- (•) Slightly familiar
- ( ) Moderately familiar
- ( ) Very familiar

How have you become familiar with drones?

Please select all that apply.

- [ ] I have flown drones before
- [ ] I have seen other people fly drones
- [ ] I have received deliveries using drones
- [ ] I have read and heard about them in the media
- [ ] I have learned about them when talking to family, friends and colleagues
- [ ] Other (Please specify)

Do you know in which industries in Australia drones are currently being used?

- [ ] Agriculture, Forestry and Fishing
- [ ] Mining
- [ ] Manufacturing
- [ ] Electricity, Gas, Water and Waste Services
- [ ] Construction
- [ ] Wholesale Trade
- [ ] Retail Trade
- [ ] Accommodation and Food Services
- [ ] Transport, Postal and Warehousing
- [ ] Information Media and Telecommunications
- [ ] Financial and Insurance Services
- [ ] Rental, Hiring and Real Estate Services
- [ ] Professional, Scientific and Technical Services
- [ ] Administrative and Support Services
- [ ] Public Administration and Safety
- [ ] Education and Training
- [ ] Health Care and Social Assistance
- [ ] Arts and Recreation Services
- [ ] Other Services (Please specify)
- ( ) I don't know

Have you used drones?

- ( ) Yes
- ( ) No

Have you used drones?

- (•) Yes
- ( ) No

For what purpose have you used drones for?

Please select all that apply.

- [ ] Work
- [ ] Recreation
- [ ] Monitoring
- [ ] Security
- [ ] Shopping
- [ ] Entertainment
- [ ] Photography & videography
- [ ] Other (Please specify)

How frequently do you use drones?

- ( ) More than 5 times a week
- ( ) 4-5 times a week
- ( ) 2-3 times a week
- ( ) 1 time a week
- ( ) Less than once a week

How do you describe your level of proficiency in using drones?

- ( ) Beginner
- ( ) Developing
- ( ) Competent
- ( ) Advanced
- ( ) Expert

Do you own a drone?

- ( ) Yes
- ( ) No

Drone technologies are currently being used to address real-world challenges across a diverse array of industrial sectors. These include urban/regional air mobility, e-commerce and deliveries, agriculture, mining, construction, public services, defence and recreational use.

In the following screens, you will be shown ***five*** sets, similar to the example set below. In each set, you have to select:

- The use case that offers the most and least **value to you and your community** (Step 1);
- The use case that you think offers the most and least **value to society at large** (Step 2); and
- The use case you are most and least likely to **accept**, if and when it is deployed in practice in your community (Step 3).

You will be shown ***five*** sets similar to the example set below.

EXAMPLE ONLY

Step 1 / 3

Offers **most** value to me and my community	Use cases	Offers **least** value to me and my community
◉	**Emergency delivery (medicine, equipment, supplies):** Drones could deliver medical supplies including cold chain vaccines and blood to meet emergency medical situations much faster than by road. This would be essential in regional areas where medical facilities can be hours away by road but also in the city and its suburbs particularly through peak hour traffic.	○
○	**Crime scene investigation:** Drones could be used by the police to quickly map and assess crime scenes, including searching for evidence using multispectral and even ground penetrating sensors.	○
○	**Livestock monitoring and herding:** Drones can be very useful in real time continuous livestock monitoring (looking out for ailing ones etc.) which is critically important to prevent devastating diseases. Drones are already complementing dogs in herding roles.	◉
○	**Environmental hazard assessment:** Drones can be easily deployed to access hard-to-reach areas for acquiring data during emergencies that is unsafe or impossible for people to carry out. They also provide first responders during emergency cases with opportunities to save time, money and, most importantly, lives.	○
○	**Construction and management:** Drones can be used on site in civil engineering projects such as construction of buildings and infrastructure projects like dams & bridges. Drones facilitate better planning, analysing, designing and supervision by engineers, architects, surveyors etc. with accurate and up-to-date	○

Select the use case that offers the most & least **value to you and your community**.

Please note:

1. In each step you must select a ***most*** and ***least*** preferred use case before going to the next step. Otherwise, you will see two error messages on your screen. The first message is a note in a red box saying, "***Something went wrong!***" at the top of the page and the second error message appears below the question saying "***Please select an answer in both columns***".
2. The same option ***cannot*** be selected as the most and least preferred use case in each step. However, the same use case can be selected among different steps.

Something went wrong!

Set 2 of 5

Please select among the five listed potential use cases for drone technologies, the use case you are **most** and **least** likely to ***support***.

Please select an answer in both columns.

I am **most** likely to support this use case	Offers **most** value to society at large	Offers **most** value to me and my community	Use cases	Offers **least** value to me and my community	Offers **least** value to society at large	I am **least** likely to support this use case
◉	◉		**Crime scene investigation:** Drones could be used by the police to quickly map and assess crime scenes, including searching for evidence using multispectral and even ground penetrating sensors.	◉		○
○			**Emergency response coordination (situational awareness):** Drones could be sent to an emergency like a fire, accident or drowning much faster, and not only provide visuals but also assess the situation using various sensors and even provide assistance such as delivering defibrillators and life vests.		◉	○
○			**Disaster Management - prevention monitoring:** Drones with multiple sensors could be used to monitor fire prone areas and flood situations more routinely and tirelessly than conventionally done.			○
○			**Drones to prevent rustling:** Drones can deter rustlers by spotting thefts in progress, capturing images of culprits and their vehicles and accessories.			
○		◉	**News photography & videography:** Drone journalism can enhance the overall quality of news by being faster on the scene and providing real time images while improving the safety of journalists and cameramen who often have to put themselves in harm's way for a better view.			○

Set 1 of 5

Please select among the five listed potential use cases for drone technologies, the use case which you believe offers the **most** and **least** value to ***you and your community***.

Offers **most** value to me and my community	Use cases	Offers **least** value to me and my community
○	**Documentation (accident reporting, building verification, site status, ...):** Drones can assist with expeditious documentation of various reports such as building inspection, site inspections, crash scene inspections etc.	○
○	**Advertising & marketing:** Drones with sophisticated cameras used for movies can also produce impressive imagery to put gloss on advertising and marketing collateral.	○
○	**Entertainment (film, television, internet, ...):** Drones can continue to provide increasingly sophisticated images from hitherto impossible angles and positions for television and movie productions.	○
○	**Personal photography & videography:** For private photography and videography, mini drones can be used to take amazing images from otherwise inaccessible positions and angles.	○
○	**Pest & disease detection & treatment:** Fitted with different types of cameras and sensors drones can provide farmers invaluable data to take timely action on issues such as pests or other unwanted visitors, crop yield, weather, and other agricultural contingencies for healthier produce efficiently.	○

Set 1 of 5

Please select among the five listed potential use cases for drone technologies, the use case which you believe offers the **most** and **least** value to ***society at large***.

Offers **most** value to society at large	Offers **most** value to me and my community	Use cases	Offers **least** value to me and my community	Offers **least** value to society at large
○	◉	**Documentation (accident reporting, building verification, site status, ...):** Drones can assist with expeditious documentation of various reports such as building inspection, site inspections, crash scene inspections etc.		○
○		**Advertising & marketing:** Drones with sophisticated cameras used for movies can also produce impressive imagery to put gloss on advertising and marketing collateral.	◉	○
○		**Entertainment (film, television, internet, ...):** Drones can continue to provide increasingly sophisticated images from hitherto impossible angles and positions for television and movie productions.		○
○		**Personal photography & videography:** For private photography and videography, mini drones can be used to take amazing images from otherwise inaccessible positions and angles.		○
○		**Pest & disease detection & treatment:** Fitted with different types of cameras and sensors drones can provide farmers invaluable data to take timely action on issues such as pests or other unwanted visitors, crop yield, weather, and other agricultural contingencies for healthier produce efficiently.		○

Set 1 of 5

Please select among the five listed potential use cases for drone technologies, the use case you are **most** and **least** likely to ***support***.

I am **most** likely to support this use case	Offers **most** value to society at large	Offers **most** value to me and my community	**Use cases**	Offers **least** value to me and my community	Offers **least** value to society at large	I am **least** likely to support this use case
○	◉	◉	**Documentation (accident reporting, building verification, site status, …):** Drones can assist with expeditious documentation of various reports such as building inspection, site inspections, crash scene inspections etc.			○
○			**Advertising & marketing:** Drones with sophisticated cameras used for movies can also produce impressive imagery to put gloss on advertising and marketing collateral.	◉	◉	○
○			**Entertainment (film, television, internet, …):** Drones can continue to provide increasingly sophisticated images from hitherto impossible angles and positions for television and movie productions.			○
○			**Personal photography & videography:** For private photography and videography, mini drones can be used to take amazing images from otherwise inaccessible positions and angles.			○
○			**Pest & disease detection & treatment:** Fitted with different types of cameras and sensors drones can provide farmers invaluable data to take timely action on issues such as pests or other unwanted visitors, crop yield, weather, and other agricultural contingencies for healthier produce efficiently.			○

As mentioned previously, drones are increasingly being used for the delivery of small items, such as groceries, medicines and food. These drone-based services could be expanded to provide an alternative to existing postal, mail and other delivery services.

How much do you like or dislike the idea of drone delivery services?

- ○ Like it a lot
- ○ Like it a moderate amount
- ○ Like it a little
- ○ Neutral
- ○ Dislike it a little
- ○ Dislike it a moderate amount
- ○ Dislike it a lot

If a drone delivery service was available to you, how likely are you to use it?

- ○ Highly likely
- ○ Somewhat likely
- ○ Somewhat unlikely
- ○ Highly unlikely
- ○ I have already used it

If a drone delivery service was available to you, how likely are you to use it?

- ○ Highly likely
- ● Somewhat likely
- ○ Somewhat unlikely
- ○ Highly unlikely
- ○ I have already used it

If a drone service was available to you, how frequently would you use it?

- ○ More than once a week
- ○ Once a week
- ○ Once a fortnight
- ○ Once a month
- ○ Once a quarter
- ○ Once a semester
- ○ Once a year
- ○ Less than once a year
- ○ Never

In the next section, we would like to understand more about your willingness to use a drone delivery service to receive different items. These items could be **letters, food, medicine** and **other goods**.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented two delivery options for the specific item you have ordered. The options will vary in terms of delivery method (manned v. drone delivery) and time, tracking option, service reliability, chance of damage and delivery cost, such as the example shown below. You will be asked to indicate the option that you would most prefer to use for delivery of this item. Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

	Option 1	Option 2
Delivery item	Letters	
Delivery size	Up to 125g	
Delivery method	Drone delivery	Traditional delivery
Delivery time	Less than 1 hour	1-2 days
Track real time location	Yes	No
Reliability of service	10 out of 10 on time	8.5 out of 10 on time
Chance of damage	2 in 100	1 in 100
Cost of delivery	$5.50	$3.50
Option I most prefer	○	○

Scenario 1 of 8

Consider the two delivery services shown to receive the following items. Please select the option that you would most prefer to use for delivery of this item.

	Option 1	Option 2
Delivery item	Other goods	
Delivery size	Less than 1kg	
Delivery method	Drone delivery	Traditional delivery
Delivery time	60 minutes or less	Same day
Track real time location	Yes	Yes
Reliability of service	10 out of 10 on time	8 out of 10 on time
Chance of damage	1 in 100	1 in 100
Cost of delivery	$36.00	$30.00
Option I most prefer	○	○

In general, how supportive are you of small-scale drones being used for commercial applications? Rate your level of agreement or disagreement with the following statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I don't want to see drones commercially deployed in practice at all	○	○	○	○	○
I am willing to accept drones being used for specialised use cases where they offer high value	○	○	○	○	○
I am supportive of drones being deployed in practice wherever they offer value	○	○	○	○	○

How concerned are you about the use of small-scale drones by the general public?

Not at all concerned	Slightly concerned	Somewhat concerned	Moderately concerned	Extremely concerned

On a scale of 1-5, please indicate how concerned are you about the following potential impacts of small-scale drone technologies?

	Not at all concerned				Very concerned
Noise pollution	1	2	3	4	5
Invasion of privacy	1	2	3	4	5
Safety risks to the general public	1	2	3	4	5
Threat of damage to property	1	2	3	4	5
Disturbance to wildlife	1	2	3	4	5
Reduce the beauty of the sky	1	2	3	4	5
Loss of jobs and employment	1	2	3	4	5
Disturbance to cultural sites	1	2	3	4	5
Impact on airspace use for other activities	1	2	3	4	5

What do you think are the key benefits of increased small – scale drone uptake for your community?

What do you think are the key challenges of increased small – scale drone uptake for your community?

Large-sized drones of the size of commercial helicopters and aircrafts, such as those shown below, are currently under research and development for transporting passengers and goods in the future (i.e. flying cars).

Would you be willing to use flying cars for travelling in the future?

- ◯ Yes, I am willing to use flying cars for travelling in the future
- ◯ No, I am not willing to use flying cars for travelling in the future
- ◯ Not sure yet

Are you willing to purchase a flying car if it becomes available?

- ◯ Yes, I am willing to purchase a flying car if it becomes available
- ◯ No, I am not willing to purchase a flying car if it becomes available
- ◯ Not sure yet

Would you be willing to use flying cars for travelling in the future?

- ◉ Yes, I am willing to use flying cars for travelling in the future
- ◯ No, I am not willing to use flying cars for travelling in the future
- ◯ Not sure yet

For which distances are you willing to travel using flying cars?

Please note that you can move both the lower and upper bars to indicate the range you are willing to travel.

0km — **200km or more**

Are you willing to purchase a flying car if it becomes available?

- ◉ Yes, I am willing to purchase a flying car if it becomes available
- ◯ No, I am not willing to purchase a flying car if it becomes available
- ◯ Not sure yet

Would you be willing to use flying cars for travelling in the future?

- ○ Yes, I am willing to use flying cars for travelling in the future
- ◉ No, I am not willing to use flying cars for travelling in the future
- ○ Not sure yet

Please explain why you would not be willing to travel in flying cars in the future:

Are you willing to purchase a flying car if it becomes available?

- ◉ Yes, I am willing to purchase a flying car if it becomes available
- ○ No, I am not willing to purchase a flying car if it becomes available
- ○ Not sure yet

In this section, we would like you to consider a trip within your city that you have made recently, such that:

- It took you more than **15 minutes** to get from your starting point to your destination; and
- You did **not** ***walk*** or ***cycle*** the entire way

This could be your trip to work, place of education, shopping or a visit to family & friends. In the questions that follow, we will ask for more details about this recent trip.

At what time did you start this trip?

Please select your answer

What was the purpose of this trip?

- Work
- Education
- Shopping
- Visiting family and friends
- Sports and exercise
- Leisure and entertainment
- Health and wellbeing
- Other (Please specify)

How many people travelled together on this trip?

- I was travelling by myself
- 2 people
- 3 people
- 4 people
- 5 people
- 6 people
- 7 people
- Other (Please specify)

Which of the following modes of transport did you use for this trip?

If you used multiple travel modes to complete your journey, please select the one you spent the longest time travelling in.

- Car
- Motorcycle
- Electric scooter
- Bus
- Train
- Tram
- Taxi/Uber
- Ferry

How long did you spend in the car to travel to your destination?

minutes

How far did you travel for this trip?

Your best guess is good enough.

km

How much did you pay for this trip (per passenger)?

Please include fuel costs, parking costs, and any other out-of-pocket costs. Your best guess is good enough.

$ per passenger

How much time (in minutes) did you spend travelling from your starting point to your car?

If it was less than a minute, please answer 1 minute.

minute(s)

How much time (in minutes) did you spend walking to your destination from where you parked your car?

If it was less than a minute, please answer 1 minute.

minute(s)

How reliable do you think this travelling with car is in general?

If multiple services were used, please consider the one that you have spent the longest travelling with.

- Less than 8 out of 10 on time
- 8 out of 10 on time
- 8.5 out of 10 on time
- 9 out of 10 on time
- 9.5 out of 10 on time
- 10 out of 10 on time

How much time (in minutes) did you spend travelling from your starting point to the bus stop?

If it was less than a minute, please answer 1 minute.

________ minute(s)

How much time (in minutes) did you spend in the bus to reach your final stop?

________ minute(s)

How much time (in minutes) did you spend travelling from the bus stop to your final destination?

If it was less than a minute, please answer 1 minute.

________ minute(s)

How far did you travel for this trip?

Your best guess is good enough.

________ km

How much did you pay for this trip (per passenger)?

Your best guess is good enough.

$ ________ per passenger

How reliable do you think travelling via bus is in general?

If multiple services were used, please consider the one that you have spent the longest travelling with.

- ○ Less than 8 out of 10 on time
- ○ 8 out of 10 on time
- ○ 8.5 out of 10 on time
- ○ 9 out of 10 on time
- ○ 9.5 out of 10 on time
- ○ 10 out of 10 on time

In this section of the survey, we would like to understand your willingness to use drones for intra-city travel. We would like you to consider the same recent **Shopping** trip you made at **6:35 AM** including all passengers that accompanied you for this journey as you mentioned in the previous question.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented the option of making the same trip using a drone passenger transport service, defined in terms of travel times, costs, reliability, etc., such as the example shown below. We have also provided the same details for your current mode of transport for this recent trip. For each scenario, you will be asked to indicate the option that you would most prefer to use for this trip.

Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	25 minutes	35 minutes
Access time (Time spent walking from starting point to drone pick-up point)	5 minutes	2 minutes
Egress time (Time spent walking from drone drop-off point to final destination)	5 minutes	10 minutes
Travel cost (per passenger)	$2.40	$3.50
Reliability of service	8 out of 10 on time	9 out of 10 on time
Option I most prefer	○	○

Scenario 1 of 8

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	25 minutes	35 minutes
Access time (Time spent walking from starting point to drone pick-up point)	3 minutes	2 minutes
Egress time (Time spent walking from drone drop-off point to final destination)	10 minutes	10 minutes
Travel cost (per passenger)	$10.00	$3.50
Reliability of service	Less than 8 out of 10 on time	9 out of 10 on time
Option I most prefer	○	○

How frequently do you use the following modes of transportation? Please select the option that best corresponds to your usage.

	Daily	A few times a week	Few times a month	Rarely or never	Unavailable	Do not use
Private transport modes (owned by yourself, family, friend, employer, etc)						
Car as driver	○	○	○	○	○	○
Car as passenger	○	○	○	○	○	○
Motorcycle or similar	○	○	○	○	○	○
Bicycle/pushbike	○	○	○	○	○	○
Walking	○	○	○	○	○	○
Public transport services (owned and operated by a third party)						
Buses	○	○	○	○	○	○
Trains, trams, light rail	○	○	○	○	○	○
Ferries	○	○	○	○	○	○
Taxis	○	○	○	○	○	○
Rental car (e.g. Hertz, Thrifty)	○	○	○	○	○	○
Carshare (e.g. GoGet)	○	○	○	○	○	○
Rideshare (e.g. UberX)	○	○	○	○	○	○
Bikeshare (e.g. Reddygo, Melbourne Bike Share, City Cycles)	○	○	○	○	○	○

For what trip length ranges are you most likely to use drones?

Select all that apply.

- ☐ Short distance (<10km)
- ☐ Medium distance (10-20km)
- ☐ Long distance (30-50km)
- ☐ Very long distance (>50km)
- ○ None

In this section, we would like you to consider a ***trip from your city to a regional centre*** that you have made recently which was longer than ***30 minutes***. In the screens that follow, we will ask some questions about this recent trip.

How often do you travel to regional and remote areas in Australia (anywhere outside the capital cities)?

- ○ Never
- ○ 1-2 times a year
- ○ 3-5 times a year
- ○ 6-10 times a year
- ○ More than 10 times a year

In this section, we would like you to consider a ***trip from your city to a regional centre*** that you have made recently which was longer than ***30 minutes***.
In the screens that follow, we will ask some questions about this recent trip.

How often do you travel to regional and remote areas in Australia (anywhere outside the capital cities)?

- (•) Never
- ( ) 1-2 times a year
- ( ) 3-5 times a year
- ( ) 6-10 times a year
- ( ) More than 10 times a year

How often do you travel to another capital city in Australia?

- ( ) Never
- ( ) 1-2 times a year
- ( ) 3-5 times a year
- ( ) 6-10 times a year
- ( ) More than 10 times a year

Which city or town did you travel to?

Please type the name of the city/town and select from the drop down list.

At what time did you start this trip?

Please select your answer

What was the purpose of this trip?

- Work
- Education
- Shopping
- Visiting family and friends
- Sports and exercise
- Leisure and entertainment
- Health and wellbeing
- Other (Please specify)

How many people travelled together on this trip?

- I was travelling by myself
- 2 people
- 3 people
- 4 people
- 5 people
- 6 people
- 7 people
- Other (Please specify)

Which of the following modes of transport did you use for this trip?

If you used multiple travel modes to complete your journey, please select the one you spent the longest time travelling in.

- Car
- Motorcycle
- Electric scooter
- Bus
- Train
- Tram
- Taxi/Uber
- Ferry
- Aeroplane

In this section of the survey, we would like to understand your willingness to use drones for long-distance inter-city (this could be a trip to capital city, reginal city or remote areas) travel. We would like you to consider the same recent **Visiting family and friends** trip you made at **6:35 AM** including all passengers that accompanied you for this journey as you mentioned in the previous question.

In the screens that follow, we will show you ***eight*** hypothetical scenarios. For each scenario, you will be presented the option of making the same trip using a drone passenger transport service, defined in terms of travel times, costs, reliability, etc., such as the example shown below. We have also provided the same details for your current mode of transport for this recent trip. For each scenario, you will be asked to indicate the option that you would most prefer to use for this trip.

Please think about each scenario independently of the previous scenarios.

EXAMPLE ONLY

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	42 minutes	60 minutes
Access time (Time spent walking from starting point to drone pick-up point)	8 minutes	1 minute
Egress time (Time spent walking from drone drop-off point to final destination)	8 minutes	15 minutes
Travel cost (per passenger)	$8.00	$10.00
Reliability of service	8 out of 10 on time	9.5 out of 10 on time
Option I most prefer	○	○

Scenario 1 of 8

Think of the same recent trip you mentioned in the previous question. Now imagine that only the following transport options were available to you. Which would you most likely choose?

	Option 1	Option 2 (Your current trip)
Travel mode	Drone passenger transport service	Car
In vehicle travel time	72 minutes	60 minutes
Access time (Time spent walking from starting point to drone pick-up point)	11 minutes	1 minute
Egress time (Time spent walking from drone drop-off point to final destination)	18 minutes	15 minutes
Travel cost (per passenger)	$6.00	$10.00
Reliability of service	8.5 out of 10 on time	9.5 out of 10 on time
Option I most prefer	○	○

Which mode(s) of transport do you usually use when undertaking long-distance travel in Australia?

Select all that apply.

- ☐ Car
- ☐ Motorcycle
- ☐ Electric scooter
- ☐ Bus
- ☐ Train
- ☐ Tram
- ☐ Taxi/Uber
- ☐ Ferry
- ☐ Aeroplane
- ☐ Other (Please specify)

Have you been involved in a traffic accident in the last 5 years?

- ○ Yes
- ○ No

Do any of the following impact on your ability to get around?

- ☐ My vision
- ☐ My hearing
- ☐ Impaired mobility
- ☐ My manual dexterity (ability to use hands)
- ☐ My ability to remember things
- ☐ General poor health
- ☐ Other (Please specify)
- ○ My ability to get around is not impacted

Please indicate how much you personally agree with each of the following statements related specifically to the use of drone technology for flying cars?

	Strong disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would be comfortable entrusting the safety of a close family member to flying cars, if deemed safe by the Australian government	○	○	○	○	○
I would be comfortable using flying cars with no pilot, if deemed safe by the Australian government	○	○	○	○	○
I would be comfortable sharing flying cars with other passengers	○	○	○	○	○
I would be comfortable using flying cars by myself	○	○	○	○	○
I would use flying cars for daily travel	○	○	○	○	○
I would use flying cars for long-distance inter-city travel	○	○	○	○	○
I would be interested to be trained and work in the drones industry	○	○	○	○	○
Flying cars allow mobility for people with driving impairments or restrictions (e.g. medical conditions, vision impairments)	○	○	○	○	○
Flying cars will reduce my travel time	○	○	○	○	○
Flying cars will allow me/my family to travel more easily	○	○	○	○	○
I am concerned about learning to operate/use a flying car	○	○	○	○	○
I would most likely relocate further away from the city centre with introduction of flying cars	○	○	○	○	○
I would most likely relocate to a remote area once flying cars become available	○	○	○	○	○

What do you think are the key benefits of increased flying car uptake for your community?

What do you think are the key challenges of increased flying car uptake for your community?

In this final section we like to know more about your socio-demographic information.

Which of the following best describes your household?

Family household

- ◯ Couple family with no children
- ◯ Couple family with children
- ◯ One parent family

Other family

- ◯ Single person household
- ◯ Group household (i.e., shared)
- ◯ Multi-generational families

How many individuals aged 65 or more live in your household?

Which of the following best describes your current dwelling (house or unit where you live)?

- ◯ Free standing house
- ◯ Semi-detached, in a row of terrace houses, townhouse, etc.
- ◯ Flat, unit or apartment
- ◯ Other dwelling (e.g. caravan, cabin, houseboat, or improvised home)

Is this dwelling:

- ◯ Owned outright
- ◯ Owned with a mortgage
- ◯ Being purchased under a shared equity scheme
- ◯ Being rented
- ◯ Being occupied rent free
- ◯ Being occupied under a life tenure scheme
- ◯ Other (Please specify)

Which of the following best describes your current work status?

- ◯ Employed full time
- ◯ Employed part time
- ◯ Unemployed
- ◯ Not in the labour force - Stay-at-home parent or caregiver
- ◯ Not in the labour force -Full-time student
- ◯ Not in the labour force - Retired
- ◯ Not in the labour force - Other

What is the highest level of education you have completed?

- ◯ PhD
- ◯ Master's Degree or equivalent
- ◯ Graduate Diploma or Graduate Certificate from university or equivalent
- ◯ Bachelor Degree or equivalent
- ◯ Advanced Diploma or Diploma from university/TAFE or equivalent
- ◯ Certificate or equivalent (e.g. Certificate III & IV or Certificate I & II)
- ◯ Year 12 or below
- ◯ Did not go to school

How many registered motor vehicles are owned or used by your household?

- *Include vans and company vehicles kept at home.*
- *Exclude motorbikes and motor scooters.*

◯ Specify number

◯ None

How many motorbikes or motor scooters are owned or used by your household?

◯ Specify number

◯ None

Before you submit the survey, if you have any opinions regarding this survey, please type in the box below. This will help us to improve our future surveys.

This concludes the survey. Thank you very much for your valuable time and feedback.

Appendix C-3: Best/Worst Choice Model

Best/worst scaling is a type of discrete choice experiment (DCE) developed by Louviere in 1988 that asks people to not only report the 'top' choice in each choice set, but also the 'bottom' choice (Finn & Louviere, 1992; Marley & Louviere, 2005). It is based on the idea that when individuals face choices among collections of three or more items or options, although they might not give sufficient thought to middle rankings, they can easily identify the best and worst options in the collection (Helson, 1964).

The options from which respondents choose 'best' and 'worst' can vary in terms of the degree of complexity (Flynn, 2010). The choice mechanism we used simply quantifies how respondents rank the different drone use cases. This type of DCE avoids known problems with category rating scales (Baumgartner & Steenkamp, 2001; Lee et al., 2007). Those scales ask respondents to rate the importance of several options; for example, this rating might be on a scale of 1 to 7, where '7' is very important and '1' is unimportant. The problems in doing this are as follows:

- This does not force respondents to make trade-offs: If one person rates most items as '7', one does not know the item that is most important if all options cannot be made available.
- Different people use rating scales differently, such as owing to cultural background differences; therefore, one individual's '7' may not be the same as another's '7' (although, generally speaking, it is not possible to determine whether these are the same).
- Rating scales lack theoretical justification; thus, there is no basis for assuming that such scales produce measures that provide information other than merely a rank ordering.

Some surveys avoid these problems by asking respondents to rank the options of interest (e.g. most important and second most important). This forces respondents to decide on the relative importance of options, but has two other problems:

- Many respondents find ranking exercises difficult and pay less attention to 'middle' rankings.
- Rankings only reveal that option *x* is preferred to option *y* but do not reveal the extent to which option x is preferred to option *y*.

To avoid these problems, a DCE was used in this study to ascertain respondents' opinion on the drone use cases that matter the most for their community and for society at large as well the drone use they find acceptable to be used commercially. This method provides a robust and accurate ranking of relative importance assigned by individuals to different drone use cases.

Appendix C-4: Latent Class Choice Models

Latent class choice models (LCCMs) are finite mixtures of discrete choice models. They were first developed in the field of marketing sciences as tools to identify relatively homogeneous consumer segments that differ substantially from each other in terms of their behaviour in the marketplace (Kamakura & Russell, 1989). They have since emerged as a very popular form of discrete choice model, finding application in a wide variety of disciplines, including but not limited to transportation.

In our case, LCCMs allow us to identify segments in the population that differ in terms of their preferences for the various research questions in this study. These are:

1. the value of drone use cases for the community,
2. consumer preferences for drone freight delivery services and
3. consumer preferences for using flying cars for intracity and intercity travel.

LCCMs comprise two components: a class membership model and a class-specific choice model. The former formulates the probability that a decision-maker belongs to a particular segment, or class, as some function of the characteristics of the decision-maker. Conditioned on the class to which the decision-maker belongs, the class-specific choice model formulates the probability that the decision-maker chooses a particular alternative as some function of the attributes of all of the alternatives in the choice set.

We begin with a description of the class membership model, formulated in our case as the familiar multinomial logit function:

$$\mathrm{P}(\mathrm{q}_{ns} = 1) = \frac{\exp(\mathbf{z}_{\mathbf{n}}'\boldsymbol{\gamma}_{s})}{\sum_{\mathbf{s}'=\mathbf{1}}^{\mathrm{S}} \exp(\mathbf{z}_{n}'\boldsymbol{\gamma}_{\mathbf{s}'})} \tag{1}$$

where q_{ns} equals 1 if household h belongs to Class *s*, and 0 otherwise; $\mathbf{z}_{\boldsymbol{n}}$ is a vector of decision-maker characteristics, such as age, gender, income and household structure; $\boldsymbol{\gamma}_{\boldsymbol{s}}$ is a vector of class-specific parameters denoting sensitivity to the decision-maker characteristics; and *S* is the total number of classes.

Next, we describe the class-specific choice model. In each task, each decision-maker is shown several different scenarios, and each scenario presents a choice between different drone services. The decision-maker is asked to indicate the option they prefer. Therefore, for a given decision-maker *n* and scenario *t*, the class-specific choice model predicts the probability that option *j* is preferred.

Let $\mathrm{u}_{\mathrm{ntj|s}}$ be the utility of alternative $\boldsymbol{j}$ for scenario *t* and decision-maker *n*, conditional on the decision-maker belonging to Class *s*, specified as follows:

$$\mathrm{u}_{\mathrm{ntj|s}} = \mathbf{x}_{\mathbf{ntj}}'\boldsymbol{\beta}_{s} + \varepsilon_{\mathrm{ntj|s}} \tag{2}$$

where X_{ntj} is a vector of attributes specific to the option; $\boldsymbol{\beta}_{\mathbf{s}}$ is the vector of class-specific parameters denoting sensitivities to these attributes; and $\varepsilon_{\mathrm{ntj|s}}$ is the stochastic component of the utility specification, assumed for the sake of mathematical convenience to be i.i.d. Gumbel with location 0 and scale 1 across schemes, scenarios and decision-makers. Assuming the decision-makers are utility-maximisers, the class-specific probability that alternative *j* is preferred over the other alternatives is given by the logit expression:

$$\mathrm{P}\left(\mathrm{y_{ntj}} = 1 | \mathrm{q_{ns}} = 1\right) = \mathrm{P}\left(\mathrm{u_{ntj|s}} \geq \mathrm{u}_{\mathrm{nt}j'|\mathrm{s}}\ \forall j' = 1, \dots, \mathrm{J}\right) = \frac{\exp\left(\mathrm{x'_{ntj}} \beta_s\right)}{\sum_{j'}^{J} exp\left(X'_{\mathrm{nt}j'} \beta_s\right)} \tag{3}$$

where $\mathrm{y_{ntj}}$ equals 1 if arrangement *j* is preferred, and 0 otherwise; and *J* is the number of alternatives shown to the decision-maker for any scenario. Note that heterogeneity in the decision-making process is captured by allowing the taste parameters $\boldsymbol{\beta_s}$ to vary across classes.

Equation (3) may be combined iteratively over alternatives and scenarios to yield the following class-specific probability of observing the vectors of choices y_n:

$$\mathrm{P}(\mathbf{y_n} | \mathrm{q_{ns}} = 1) = \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\mathrm{P}\left(\mathrm{y_{ntj}} = 1 | \mathrm{q}_{ns} = 1\right)\right]^{\mathrm{y_{ntj}}} \tag{4}$$

where $\mathbf{y_n} = \langle \boldsymbol{y_{n11}}, \dots, \boldsymbol{y_{nTJ}} \rangle$; and *T* is the number of scenarios shown to a single decision-maker.

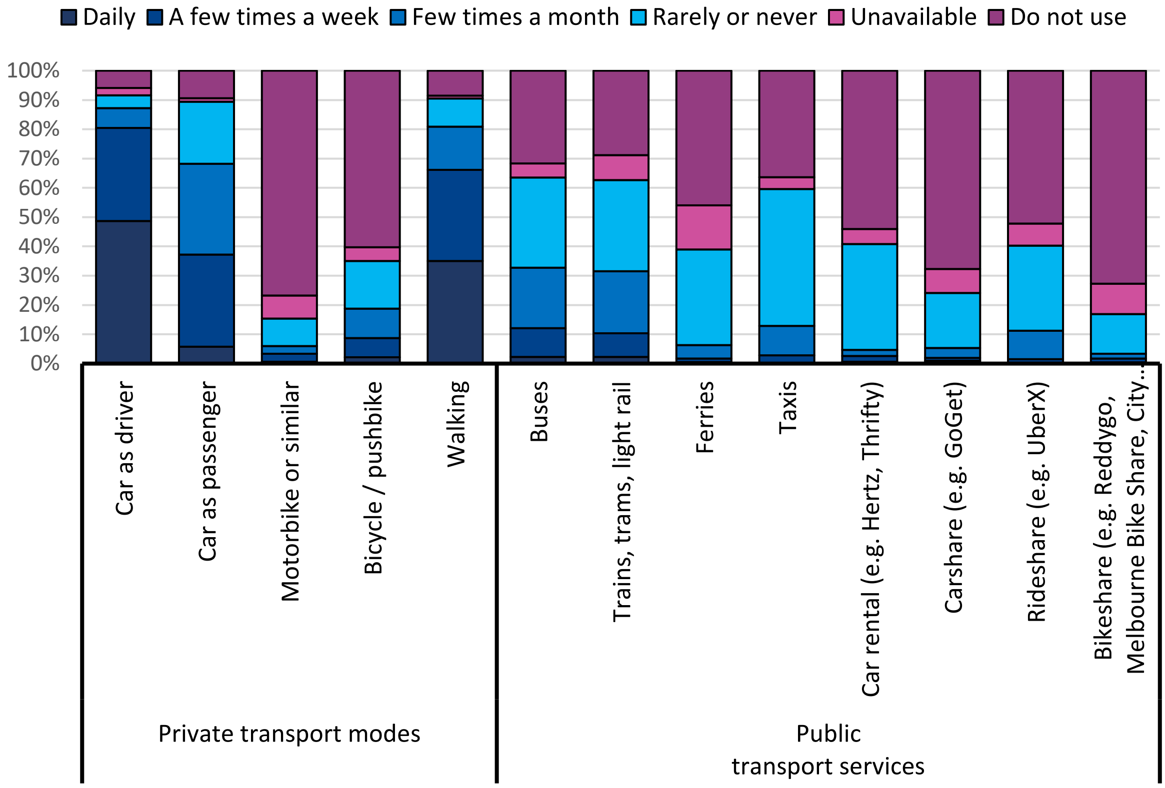
Equations (1) and (4) may be combined and marginalised over classes, to yield the unconditional probability of observing the vectors of choices $\mathbf{y_n}$, which, in turn, may be combined iteratively over decision-makers to yield the following likelihood function for the data:

$$\mathrm{L}(\boldsymbol{\beta}, \boldsymbol{\gamma} | \mathbf{y}, \mathbf{w}, \mathbf{x}, \mathbf{z}) = \prod_{\mathrm{n}=1}^{\mathrm{N}} \sum_{\mathrm{s}=1}^{\mathrm{S}} \mathrm{P}(\mathbf{y_n} | \mathrm{q_{ns}} = 1) \mathrm{P}(\mathrm{q_{ns}} = 1) \tag{5}$$

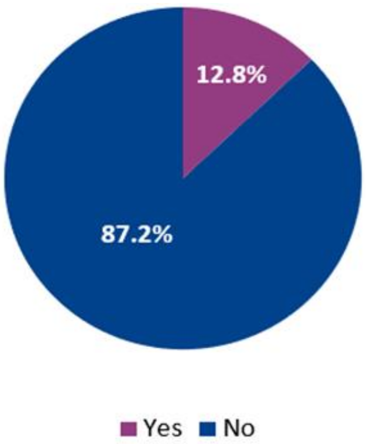
The unknown model parameters $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ may be estimated by maximising the likelihood function. All models for this study were estimated using the software package PandasBiogeme (Bierlaire, 2016). Because we stratified our sample exogenously according to demographic and geographic variables, we did not reweight the sample during model estimation (Ben-Akiva & Lerman, 1985).

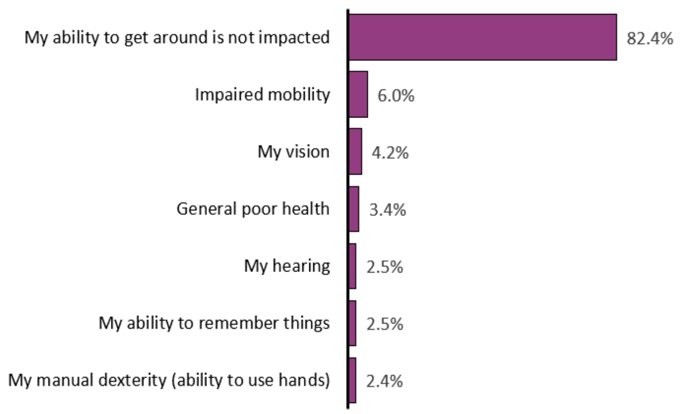
Appendix C-5: Mobility-related Response

How frequently do you use the following modes of transportation?



(a) Have you been involved in a traffic accident in the last 5 years? (b) Do any of the following impact on your ability to get around?

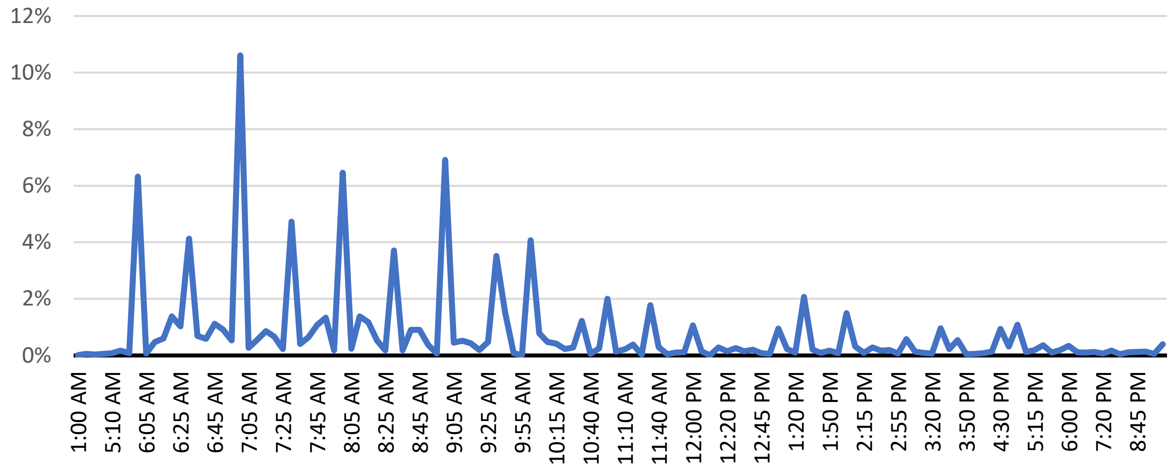




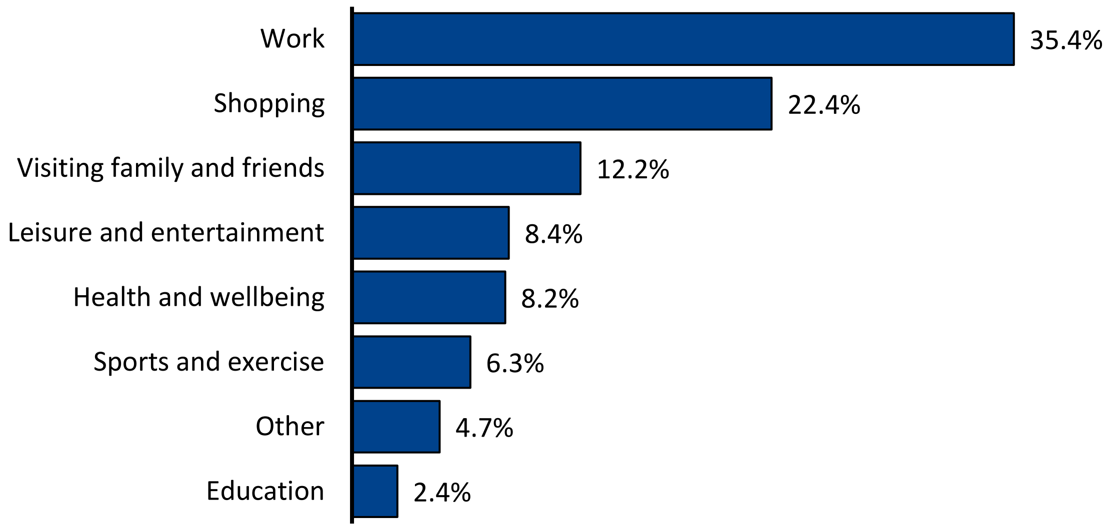
(a) (b)

Appendix C-6: Recent Trip for Intracity Travel Responses

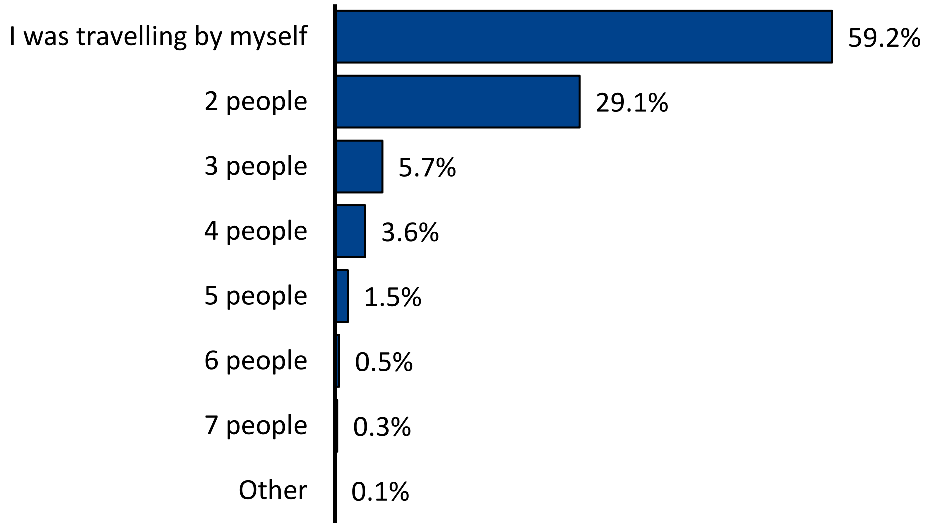
At what time did you start this trip?



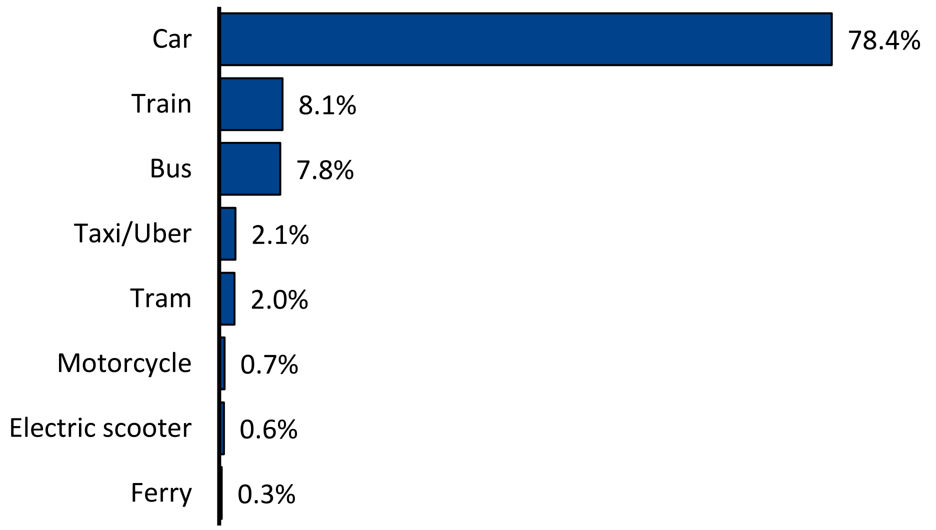
What was the purpose of this trip?



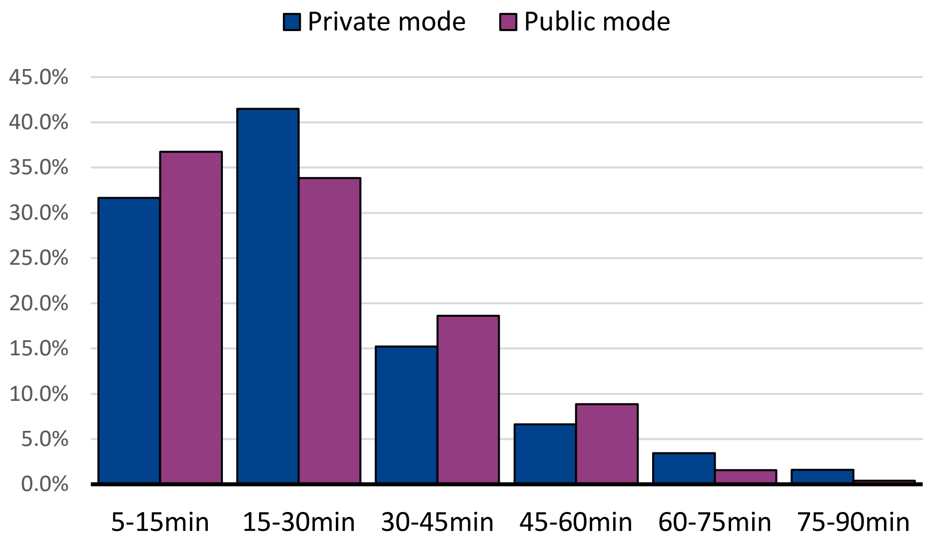
How many people travelled together on this trip?



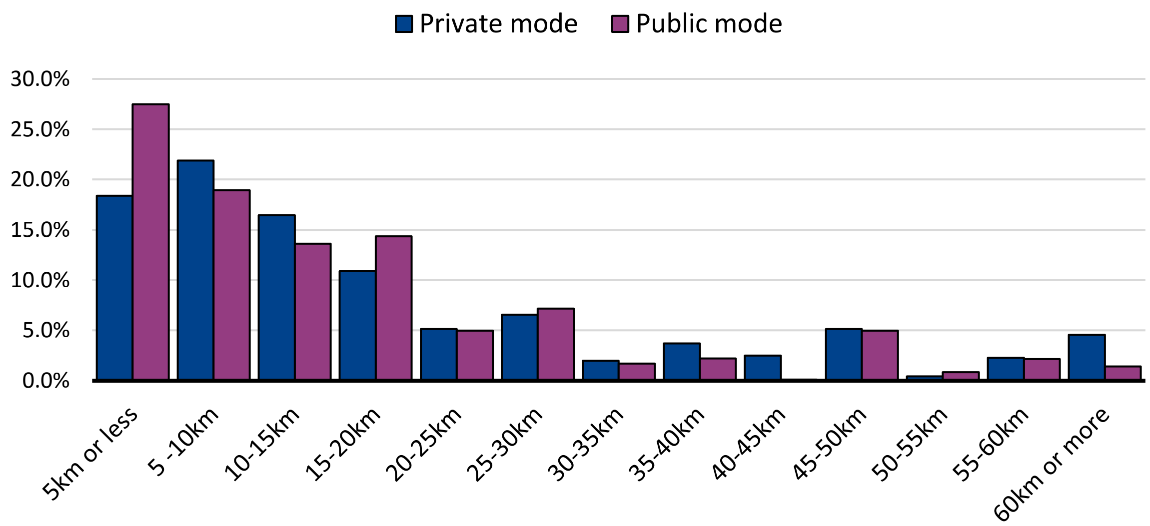
Which of the following modes of transport did you use for this trip? If you used multiple travel modes to complete your journey, please select the one with which you spent the longest time travelling.



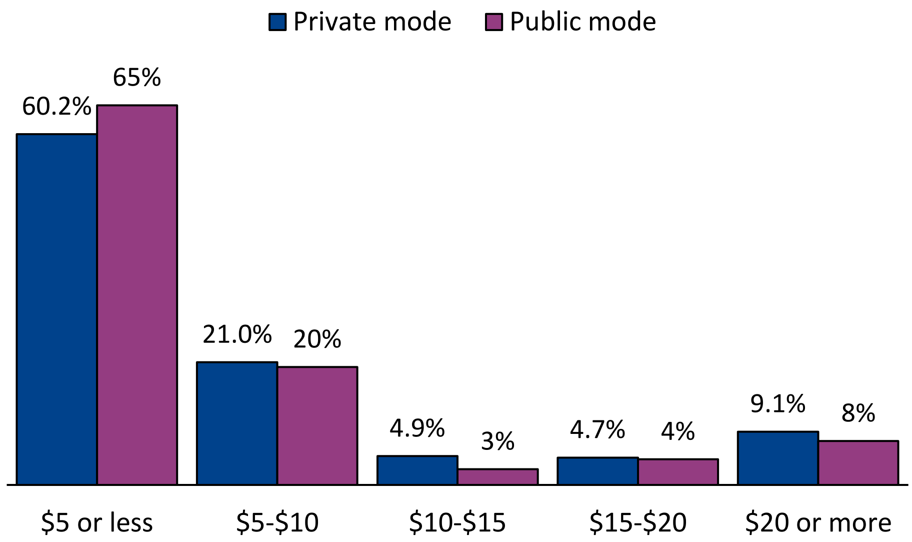
How much time (in minutes) did you spend travelling to your destination?



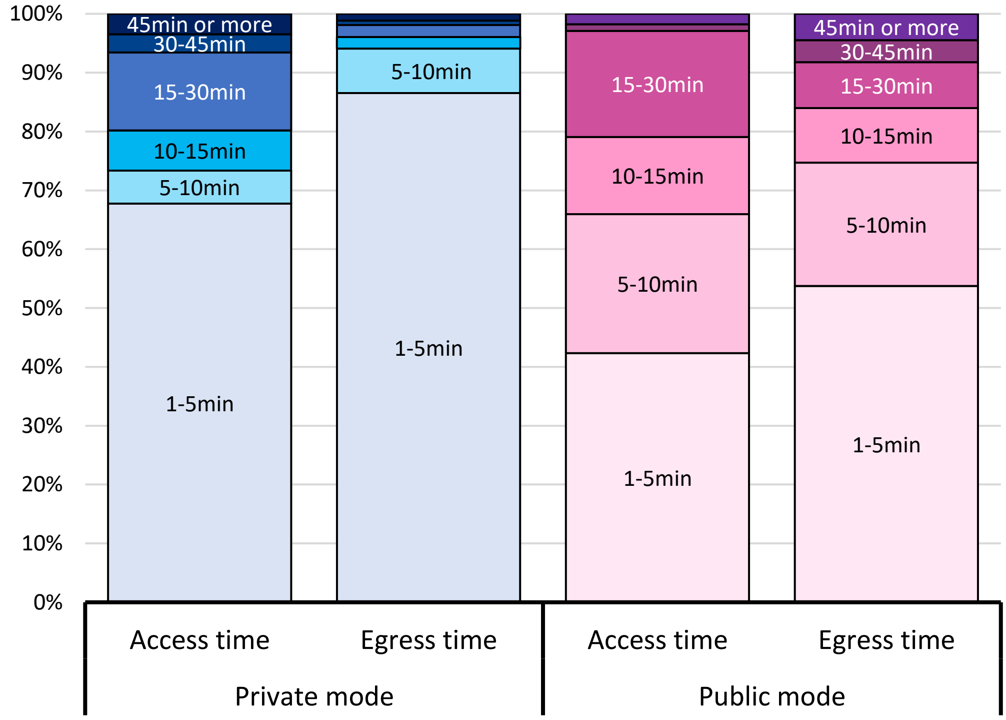
How far did you travel for this trip? Your best guess is good enough.



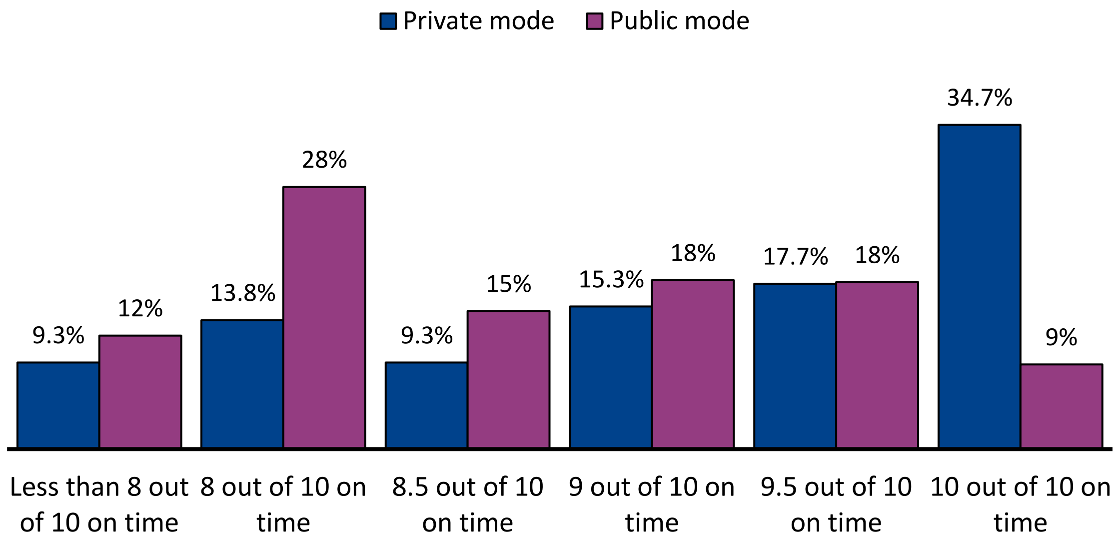
How much did you pay for this trip (per passenger)?



How much time (in minutes) did you spend travelling from your starting point as well as getting to your final destination.

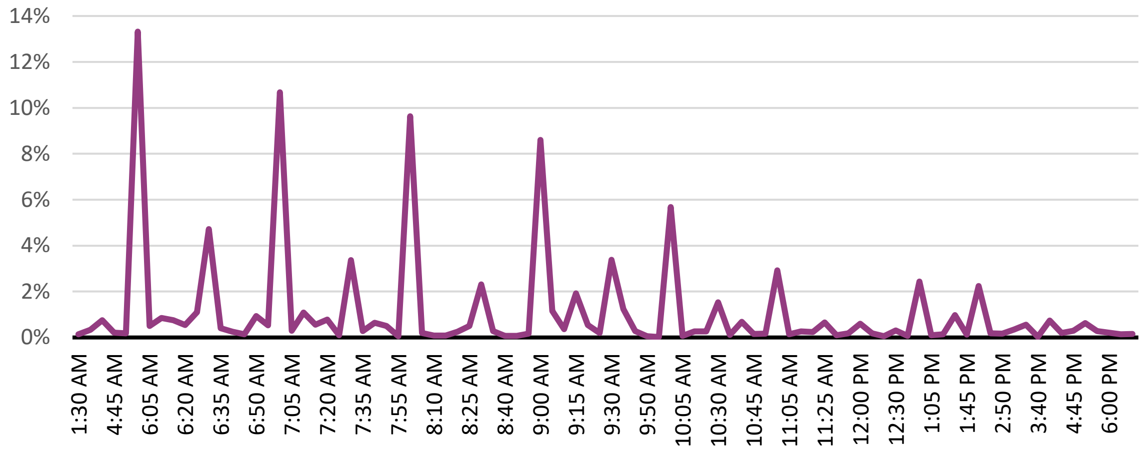


How reliable do you think this mode is in general?

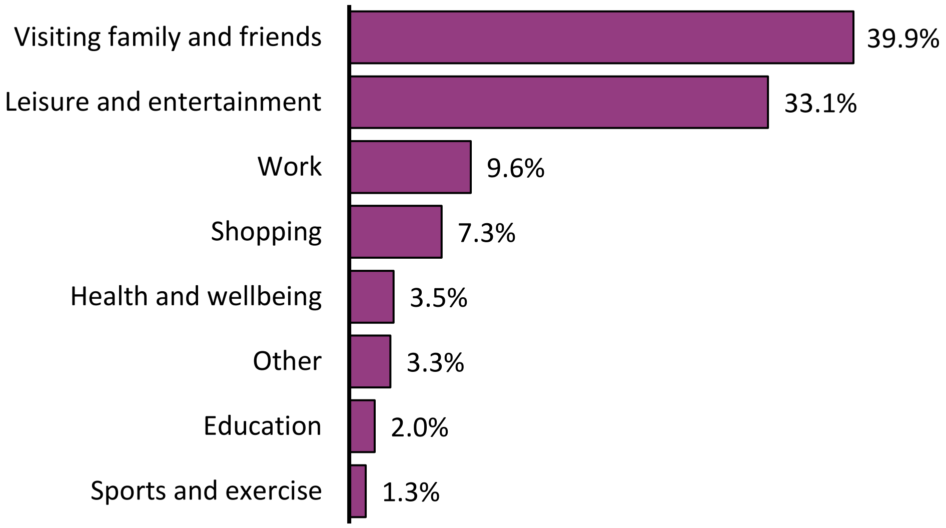


Appendix C-7: Recent Trip for Intercity Travel Responses

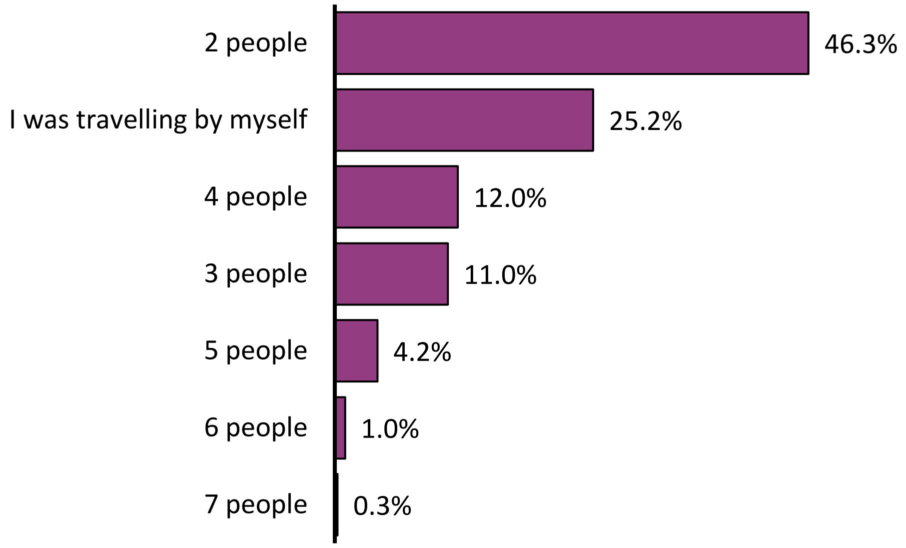
At what time did you start this trip?



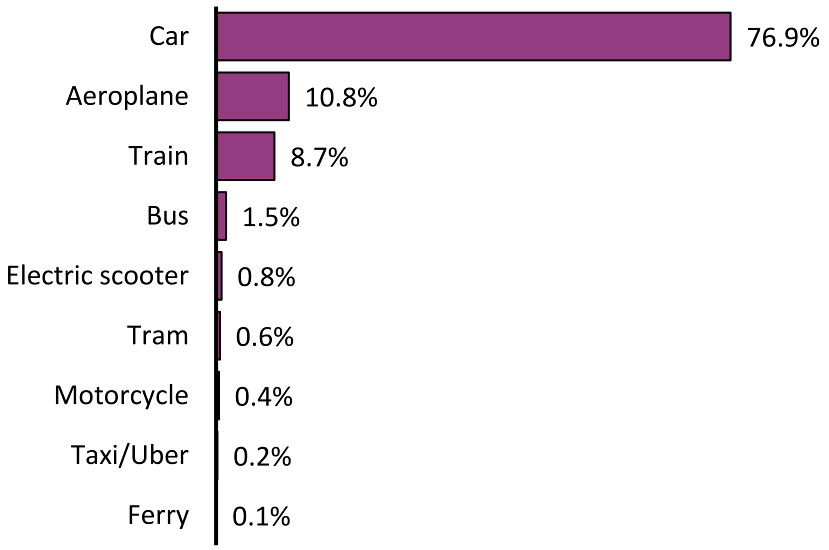
What was the purpose of this trip?



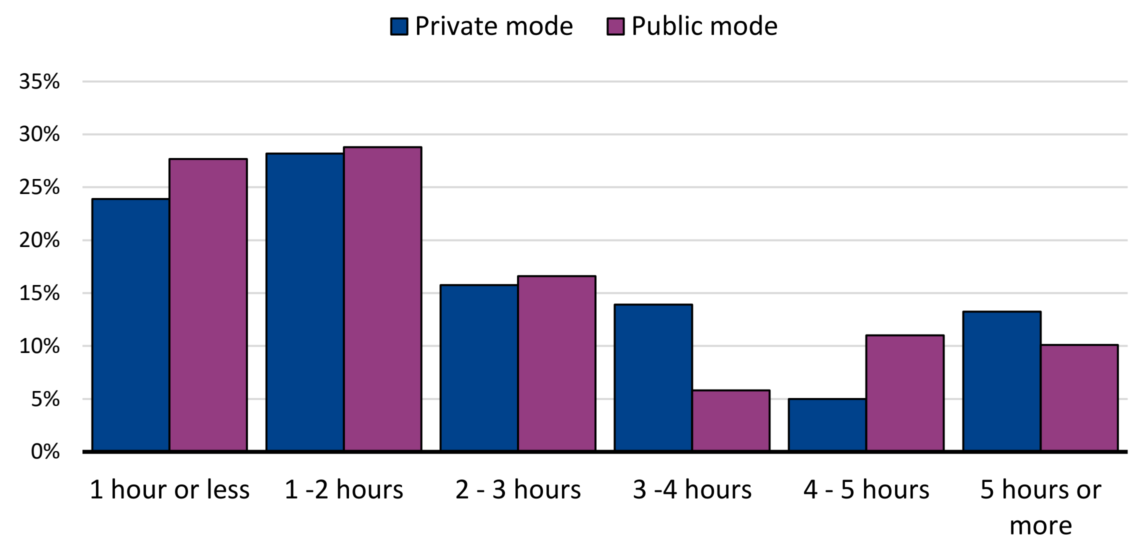
How many people travelled together on this trip?



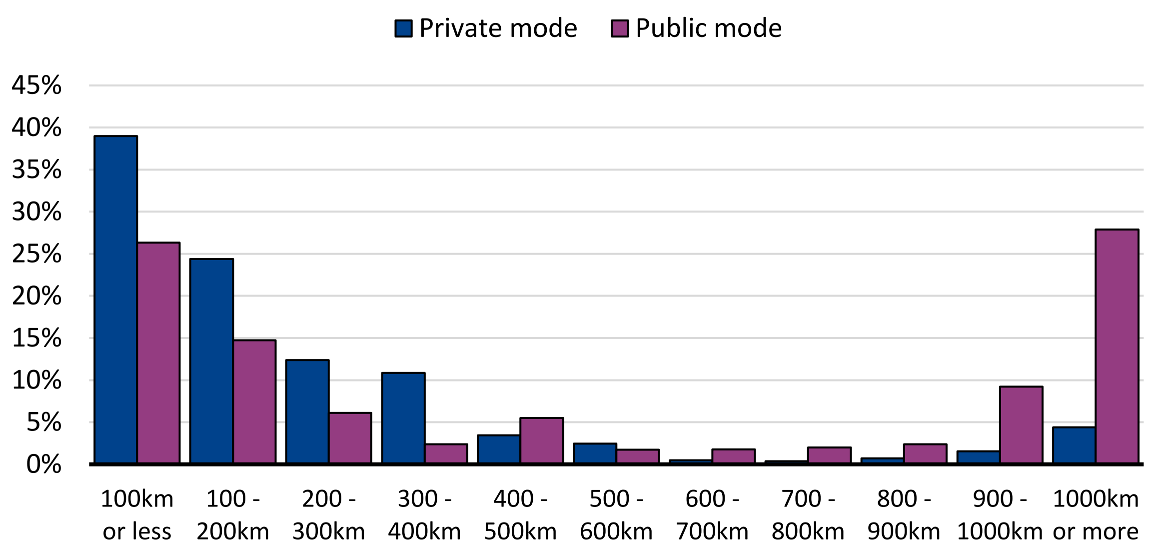
Which of the following modes of transport did you use for this trip?



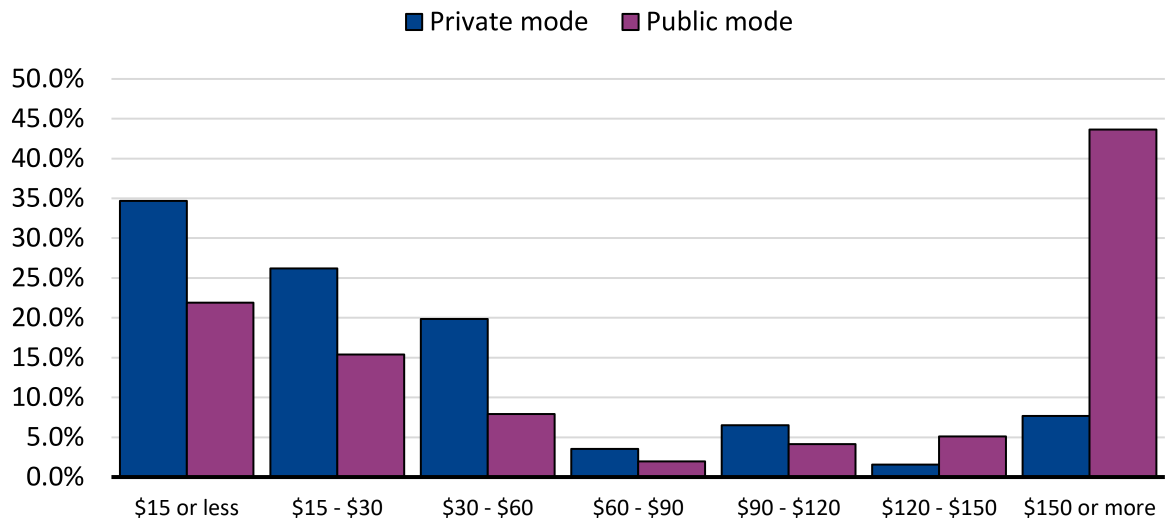
How long did you spend in the car to travel to your destination?



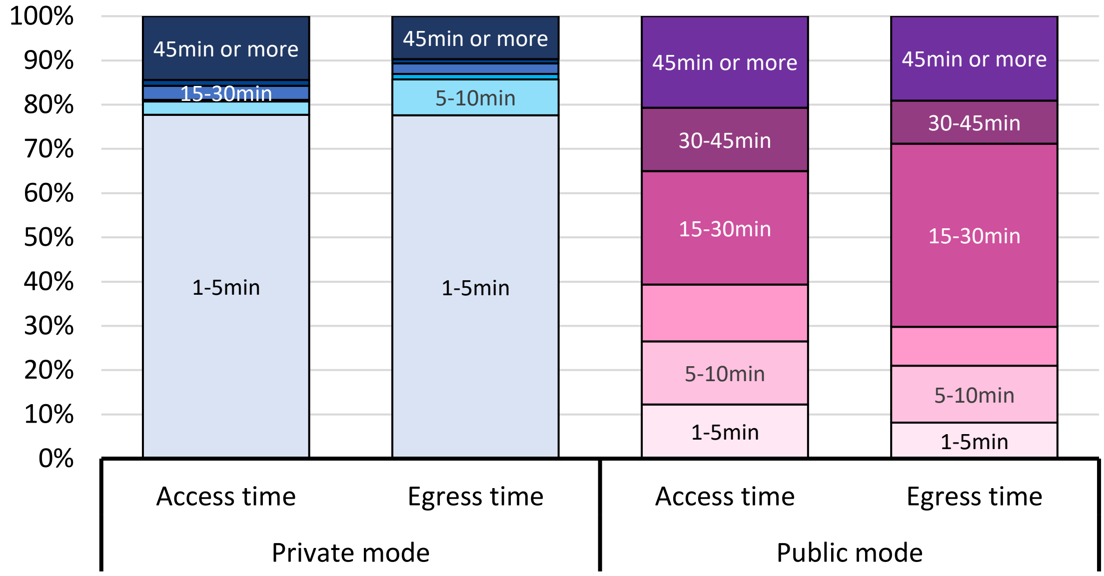
How far did you travel for this trip?



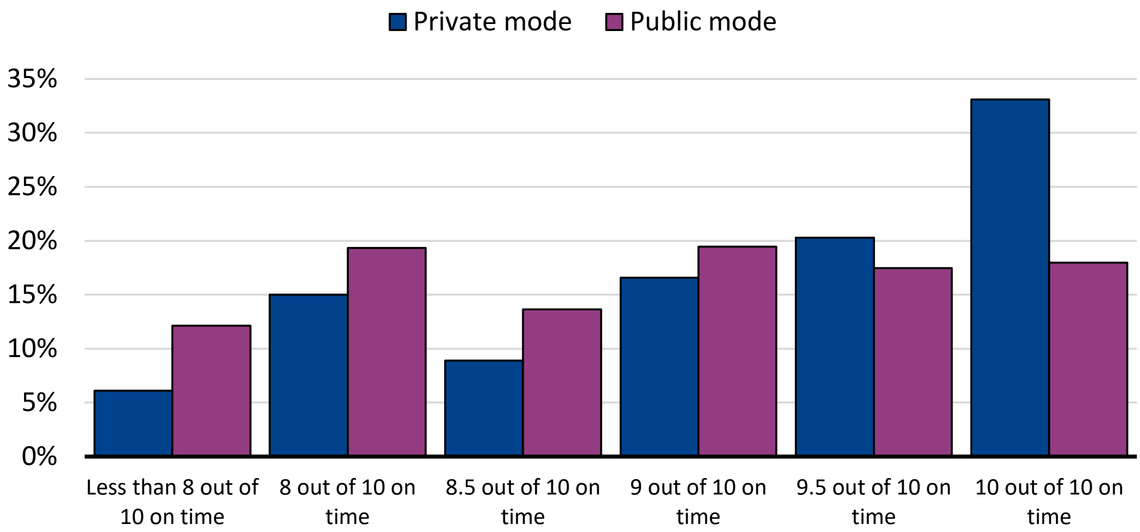
How much did you pay for this trip (per passenger)?



How much time (in minutes) did you spend travelling from your starting point as well as getting to your final destination?

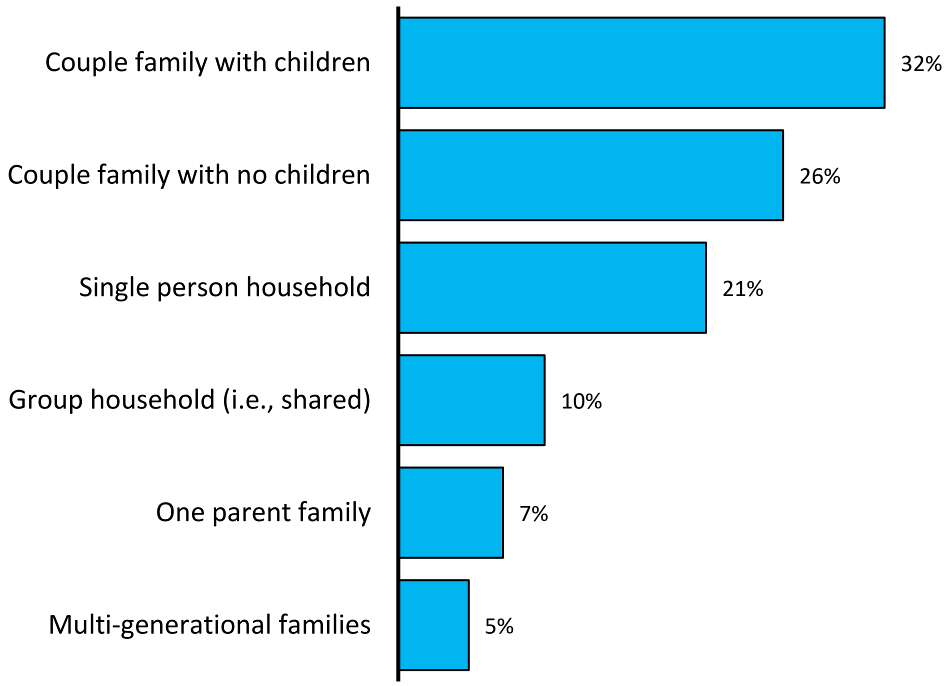


How reliable do you think travelling with this mode is?

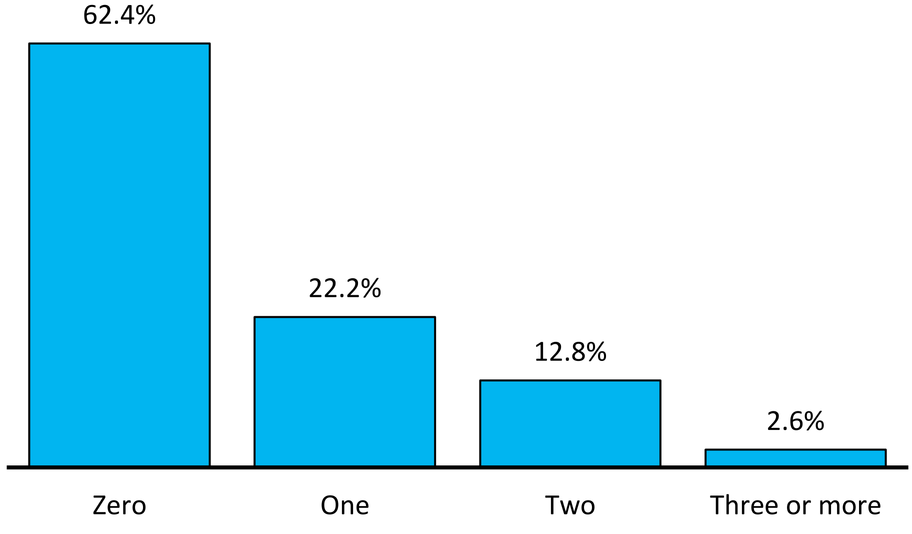


Appendix C-8: Baseline Demographics

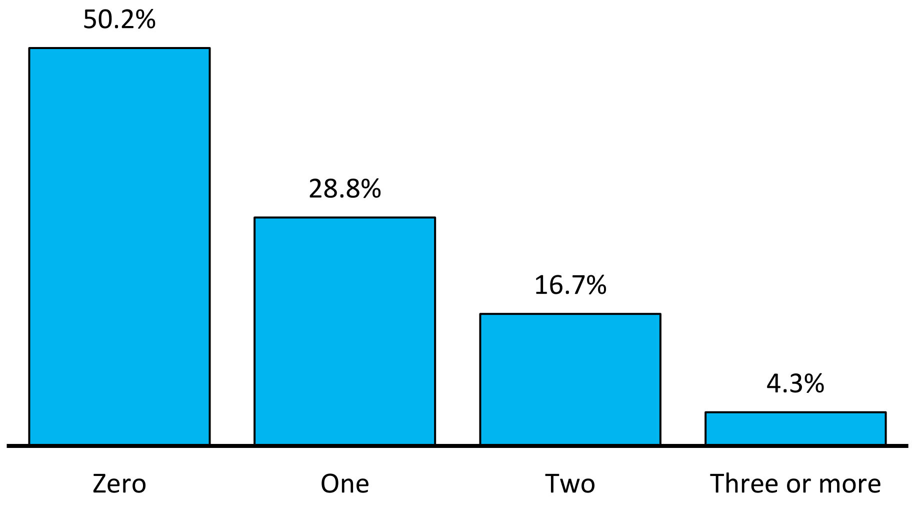
Which of the following best describes your household?



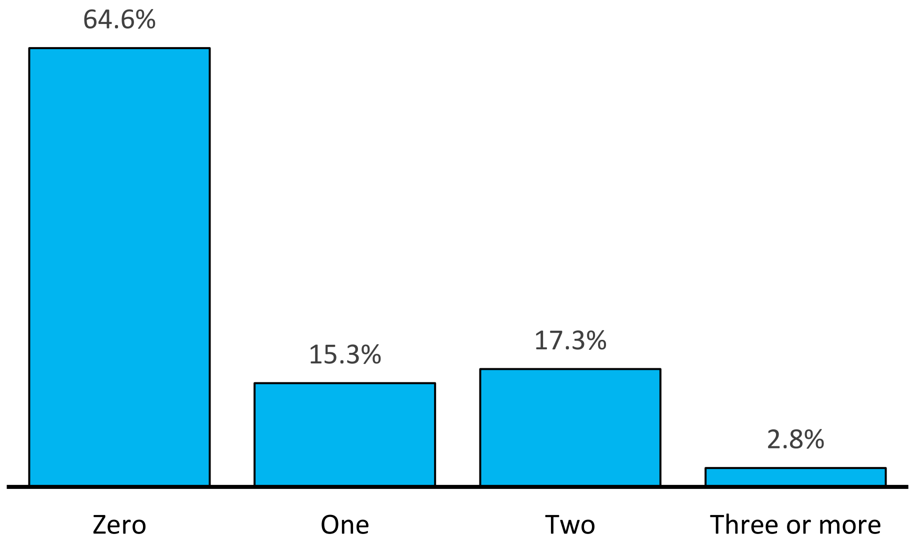
How many children less than 6 years old live in your household?



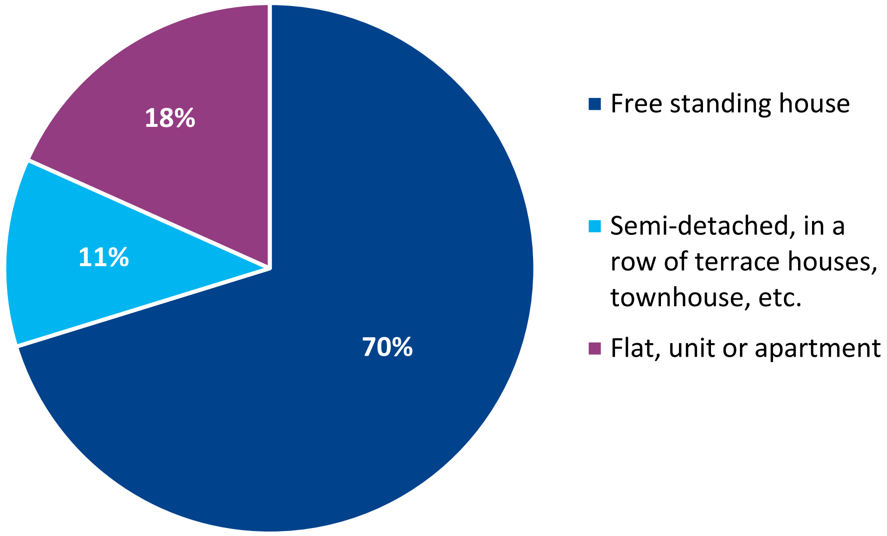
How many children aged between 6 and 18 years live in your household?



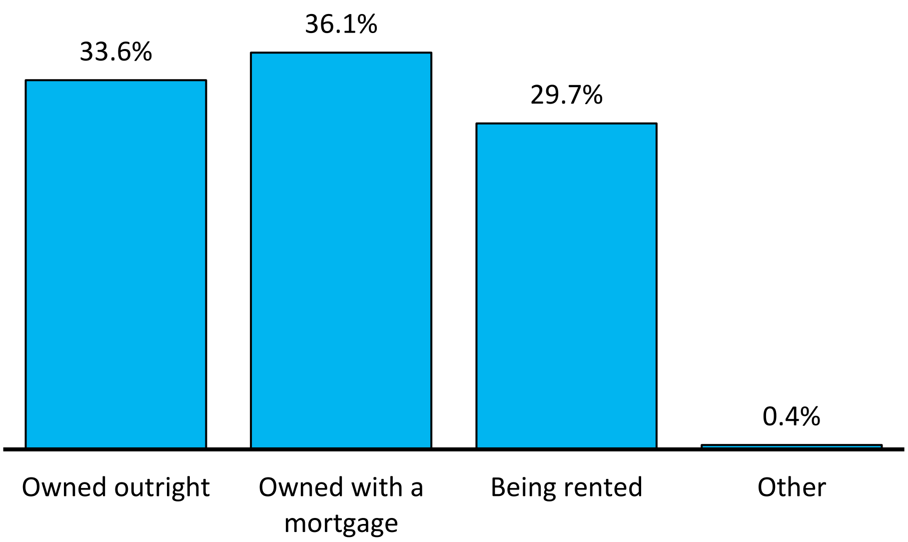
How many individuals aged 65 or more live in your household?



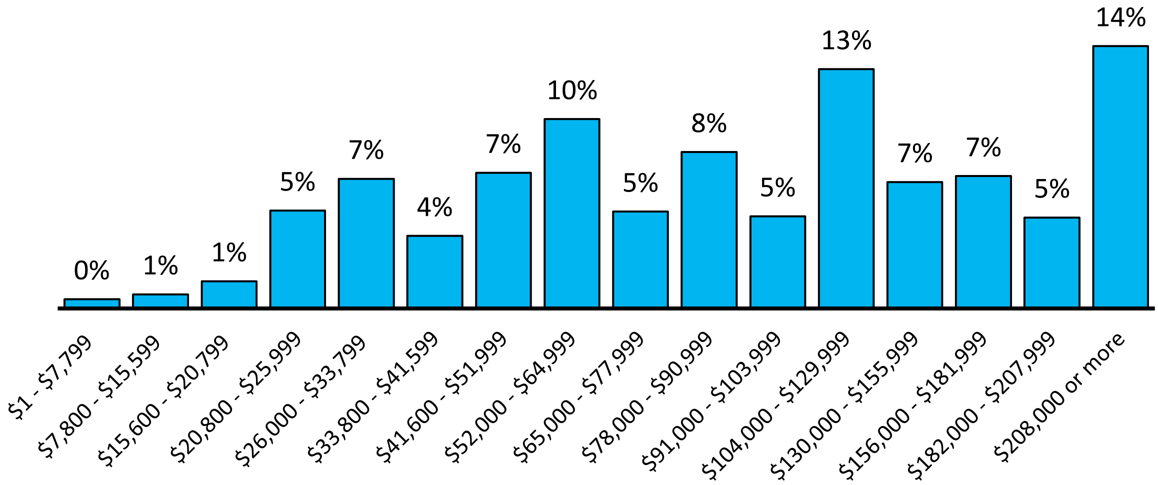
Which of the following best describes your current dwelling (house or unit where you live)?



Is this dwelling owned or rented by you?

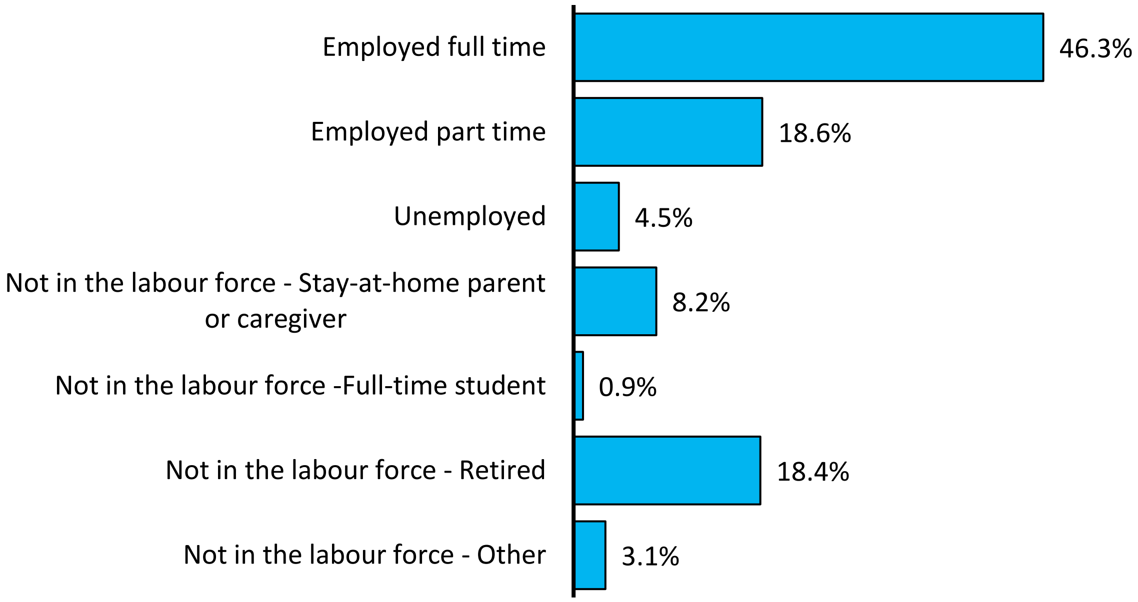


Which one of the following categories best describes your annual total household gross income (before tax)?

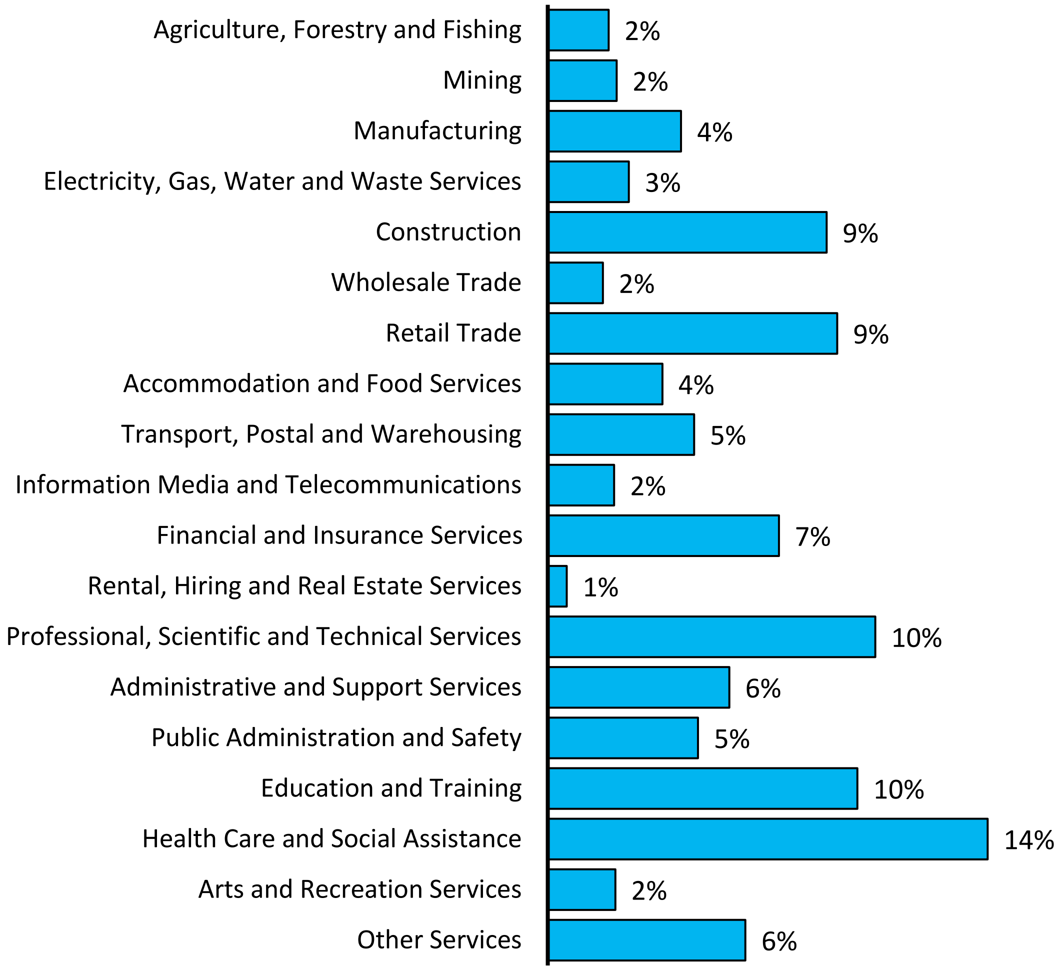


Median = $91,000–$103,999

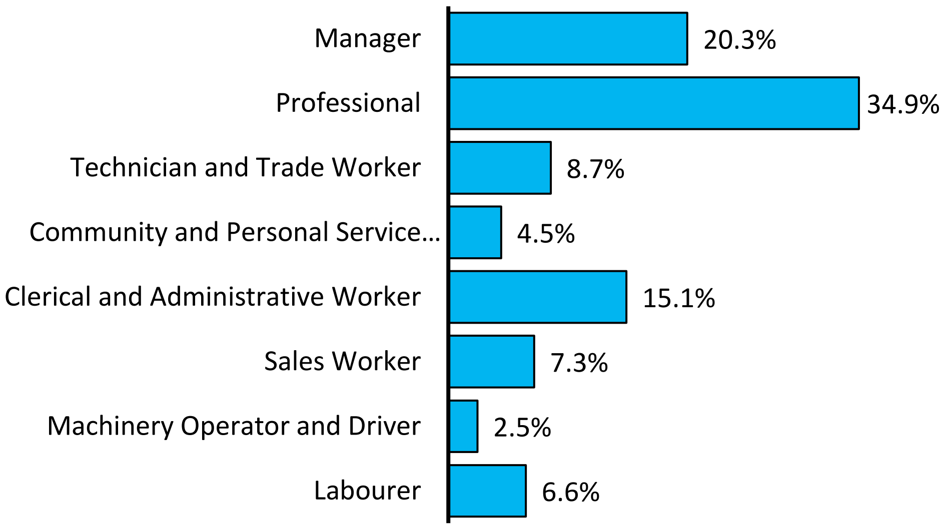
Which of the following best describes your current work status?



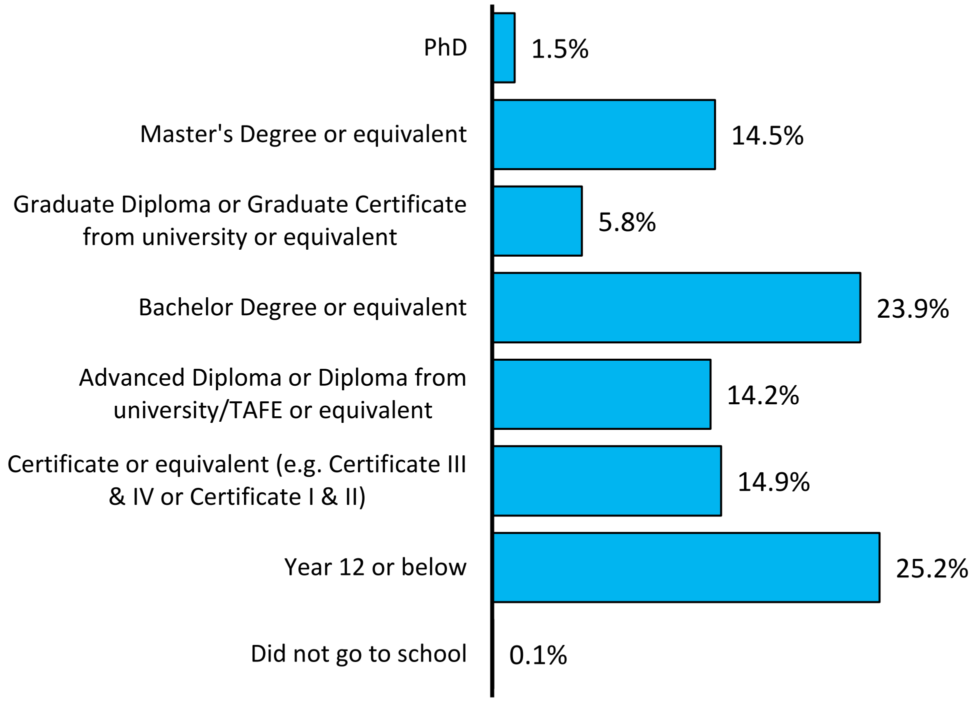
Which of the following categories best describes the industry sector in which you are employed?



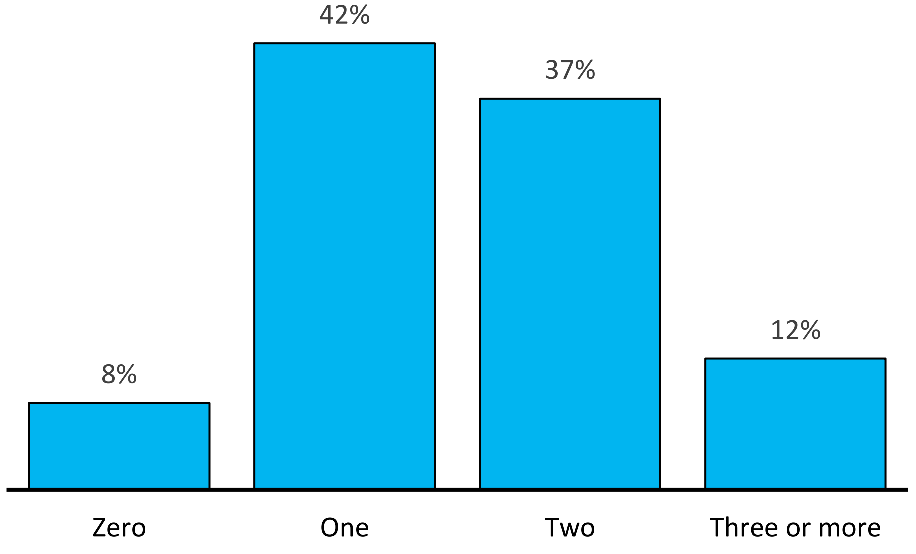
Which of the following categories best describes your occupation?



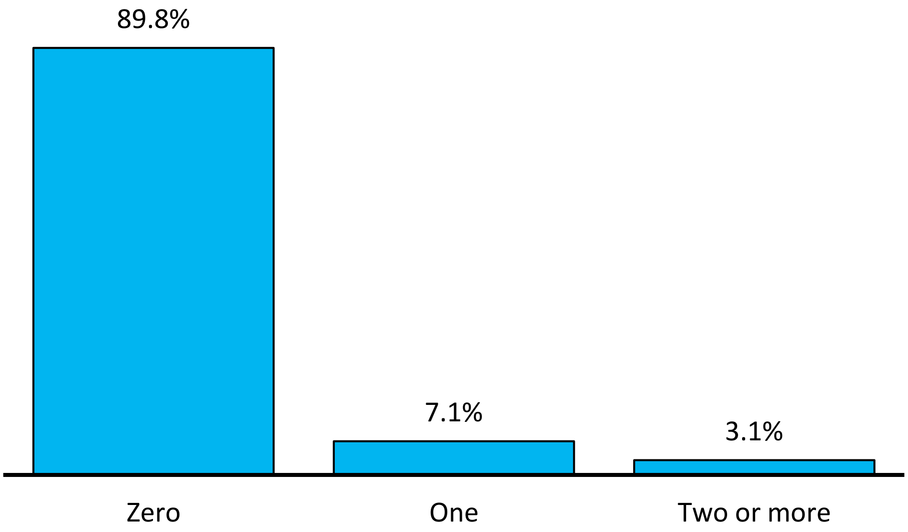
What is your current highest level of education achieved?



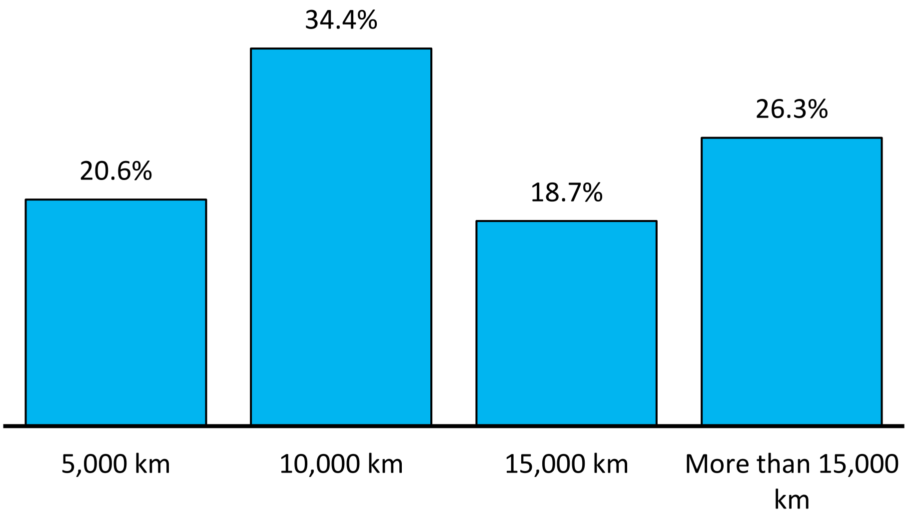
How many registered motor vehicles are owned or used by your household?



How many motorbikes or motor scooters are owned or used by your household?



Approximately how many kilometres do you travel annually using all privately owned vehicles?



Survey feedback:

SECTION D: Expert Survey

Stage III: Qualitative engagement with drone experts

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D.1 Introduction

Because of their ability to travel quickly, access difficult-to-reach or dangerous areas and collect data and information accurately, drones offer a unique value proposition compared with the current technology in some sectors. Consequently, drones have been regarded as a new means to gain a competitive advantage, reduce costs and increase productivity. While the use of drones appears promising in numerous sectors, ranging from emergency services to agriculture to mining, their adoption continues to face many obstacles, which prevents them from yielding their potential benefits. Therefore, the qualitative work of this project aims to contribute to the following research aims:

- Providing an overview of the Australian drone sector;
- Exploring the key benefits and challenges to increased drone uptake; and
- Improving understanding of the geographic and demographic implications for increased drone uptake in Australia.

To achieve these research goals, this qualitative study was based on the collection of the perspectives and opinions of drone experts. The Delphi method was chosen. As drones are considered an emerging technology, it remains unclear how the adoption of drones has been accelerating in Australia. By implementing the Delphi method, we aimed to capture experts' viewpoints on the benefits and challenges of drone uptake in Australia. Although originally the Delphi method aims to reach consensus among experts, this study used the method to examine the areas about which they most commonly agreed and disagreed. Given that we used a sample and method that differs from those used for the other studies in this project, this qualitative study is independent from but complements the studies based on the demand survey and the computable general equilibrium (CGE) modelling.

D.2 Method and Approach

We chose a two-stage Delphi method to extract experts' view on drone uptake. The Delphi method is a systematic process of collective judgements on a particular topic (Ven & Delbecq, 1974). In its original purpose, the method aims to facilitate an efficient group decision-making process. This method is often conducted in several rounds of survey where participants receive feedback after each round. The method is particularly beneficial when existing knowledge about a topic is incomplete. Figure D.1 shows the principle of the Delphi method.

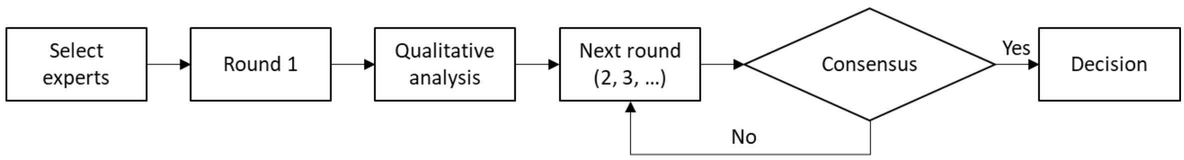

Figure D.1: Delphi method

We selected the Delphi method for this qualitative work for several reasons. First, by engaging experts through this method, we ensured that we obtained only high-quality, valid, relevant opinions for analysis. Second, this method allows to avoid the problems commonly associated with panel interview sessions, such as one individual dominating and influencing the group opinion, bias on experts' opinions, reluctance to modify publicised opinions and the band wagon effect (Fischer, 1978). In the Delphi method, there is no interaction among the experts. With such anonymity, experts feel more comfortable to express their opinions on sensitive issues (Strauss & Zeigler, 1975). Third, the survey usually leads to higher response rates and better-quality data as there is no socio-psychological pressure on the Delphi participant (von der Gracht, 2012). Last, having more than one round improves the robustness of outcomes.

It allows the experts to change their opinions, which stabilises the findings by reducing intentional and unintentional noise (von der Gracht, 2012).

D.2.1 Defining experts

We started the Delphi method by defining experts as those who are knowledgeable, experienced and influential (Baker et al., 2006) in their relevant sector. Given the emerging state of the technology, we acknowledge that long career experience with drones may be difficult to obtain, and therefore, we expect that those with a continuous engagement as a stakeholder from the groups, as identified below, will qualify as an expert, providing that they have achieved at least five years' work experience with one or more of the following:

- drone applications,
- related areas of aviation,
- research and development in drone-related technologies and
- industry/firm innovation and/or development in the target industry sectors.

In this project, our search for experts also considered the heterogeneity of opinions among them. Consequently, the findings are not formed by any individual (expert) contribution but by the collective representation of the diverse views of those who have contributed to the early establishment and growth of the drone sector/industry. Specifically, we searched for experts from sectors where drones have been widely implemented, as identified in the literature review (presented in Section B), such as mining or agriculture, and sectors where drones are still in the early stage of diffusion, such as in advanced air mobility (AAM). Apart from the sectoral background, we also considered experts who represent various key players in the ecosystem, such as drone operators, consultants, researchers, peak industry bodies and government officials.

To build the list of potential experts, we started by searching the internet, reviewing reports/studies, contacting peak bodies or industry association representatives and attending conferences. Thus, we identified 45 individuals for potential participation in this study. After examining their level of expertise, we sent interview invitations to 28 experts. Among these, six experts declined to participate owing to time limitations, whereas we obtained informed consent from 22 experts who agreed to be interviewed. The 22 experts included in the final sample were equally distributed and covered most of the identified sectors and stakeholders (see Table D.1). Our sample is significantly larger than that of most Delphi studies, which typically have approximately 10 participants.

Table D.1: Study sample

Group	Number of Potential Experts	Number of Invitations	Number of Interviews
Agriculture	4	3	3
Construction	3	3	1
Public services	6	3	2
Advanced air mobility	8	3	2
Mining and resources	1	1	0
Representatives in existing trials	9	5	5
Peak body	7	6	5
Drone operators	7	4	4
Total	45	28	22

D.2.2 Delphi method procedure

Since its development in the 1950s, the Delphi method has undergone several refinements. In fact, universal agreement on the definition and procedural technique of this method is lacking. Hence, in this study, we decided to conduct two rounds of data collection (see Table D.2). In the first round, we collected data through interviews. As the literature on the Delphi method is still inconclusive, we analysed these data using qualitative methods to identify factors that may contribute to drone adoption in Australia. From the analysis findings, we constructed several statements representing the status, benefits and challenges of drone uptake in Australia. In the subsequent round, we asked the experts to respond to the statements. While most Delphi methods end once an acceptable level of consensus has been reached, in this study, we were interested in addressing the study objectives in two stages and in drawing conclusions on the basis of these experts' opinions.

Table D.2: Two-stage Delphi study procedure

Steps	Task Description
1	Identified potential experts for Delphi study.
2	Conducted a review of each contact's profile from social media or organisational sites to confirm their depth of experience related to the classification as an expert.
3	Refined the list of experts to represent different groups and sectors.
4	Conducted Stage 1 Delphi study (interview). The objective was to draw out experts' viewpoints on the strengths, weaknesses, opportunities and threats (SWOT) of drone adoption.
5	Analysed interview data to identify common themes and variations associated with each of the SWOT quadrants.
6	Conducted Stage 2 Delphi study (survey). The survey was designed based on the analysis of common themes across the SWOT.
7	Analysed collected data and concluded the study.

D.3 Stage 1: Interview

The first round of the Delphi method elicited extensive opinions from the experts. The interviews were conducted during the first two weeks of October 2022. The primary data collection method was semi-structured interviews (see Appendix D-1 for the interview protocol). We started each interview by obtaining information on the expert's background and experience in drone technology. This set of questions allowed us to validate their expertise and also provided a rather broad background about the context. To address the objectives of our analysis, we used the SWOT (strengths, weaknesses, opportunities and threats) framework. This framework guided the interview process in a structural way as well as helped the experts from businesses and drone operators to articulate their responses at three levels, namely at the firm, national and community levels. With regard to the experts from existing trials, we modified the questions to capture reflections from these trials as well as reflections on the wider applications of drones. Similarly, we altered the questions we asked interviewees representing peak industry bodies.

The interviews lasted 45–90 minutes, and all were conducted via an online communication tool. We recorded the interviews and took notes. All interviews were transcribed verbatim. The interview guide used in the project comprised open-ended questions to permit the respondents to use their own terms and express their own opinions on their subjects that they thought were relevant. The interviewees did not receive the guide in advance.

In the analysis, we followed Gioia et al. (2013) and gathered concepts, themes and aggregate theoretical dimensions from the raw data excerpts. We analysed the qualitative data by following three key steps (Locke, 2001; Miles & Huberman, 1994). The first step consisted of creating provisional categories or first-order codes. For each question, we began by identifying statements on our experts' views via open coding (Locke, 2001), and thereafter drew on common statements to form provisional categories and first-order codes. Guided by the SWOT framework, we organised our data around three levels of analysis: firm, national and community. Following Miles and Huberman (1994), we used a contact summary form in Excel to record the provisional categories that emerged. Each researcher developed their own coding. As the list was completed, one researcher was assigned to review the codes. In total, 65 first-order codes emerged from the data. The researcher rechecked the codes to ensure that they fitted the emerging abstractions. The second step consisted of integrating the first-order codes and creating second-order themes. This stage of analysis allowed us to explore the relevancy of themes across levels, from the lowest level (firm) to the highest level (community). As we consolidated the categories, they became more theoretical and abstract, and hence, we moved from open to axial coding (Locke, 2001). The third step involved aggregating the second-order themes. After we generated these themes, we sought to aggregate the dimensions underlying these themes in an attempt to understand how different themes fitted into the bigger picture across the levels (see Table D.3). Figure D.2 presents examples of the process that we followed, showing our first-order codes, second-order themes and aggregate theoretical dimensions.

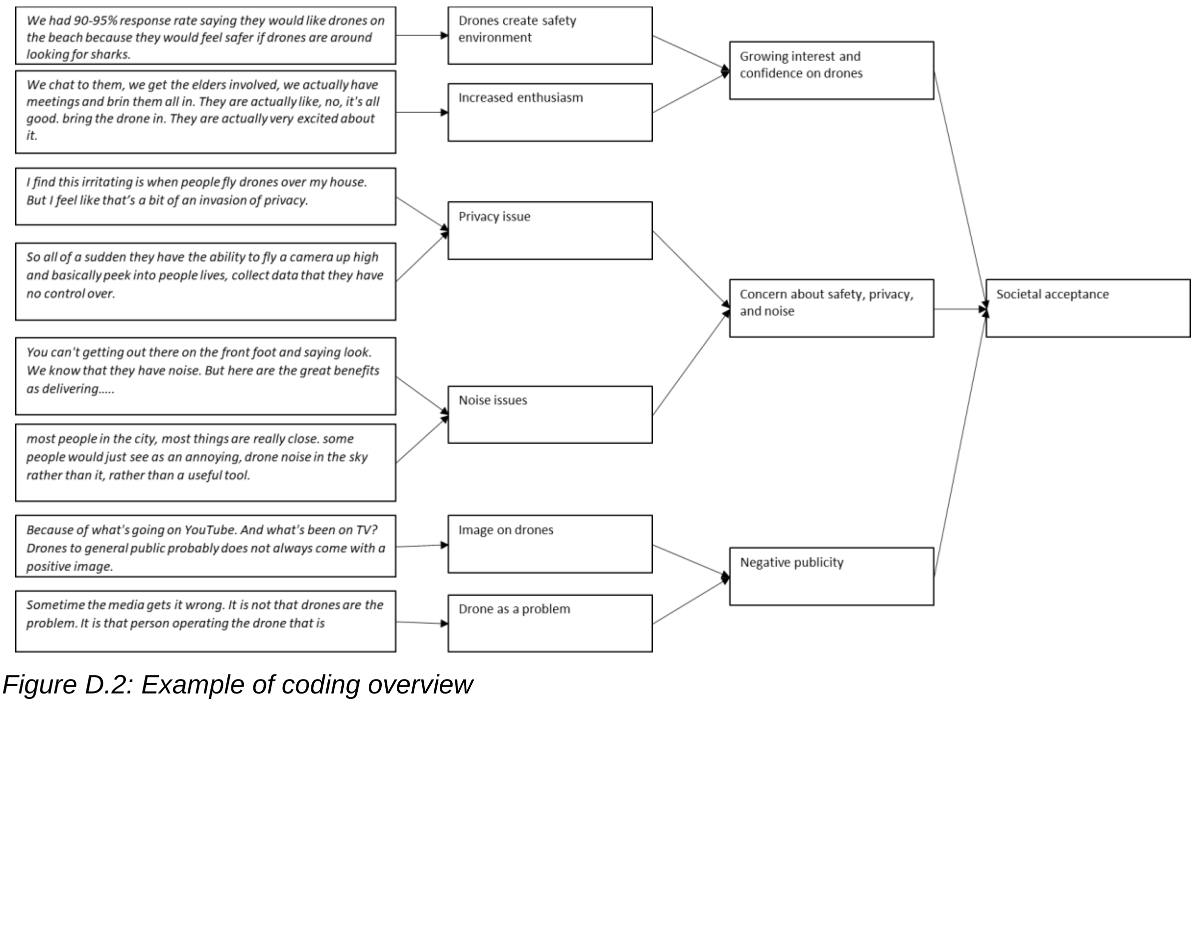

Figure D.2: Example of coding overview

Table D.3: All second-order themes and aggregate theoretical dimensions

Second-order themes	Aggregate theoretical dimension
• Growing interests • Concerns about safety and privacy • Concerns about noise • Publicity on drones	1.Societal acceptance
• Government funding • Private investment	2.Funding and investment
• Regulation has not fully matured • Frequent review on regulation • Problems in gaining clearance and extensive compliance process • Regulators are accommodative and open for change	3.Regulations on drones
• Education and exposure on drones' benefit • Communication	4.Public engagement
• Variation in policy on drones • Innovation culture • Australian geography and demography • Access to rural areas	5.Contextual condition
• Limited supply chain • Limited market • Limited knowledge and skills • Lack of education and training	6.Market readiness
• Uncertainty and speed of technological development • Benefits of drones	7.Technology readiness

As shown in Table D.3, the analysis produced seven final themes as aggregate theoretical dimensions:

- societal acceptance,
- funding and investment,
- regulations on drones,
- public engagement,
- contextual condition,
- market readiness and
- technology readiness.

In the next section, we present some excerpts from the interviews to support the findings.

D.3.1 Analysis of interview data: Identifying emerging themes

D.3.1.1 Societal acceptance

Among other findings, societal acceptance can be used to measure the rate of drone adoption, and the acceptance or rejection of drones by the public. The analysis found that the overall awareness around drones is increasing, as one of the experts stated:

> We got NT health to support us. They want to see this come through. We want to make it happen. (3/E/16)

While an increasing number of businesses and organisations have begun to examine the potential of drone technology, the public still has some concerns regarding drones. For example, the experts acknowledged the presence of public concerns on several topics, such as noise, privacy and safety. According to the experts, addressing those factors are critical to the process of drone adoption:

> A few still worried about privacy … we do get feedback quite often on privacy-related matters and privacy-related operations. (3/E/10)

> One of the biggest challenges we run into is around privacy. … So, given that some people have reservations regarding use of drones. … Imagine that you are flying above my house, and you are taking a photo of my house. You are not allowed to do that. It pulls you out of the drone space and moves into privacy debate. Australia doesn't have a good privacy law. (2/D/14)

However, the experts also noted that the concerns can be relevant in certain geographical locations. Apparently, people in urban or highly populated areas have more reservations than those in other areas. Here, we need to be aware that some areas may receive more negative feedback than others. This is an important insight, especially in the effort to reduce public concern surrounding drones. The following are some relevant comments:

> In the city more, we might start to get a bit more comments or issues, I think. (3/E/21)

> Flying over sacred sites. So, if you're taking photos of these areas, the photos, there are definitely concerns about whether is there going to be a camera on these drones. (3/E/21)

Another factor that may tarnish the effort to increasingly the adoption of drone technology is the way in which the image of drones has been built. For instance, news about an accident involving drones or someone using drones for illegal activities will hinder public recognition of the benefits of drones. The following comment illustrates this aspect:

> One of the limiting factors is that I hadn't spoke about is probably people that go and do the wrong thing and then give those drones a bad name, and that can’t help and set us back because then you get people that are against it, even though there are benefits in the drone usage. … a negative view of drones can be very difficult to actually change. (1/S/14)

The experts also revealed that while there are some concerns and negativity around drones, society is slowly seeing the benefits of drones. The following excerpt shows that the public acceptance is positive when they can clearly understand the benefits of drones.

> We had 90–95% response rate saying they would like drones on the beach because they would feel safer if drones are around looking for sharks. (2/D/12)

D.3.1.2 Funding and investment

The next factor relates to the support mechanism for drone trials. It includes funding from the government and private investments. In many countries, governments have been pouring funding and grants for research on drones. This money has been invested into studies on wideranging applications of drones, such as for the military, transportation and public services. In this regard, the experts we interviewed echoed the importance of the government's support through funding, as well as of an improved and targeted funding mechanism. For instance, two of them raised concerns about the fact that the Australian drone sector relies heavily on overseas suppliers because of the limited investment in local suppliers and capabilities:

> I was involved with setting up … and the government got on board and gave us $20million, I think. Having access to those sorts of grants in this innovation space is really critical. (2/D/12)

> We don't invest, and we don't back local manufacturers to develop something which is tailored for us. … And so, and I think it means that we end up with less services and a less diverse economy than what we could have. (1/AM/9)

D.3.1.3 Regulation

Given the rapid growth of drone adoption, there is a need for regulation. Interestingly, we found that the experts can both agree and disagree on the roles of regulation in influencing the uptake of drones. While drone use is restricted by many regions owing to regulation, regulation can also provide stability and certainty for organisations in their endeavour to adopt drones. The findings, exemplified here, show that most of the experts agree on the important role of regulation to guide the safe adoption of drone technology:

> Regulation in some sense provides a bit of certainty and provides structure to deal with the cowboys. (2/D/8)

> I actually think they are doing a pretty good job to be upfront … I don't think we should change aviation rules that quickly just because drones are coming. I think you got to put safety first. I think you got to do it in the right way, and I think we are doing it correctly. (2/D/14)

However, simultaneously, regulation can be a barrier to faster drone adoption. This finding is not surprising as uncertainty regarding new technology may influence the process of regulation development. The lack of suitable regulation and enforcement is believed to be the main barrier to the adoption of drones. In many countries, the regulations on drones are available but focus mainly on regulating the following three aspects: (1) the use of airspace by drones; (2) the operational limitation of drones, such as size and capabilities; and (3) the administrative procedures, such as issuing licences and flight permissions (Ayamga et al., 2021). Similarly, the experts argued that the problem lies in the number of administrative procedures and the speed of the process, as the following interview excerpts reveal:

> The restriction is actually around the legislation, and that's, and of course, it needs to be there to try and make air travel safe. but it's then trying to ensure that, we can still do the work that we need to do and do it in a safe manner. It's just trying to maintain that legislative requirement and ensure that you're doing it can be time-consuming and can hinder the operations in some cases. (1/S/14)

> There're a few bits where the rollout of the regulation can be a problem. It needs to be done in a way that people can meet the regulation in a timely fashion as opposed to rolling out the regulation, which then stop everybody from operating because it introduced a new category and a new licence and there was no way to get that new licence. (1/AM/9)

During the interviews, the experts pointed out the need for Australian regulation to adapt to catch up with technology, drone applications and the market dynamics. They proposed, as follows, that the regulation should move faster and be more reactive to the changes and the needs:

> We have a very permissive regulatory authority [and] regulatory environment at the moment, but it has its challenges in the sense that it needs to be adequately resourced to be able to process those applications, and so, you need to be able to regulate at scale. It's very different to just regulating one or two. … It takes about 5 to 10 years to write them and then once they're in there, they stay there and it takes a lot to change them. So, we need to make sure that our regulatory environment continues to evolve. (2/P/2)

> If we can move a little bit faster, that would be great because the market in the industry is moving very quick. And in some extent, it does hold us back sometimes with the capacity of the departments and also with simply the regulations are not changing fast enough for us. (1/A/5)

D.3.1.4 Public engagement

In the process of adopting drones, it is important to recognise that businesses/firms and the public have not unanimously accepted drones. Australian businesses have been incorporating drones as a part of their operations. Drones have been frequently used in various industrial operations, from mining to entertainment. They have reached places that are otherwise difficult to access. Hence, the advantage of drones should be considered with regard to future possibilities rather than just as a cost. However, the public is yet to fully understand the benefits of drones. Members of the public who are better informed about these benefits are more likely to hold a positive view towards drones. They have fewer concerns and are generally more supportive of drones. This argument is also supported by the experts, who agreed that public or community engagement is necessary to support the adoption of drones. Some comments include:

> A part of what we would do as a consultancy is to help understand what the community's concerns are and then put them in place with [a] mitigation plan. (2/D/8)

> I think if you just bought the technology in and didn't do that [community engagement], you wouldn't be successful with it. (3/E/7)

> The huge factor is really public education. How do we bring the communities along with the journey, and how do we educate communities from different age groups and generations? (2/P/17)

Literature (e.g. Lidynia et al., 2017) has found that the opinions of non-drone users were significantly different from those of drone users. However, some studies have found higher levels of support for the use of drones when the application is for the public good, such as safety, than when it is for commercial and amateur/hobbyist uses (Smith et al., 2022). Nevertheless, as soon as the public starts to see and experience the benefits of drones through public engagement and education, drone uptake will increase.

D.3.1.5 Contextual conditions

The adoption of drones is also influenced by contextual conditions. Australia is a vast country with an extreme geography and climate. However, its geographical conditions, culture and demography offer opportunities for drone use. Those contextual conditions were also captured by the experts, as follows:

> Australia is a forward-leaning country in terms of innovation, and governments have been and very proactive with drones. (2/P/4)

> In Australia, we're well positioned to, to really to use that. And Australia is a really good place to test lots of drones as well. We've got lots of wide-open areas and we. that aren't that populated, so we can. We can test a lot of the new drones. (2/D/23)

The experts also acknowledged that in certain sectors and contexts, such as in agriculture or rural areas, opportunities to utilise drones are increasing. Mainstream and niche sectors have both started to adopt drones, but different contexts require different adoption rates and strategies, as exemplified in the following comments:

> So it's a lot easier to train Australian farmers to become an operator because they already have that knowledge. They're very hands on. They generally know how to fix stuff. (1/A/5)

> And so those areas where there is a drastic improvement in services … we'll see faster adoption. … an example might be the Torres Strait. There's an opportunity for drone services to provide new level of connectivity. (1/AM/9)

Interestingly, the experts also noted the political system and different policies in each state may influence drone adoption. For instance:

> Comparing to some of the Asian countries, we're definitely a lot more regulated, but most challenging part is it's regulated from state to state. To just say if you got approval to fly and spray in NSW, that's not necessarily say that you actually got the right to spray in the WA. … It makes me feel like, WA is a different country to NSW. (1/A/5)

D.3.1.6 Market readiness

Another factor that contributes to the speed of adoption is market readiness. While many businesses have started to acknowledge the benefits of drones, they need to acquire the knowledge and skills necessary to operate drones. The experts also expressed their concerns, as shown here, about the readiness of logistics and the supply chain in Australia to support the drone sector:

> For it, unfortunately in Australia we don't have that sort of supply chain to do so, but our strength is actually in product development. (1/A/5)

> I think the government needs to stop looking at the facilitation of investment and rather look at the facilitation of sales. … We'll shift the sector again, but at that point, if the Australian Government and ecosystem haven't facilitated tech companies in Australia to be part of that, we are a consumer again of the technology rather than an exporter of the technology. (2/D/14)

D.3.1.7 Technology readiness

From the interviews, we learned that commercial drones have been adopted by a predominately new market and a few mature market niches. Drones are more accessible currently, and their adoption will bring various benefits, such as cost reduction, increased productivity and a safer alternative to current procedures, as illustrated in the following comments:

> One of the key drivers, I suppose, is safety. People are using drones in situations, typically commercial situations, that replace people. Instead of sending someone up in a crane or scaffolding, they will use a drone, because it is safer. (3/E/10)

> And also much more safer because they don't need to send a guy up on the glass roof and stepping in the very fine little narrow gutter. (1/A/5)

While the technological development is rapid, the future technological trajectories are still uncertain. The experts have stated some limitations, as follows:

> I think health care is a great one, but again, you are limited by payload because you might need 20 kilos of medicine, but you can only put 2 kilos in the drone. (3/E/16)
>
> Batteries always are going a little bit. That's probably gone, actually. There's always going to be a limit to the drones. (3/E/21)
>
> That drone doesn't do anything. Really. The actual cameras on there make the difference. And because we use a lot of them or a lot of our work, it's their imagery that's always going to be a bit of a limiter because those good demo cameras are huge. (3/E/21)

D.3.2 Making sense of the adoption process

The findings of Round 1 reveal several pieces of information that can be used to understand the factors that influence drone uptake in Australia (see Figure D.3). First and foremost, it is apparent that the nature of societal acceptance is a central consideration. While the experts recognise that acceptance is increasing, the public still have some concerns. Our understanding of the factors that influence the acceptance are public engagement, funding and investment, market readiness and technology readiness. All those factors are well documented in the literature, and evidently are still relevant in the context of Australia. The higher the levels of those factors, the higher the chances of acceptance. Interestingly, we also identified that factors such as regulation on drones and contexts can create both barriers and opportunities for drone use. For instance, the impact of funding on the adoption of drones will be determined by other contextual factors, such as opportunities.

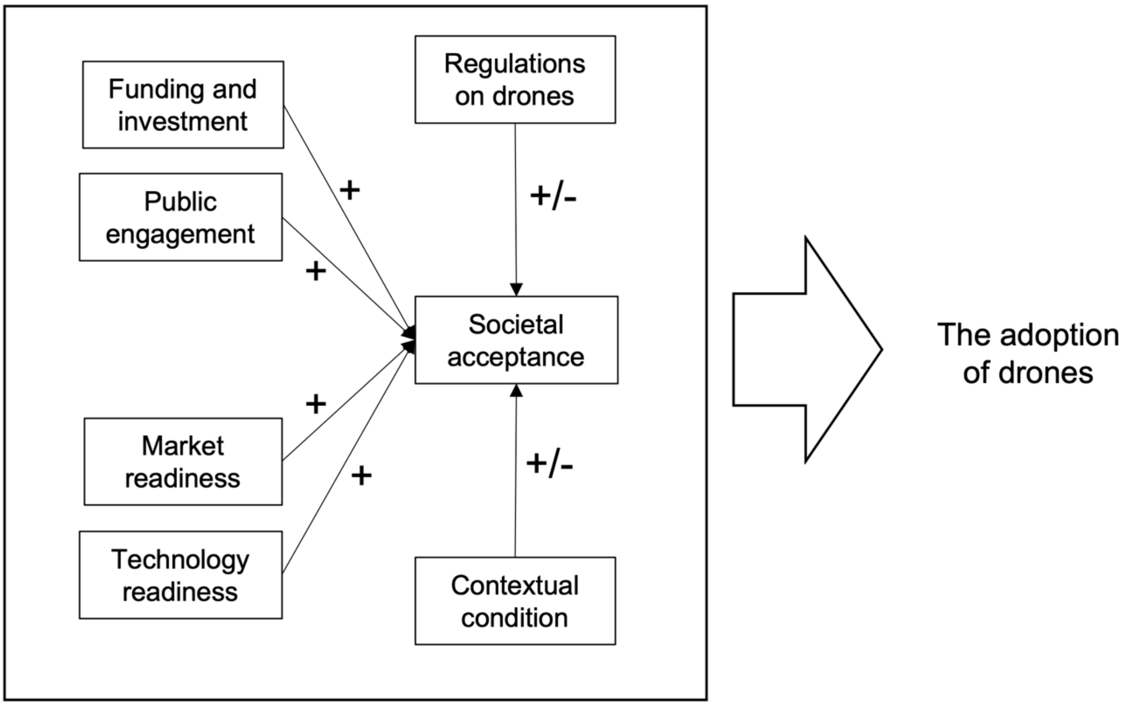

Figure D.3: Factors that influence the adoption of drones

D.4 Stage 2: Survey

In Round 2, we conducted a survey to examine the current status of drone uptake, as well as the benefits and challenges of drone adoption. We also tested numerous statements against different sectors (see Appendix D-1 for the survey protocol). In constructing the statements, the second-order themes of all factors (see Table D.3) were used. While the first two sets of statements represent factors such as societal acceptance and the determinant factors for drone uptake, the third set contains statements about the contextual conditions. The last set of statements intends to capture experts' opinion on the differences among the Australian sectors, in terms of their adoption of drone technology. We sent the survey to 22 experts and received 15 questionnaires at the end of November 2022 following several reminders from us.

D.4.1 Experts' insights on drone adoption in Australia

For each statement, we calculated the mean and standard deviation. In addition, we also calculated the percentage of experts who agree or disagree with the statements. Table D.4 and Table D.5 show the descriptive statistics for each statement.

Table D.4: Overview of Australian drone sector

Statements	**Mean**	**SD**	**Cat 1 (%)**	**Cat 2 (%)**	**Cat 3 (%)**
1. Growing interest in drone technology among Australian firms has helped faster adoption of drones	4.20	0.77	6.67	0	93.33
2. Increased funding for drones has helped faster adoption of drones	3.93	0.88	6.67	20	73.33
3. Commercial-grade drones are readily accessible and affordable in Australia	3.47	1.06	26.67	13.33	60.00
4. The Australian community has generally accepted drones in various applications without too many concerns	3.33	1.05	26.67	26.67	46.60
5. The regulators in Australia are very accommodating in the development of aviation policy and regulations for drones	2.93	1.11	53.33	6.67	40.00
6. Different states in Australia have their own policy, infrastructure or obstacles that may hinder the adoption of drones	3.53	0.99	20.00	20.00	60.00
7. An underdeveloped market and limited supply chain options in relation to drone technology have limited the adoption of drones in Australia	2.93	0.88	40.00	26.67	33.33
8. Technological uncertainty and the speed of technological changes have limited the adoption of drones among Australian firms	3.00	1.07	40.00	13.33	46.67
9. A lack of drone education and training providers has limited the adoption of drones	2.53	1.06	60.00	13.33	26.67
10. Regulation on drones in Australia has not fully matured, such as it needs to accommodate the current technological development	4.60	0.51	0	0	100.00
11. The Australian community is still concerned with the societal impact of drones in relation to public safety and privacy	3.73	0.96	13.30	20.00	66.67

12. Noise is still an issue for many Australian community members that prevents them from fully accepting the application of drones	3.40	0.83	13.30	40.00	46.67
13. Negative publicity on drones and low awareness of drone application have limited the adoption of drones by the Australian community	3.60	0.99	20.00	13.30	66.67

Note: The experts were asked to indicate whether they agree or disagree with the statement in 5 Likert scale; Cat 1: Strongly disagree/disagree Cat 2: Neither disagree nor agree; Cat 3: Strongly agree/agree

Table D.5: Key benefits of, and challenges in, increasing drone uptake

Statements	**Mean**	**SD**	**Cat 1 (%)**	**Cat 2 (%)**	**Cat 3 (%)**
1. Increasing the availability of government funding will speed up the adoption of drones	4.33	0.72	0	13.33	86.67
2. Increasing the availability of private investment in drones will speed up the adoption of drones	4.00	0.93	6.67	20.00	73.33
3. Public engagement and open communication will improve the acceptance of drones by the community	4.60	0.51	0	0	100
4. Public education and more exposure to drone capabilities will improve the acceptance of drones by the community	4.40	0.63	0	6.67	93.33
5. More frequent reviews of regulations in various sectors will increase the adoption of drones	4.20	0.86	0	26.67	73.33
6. Difficulties in gaining regulatory clearance and the extensive compliance process limit the adoption of drones	4.67	0.62	0	6.67	93.33
7. Limited skills and knowledge in drone operation among Australian firms limit the adoption of drones	3.60	1.12	20.00	26.67	53.33
8. Widespread use of drones will never be achieved across industry sectors under the current regulatory and/or technological limits (such as limited battery life for long trips)	2.87	1.36	40.00	26.67	33.33

Note: The experts were asked to indicate whether they agree or disagree with the statement in 5 Likert scale; Cat 1: Strongly disagree/disagree Cat 2: Neither disagree nor agree; Cat 3: Strongly agree/agree

In the following section, we discuss the main findings.

D.4.1.1 Regulations on drones

While drones bring huge potential benefits, they also carry some risks. Unfortunately, developing regulation to mitigate all potential risks is not an easy task. On one side, regulators are very willing to work with businesses and develop regulation that increases the adoption process. Despite firms' impatience with the slow approach to drone regulation, the experts also noted that a failure to sufficiently test and address the risks of drones could jeopardise the current trend of drone adoption. On the other side, the public's concerns regarding many aspects, such as safety, need to be addressed in the regulation. The challenge is in how to develop regulation that meets the commercial expectation and safety needs, as well as develop it fast enough to react to the dynamics of the technology and market. Through the survey, we found that most of the experts consistently agreed on the role of regulation in supporting the adoption of drones, as follows:

- Difficulties in gaining regulatory clearance and the extensive compliance process limit the adoption of drones (Mean: 4.67; SD: 0.62).
- Regulation on drones in Australia has not fully matured, such as it needs to accommodate the current technological development (Mean: 4.60; SD: 0.51).
- More frequent reviews of regulations in various sectors will increase the adoption of drones (Mean: 4.20; SD: 0.86).
- The regulators in Australia are very accommodating in the development of aviation policy and regulations for drones (Mean: 2.93; SD: 1.11).

D.4.1.2 Facilitating public engagement

The next factors that score high are related to public engagement and education. Most of the experts agreed that educating and communicating with the public about the benefits of drones will improve the acceptance rate. Activities such as public workshops provide a platform for stakeholders to build a wider understanding of drones. Communication should be established in areas where drones are operated. Developing people's perception on benefits, addressing misconceptions and mitigating risks are critical for drone adoption, as illustrated in the experts' level of agreement with the following statements:

- Public engagement and open communication will improve the acceptance of drones by the community (Mean: 4.60; SD: 0.51).
- Public education and more exposure to drone capabilities will improve the acceptance of drones by the community (Mean: 4.40; SD: 0.63).

D.4.1.3 Funding and investment for drones

As in the case of other innovations, there is a gap between drone technology and application. This is where government or private investors can facilitate the adoption of drones through the provision of funding, grants or investment. The survey showed that there is agreement among the experts about the role of funding and investment in supporting drone adoption:

- Increasing the availability of government funding will speed up the adoption of drones (Mean: 4.33; SD: 072).
- Increasing the availability of private investment in drones will speed up the adoption of drones (Mean: 4.00; SD: 0.93).

D.4.1.4 Market readiness and technology readiness

While there is strong agreement among the experts on factors such as regulation, public engagement and funding and investment, they were divided on the topics of market readiness and technology readiness. The findings show that for the statement on the underdeveloped market and limited supply chain, 40% of the experts strongly disagreed or disagreed while the remaining were either neutral or agreed. Similarly, their opinions about the statement on technological change differed. There was also a slight discrepancy among the experts regarding the limited skills and knowledge among Australian firms. This finding shows that there is still a debate and different opinions on whether the Australian market and technological capabilities are ready for wide-scale drone adoption:

- An underdeveloped market and limited supply chain options in relation to drone technology have limited the adoption of drones in Australia (Mean: 2.93; SD: 0.88)
    - Strongly disagree/disagree: 40%
    - Neither disagree nor agree: 26.67%
    - Strongly agree/agree: 33.33%

- Technological uncertainty and the speed of technological changes have limited the adoption of drones among Australian firms (Mean: 3.00; SD: 1.07)
    - Strongly disagree/disagree: 40%
    - Neither disagree nor agree: 13.33%
    - Strongly agree/agree: 46.67%

- Limited skills and knowledge in drone operation among Australian firms limit the adoption of drones (Mean: 3.60; SD: 1.12)
    - Strongly disagree/disagree: 20%
    - Neither disagree nor agree: 26.67%
    - Strongly agree/agree: 53.33.%

D.4.1.5 Contextual conditions and their influence on drone adoption

Table D.6 shows the level of agreement or disagreement among the experts on the role of contextual conditions. Overall, the finding shows that the experts mostly agreed on the statements about the role of contextual conditions in supporting drone adoption. They were unified on the importance of use cases to showcase the benefits of drones (mean = 4.47), and all of the experts agreed with the statement.

It is also important to emphasise the opportunities for drone use that the Australian geographical and demographical contexts create. The statement receives an average of 4.53 with 93.33% of the experts having agreed with the statement. They also regarded Australia's innovation culture and capability as critical factors—93.33% agreed with the statement. Nevertheless, the experts did not completely agree on the quality of human capital—only 60% agreed with the statements. Notably, the experts believed that drones would help lagging regions to catch up with development—80% of them agreed with the related statement presented to them.

Table D.6: Geographic and demographic implications of drone uptake

Statements	**Mean**	**SD**	**Cat 1 (%)**	**Cat 2 (%)**	**Cat 3 (%)**
1. Demonstration of successful use cases focusing on the application of drones in different sectors and regions in Australia increases the adoption of drones.	4.47	0.52	0	0	100.00
2. Australia's innovation culture and ingenuity in applications will help to accelerate the adoption of drones in Australia	4.20	0.77	6.67	0	93.33
3. The high-quality and qualified human capital in Australia will aid the adoption of drones	3.67	0.98	13.33	26.67	60.00
4. Australia's geographical and demographical contexts, such as its strong economy, low population density and large rural areas, create opportunities for drones	4.53	0.64	0	6.67	93.33
5. Drones reduce imbalances between geographical areas across Australia, especially in places where productivity and living standards are lagging	4.07	1.22	13.33	6.67	80.00

6. As more firms employ drones, new applications and opportunities to innovate with drone technology will also expand	4.40	0.83	0	20.00	80.00

Note: The experts were asked to indicate whether they agree or disagree with the statement in 5 Likert scale; Cat 1: Strongly disagree/disagree Cat 2: Neither disagree nor agree; Cat 3: Strongly agree/agree

D.4.2 Sectoral differences in drone adoption

We were interested to know how the experts perceive the development of drones across the sectors. They were presented options to choose the sectors most relevant to the statements. Table D.7 shows the top three sectors that are relevant for each statement, and Table D.8 presents the complete result.

With regard to the benefits of drones in terms of improving productivity and reducing cost, the experts agreed that these benefits can be clearly observed in mining, agriculture and environmental management. Similarly, the advantage of drones as a better alternative to the current technology can be found in those sectors. Notably, public sector serviced received significant attention from the experts. According to them, drones offer new opportunities, services and applications in the public sector. While it is clear that the adoption of drones in the public sector is still low compared with that in other sectors, such as mining and agriculture, more research should be conducted to understand the needs, challenges and business model for drones in public sector services. Moreover, the experts also agreed that this sector needs government support in the form of funding, skill and knowledge upgrades, and regulation. Other sectors, such as AAM, freight and last-mile delivery, also need government support and intervention in terms of regulation and funding.

Table D.7: Top three sectors for each statement

Statement	**Rank 1**	**Rank 2**	**Rank 3**
1. Drones improve productivity	Mining	Environmental management	Agriculture
2. Drones help to reduce cost of production	Agriculture	Mining	Environmental management
3. Drones offer faster, cleaner and safer alternatives to current/existing technology	Agriculture	Mining	Environmental management
4. Drones create more opportunities, new applications, processes and services	Agriculture	Public sector services	Environmental management
5. Drones offer access to better-quality data	Environmental management	Construction	Mining
6. The application of drones in this sector will provide better services and access for rural and remote communities	Environmental management	Public sector services	Freight and last-mile delivery
7. Knowledge, skills and capability in this sector are still lacking to fully adopt drones	Public sector services	Freight and last-mile delivery	Agriculture

8. Government's funding and/or grant is needed in this sector to facilitate the adoption of drones	Public sector services	Advanced air mobility	Agriculture
9. Regulation for drones in this sector needs to be reviewed to facilitate the adoption of drones	Public sector services	Advanced air mobility	Freight and last-mile delivery
10. The Australian community has generally accepted the application of drones in this sector without too many concerns	Mining	Media, recreation and entertainment	Agriculture

Table D.8: Sectoral differences in the adoption of drones (Percentage of expert response for each sector)

	Agriculture (1)	**Freight and Last-mile Delivery (2)**	**Construction (3)**	**Public Sector Services (e.g. Fire, Medical, Emergency and Police) (4)**	**Mining (5)**	**Environmental Management (6)**	**Advanced Air Mobility (7)**	**Media, Recreation and Entertainment (8)**
1. Drones improve productivity	80.00	33.33	60.00	53.33	93.33	73.33	33.33	46.67
2. Drones help to reduce cost of production	86.67	20.00	60.00	40.00	73.33	73.33	6.67	33.33
3. Drones offer faster, cleaner and safer alternatives to current/existing technology	93.33	53.33	53.33	80.00	60.00	66.67	46.67	20.00
4. Drones create more opportunities, new applications, processes and services	86.67	53.33	46.67	80.00	73.33	80.00	40.00	66.67
5. Drones offer access to better-quality data	60.00	0.00	86.67	53.33	73.33	93.33	20.00	26.67
6. The application of drones in this sector will provide better services and access for rural and remote communities	53.33	66.67	13.33	66.67	33.33	86.67	26.67	26.67
7. Knowledge, skills and capability in this sector are still lacking to fully adopt drones	46.67	60.00	33.33	86.67	33.33	40.00	40.00	26.67
8. Government's funding and/or grant is needed in this sector to help the adoption of drones	60.00	6.67	40.00	86.67	13.33	46.67	60.00	13.33
9. Regulation for drones in this sector needs to be reviewed to help the adoption of drones	40.00	73.33	13.33	86.67	13.33	26.67	93.33	33.33
10. The Australian community has generally accepted the application of drones in this sector without too many concerns	53.33	6.67	26.67	26.67	80.00	40.00	0.00	66.67

D.5 Conclusion

This qualitative study set out to establish an overview of the Australian drone sector and to explore how experts perceive the debate on factors that may influence the adoption rate of drones in Australia. Our analysis of interviews and an adapted Delphi method shows an increased awareness of the benefits of drones, but that some public concerns remain. The statement, ‘The Australian community has generally accepted drones in various applications without too many concerns’, received an average score of 3.3 with less than 50% of the experts agreeing with the statement. The statement, ‘The Australian community is still concerned with the societal impact of drones in relation to public safety and privacy’, received an average of 3.7 with 66.67% of the experts supporting it. This finding shows that the overall acceptance of drones is still unsettled, as expressed in the following statements from the initial interview:

> There is a community perception that somebody's always trying to look in your windows, so it's a very fine line for our industry to kind of balance the two things that I see quite a lot. (1/A/2)

> The public acceptance, I think, a lot of people are a little bit uncomfortable with the idea of an unmanned aircraft flying around. Even though if you look at the crash statistics, manned aircraft is still way ahead of an unmanned aircraft crash statistic. (2/P/13)

Furthermore, the experts also raised a point on the lack of ownership in dealing with the issues, as shown from the following excerpt:

> No one up until recently had ownership of some of these topics like noise. It was sort of handballed between different groups. It sits with the Department of Infrastructure, Transport and Regional Communities. At the moment, things like privacy have just been a hot topic. That's been at the state level versus the national level. So, from a government perspective, there has been largely a lack of ownership. At this point where you've got an embryonic industry, it just doesn't have the resources to help itself. (2/P/2)

The public views drones as a risky technology that directly interferes with their privacy. Probably, the public is not aware of most future drone applications and many of its current applications. To solve this problem, stronger, more active engagement with the public is needed. Information about the risks should be communicated clearly. Key players in the drone ecosystem should actively engage in providing the public with information and educational materials on the benefits of drones. Most public perceptions regarding drones have been formed by the use of drones for hobbies and leisure, when in fact, drones have a wide range of benefits in other sectors unknown to the public. From businesses and the industrial sector, the efforts to disseminate the application of drone technology face the same problem. Businesses lack knowledge and information about drones and their capabilities. Businesses familiar with drone technology are more likely to accept drones, but many businesses need support to upgrade their knowledge on drone operation. The survey showed that the experts encourage more use cases or trials in order to overcome this deficiency in information. The statement, ‘Demonstration of successful use cases focusing on the application of drones in different sectors and regions in Australia increases the adoption of drones’, received an average score of 4.47 and all experts either agreed or strongly agreed with the statement. This finding is in line with the comments in the interviews, in which experts proposed the need for engagement and communication with the public on the benefits of drones. Some comments are presented here:

> But with ease and convenience of purchasing drones comes the challenge for us. Both CASA and for industry as well, as to how do we educate? How do we get those safety promotion messages out? How do we ensure people are doing the right thing? (2/P/4)

> I think once we start demonstrating that they can be a lot safer than a helicopter, which they undoubtedly are, and people start trusting in the actual technology, you'll get massive adoption. (2/P/13)

The survey also found that the main reason causing some setbacks in the adoption of drones is regulation and the compliance process. The experts also agree that Australian regulation on drones needs to catch up with the fast development of technology, business needs and new opportunities. Most of the statements on regulation received higher scores than the other statements, showing an agreement among the experts. This finding echoed their opinions during the interviews, in which the following views emerged:

> Regulatory compliance is probably the major hurdle, and that's like with any new technology, the regulators need to catch up to the technology. … To facilitate wide-scale drone use in major cities and metropolitan areas, the drones need to prove to the regulator that they're not going to fall out of the sky. (2/D/12)

> In terms of the next 5 to 10 years, I think that's where you really want to see a shift in regulation. You want to be on the visual line of sight reduction of height. There's a cap on the ceiling that drones can fly without approvals. I think there's a range of components like that flying over populated areas, all those components will need to be reviewed. (2/D/14)

> I think that type of operation and getting that into our current regulations to allow a lot of those operations in this country would be a huge plus because it means we could be local suppliers, we could develop the industry here and support a new and emerging aviation sector. (2/P/13)

The last factor the experts mentioned is the need for funding and investment. Funding is critical as it will help businesses leverage the risks of investing in a new technology. Government support on trials or use cases will also help to convince businesses and organisations to incorporate drone use in their operations. The following statements from the experts corroborate the finding:

> There's a lot of ideas that we want to use drones for, but when you look at them as separate ideas, there's never enough money in that pot to help a drone manufacturer or an operator to invest and actually develop the capability. (1/C/5)

> Sometimes, drone programs can be expensive, and it doesn't make sense to roll out a drone program when the value of the problem that you're trying to solve doesn't stack up against the cost of the drone program. (2/D/8)

Moreover, the analysis presented in this work demonstrates the challenge of gauging societal acceptance, given the low readiness in market and technology, with some experts being less optimistic than others. In terms of market readiness, only half of the experts agreed on the statements. The statement, ‘An underdeveloped market and limited supply chain options in relation to drone technology have limited the adoption of drones in Australia’, received an average score of 2.93, and the statement, ‘Technological uncertainty and the speed of technological changes have limited the adoption of drones among Australian firms’, received an average score of 3.00. To illustrate these findings, the following excerpts from the interviews are presented:

> So, I think, in terms of a commercial product. The supply can't just supply the drones. In order to attract a lot more market, they would have to not only supply the drones but supply the operational service or the training required to operate the drone. (2/P/13)

> For it, unfortunately, in Australia we don't have that sort of supply chain to do so, but our strength is actually in in product development in creating a higher standard. (1/A/5)

> and 95% of all drones in Australia, probably 99% of all drones, are DJI [a Chinese company] products. (2/D/6)

> I don't think the market has been particularly ready. It is now we are starting to see people say okay, we have done with the hobby drone style. Now we want to do something a bit more serious. The actual development of that infrastructure and the cost of that infrastructure for most of these technologies are quite low. (2/D/8)

The global market for drones has grown and is expected to grow to US$27.78 billion during 2021–2025 (Researchandmarket.com, 2023). This significant trend is driven by the increase in the acceptance of drone operations for commercial applications. In many commercial activities, drones have replaced traditional methods of operation. Drones can reduce expenditure in terms of time and money and enhance data analytics, which allow businesses to increase performance and productivity. Drones also offer new opportunities and applications. In the Australian context, we asked the experts to state their opinions on whether different sectors have adopted drones differently and face different obstacles (Figure D.4).

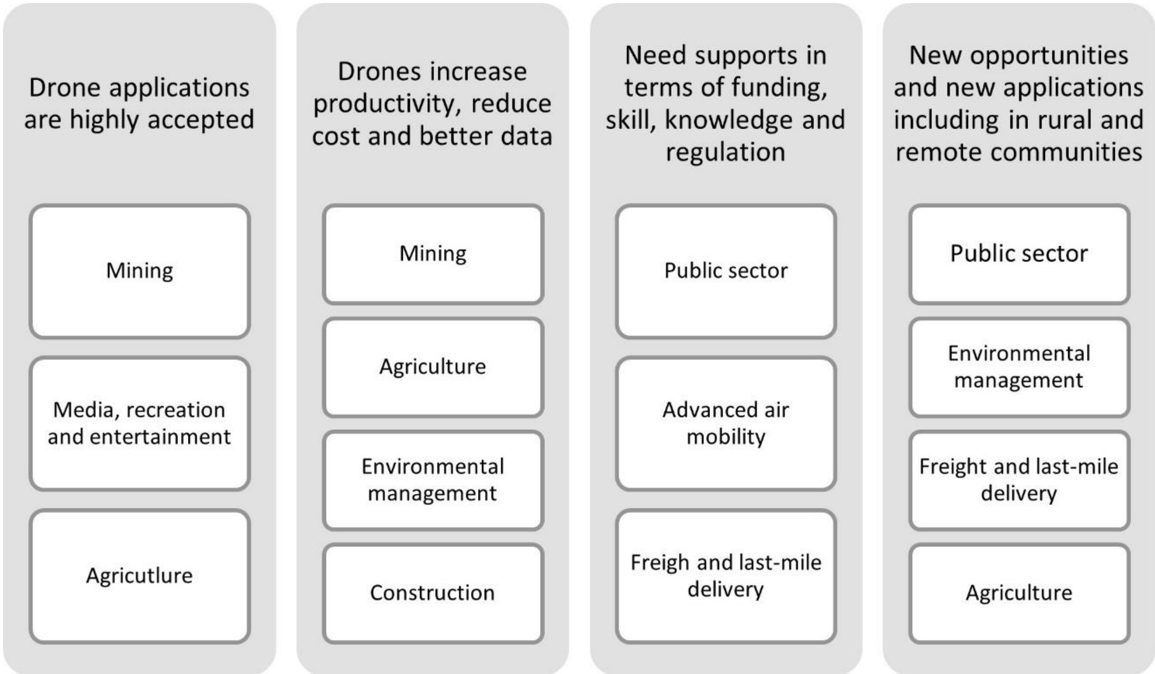

Figure D.4: Drone adoption by sector

We call for regulations and policies on drones so as to move beyond a general model of adoption to one that identifies a desirable use of drones in a specific sector, such as increasing the popularity of drone use in environmental management, or new applications in public sector services. In the first instance, this requires more evidence-based studies and use cases to establish how the system of provision may function and be regulated. In addition, a detailed understanding of, and response to, public concerns, such as privacy and safety, is required. To guarantee sustainable returns and societal change following the wider adoption of drones, future policies on drones should be co-developed by including all stakeholders, such as businesses, regulators and the public.

References

Ayamga, M., Tekinerdogan, B., & Kassahun, A. (2021). Exploring the challenges posed by regulations for the use of drones in agriculture in the African context. *Land*, *10*(2), Article 164. https://doi.org/10.3390/land10020164

Baker, J., Lovell, K., & Harris, N. (2006). How expert are the experts? An exploration of the concept of 'expert' within Delphi panel techniques. *Nurse researcher*, *14*(1)

Fischer, R. G. (1978). The Delphi method: A description, review and criticism. *Journal of Academic Librarianship*, *4*, 64–70.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Lidynia, C., Philipsen, R., & Ziefle, M. (2017). Droning on about drones: Acceptance of and perceived barriers to drones in civil usage contexts. In P. Savage-Knepshield, & J. Chen (Eds.), *Advances in human factors in robots and unmanned systems* (pp. 317–329), Advances in Intelligent Systems and Computing (Vol. 499). Springer. https://doi.org/10.1007/978-3-319-41959-6_26

Locke, K. (2001). *Grounded theory in management research*. Sage.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Researchandmarket.com. (2023) Global drone market 2021-2025. https://www.researchandmarkets.com/reports/5513572/global-drone-market-2023-2027

Smith, A., Dickinson, J. E., Marsden, G., Cherrett, T., Oakey, A., & Grote, M. (2022). Public acceptance of the use of drones for logistics: The state of play and moving towards more informed debate. *Technology in Society*, *68*, Article 101883. https://doi.org/10.1016/j.techsoc.2022.101883

Strauss, H. J., & Zeigler, L. H. (1975). Delphi, political philosophy and the future. *Futures*, *7*(3), 184–196. https://doi.org/10.1016/0016-3287(75)90063-4

Ven, A. H. V. D., & Delbecq, A. L. (1974). The effectiveness of nominal, Delphi, and interacting group decision making processes. *Academy of Management Journal*, *17*(4), 605–621. https://doi.org/10.5465/255641

von der Gracht, H. A. (2012) Consensus measurement in Delphi studies: Review and implication for future quality assurance. *Technological Forecasting and Social Change*, *79*, 1525–1536. https://doi.org/10.1016/j.techfore.2012.04.013

Appendix D-1: Interview Protocol—Round 1 Delphi Method

Category: Drone Operator/Peak Industry Body/Use Case/Existing Trial/Other

Screening question	• What is the main business of your company/organisation? What is your position in the company/organisation? • How long have you been working in this company/industry? Or, for how long have you been involved in drone technology/usage of drones?
Firm level	• How has your company invested in or used drone technology? • What factors supported your company's investment or use of drone technologies? (Opportunities and Strengths) • From your perspective, what factors hinder your company's investment or use of drone technology? (Threats and Weaknesses) • Probing question: • Could you tell me more about your drone project? • Have [productivity/employment/competition/reduction in costs] been primary reasons for your company to adopt drone technology?
Sector/National level	• Tell us a bit about your vision in relation to drone technology adoption in your sector in Australia. Is now the right time for industries in your sector to adopt drone technology? If yes, why? If no, why? • In general, what are the driving factors in adopting drone technology in your sector? (Opportunities and Strengths) • In general, what are the major challenges in adopting drone technology in your sector? (Threats and Weaknesses) • Thinking broadly and from your experience with drones in your sector, will drones be more highly adopted within certain applications for certain geographical places or flight paths than others in Australia? If so, can you please share your views and reasons for this forecast?
Community/society level	• What has been your experience with public or community acceptance in general? • Given that some people will worry or have reservations regarding the adoption of drone technology, what are the major points of public objection to drone technologies and what reasons do they predominantly give for these objections? What do you say to those people? And what can we all do to overcome those reservations? (Threats and Weaknesses) • In what service areas and/or where do you see the strengths and opportunities in Australian society that compel the adoption of drone technology more so than in other countries? (Opportunities and Strengths) • What differences in drone use might there be from community to community, or region to region? How might the value proposition differ for different regions, communities or demographics in Australia?
Final remark	• Do you have any other comments or observations that we should consider in our report on drone technology or drone adoption in Australia?

Guide 2: Interview Questions—Peak Industry Bodies & General Knowledge (e.g. Government and Universities)

Screening question	• What is the main business of your company/organisation? What is your position in the company/organisation? • For how long have you been involved with drones?
Sector or firm level	• Tell us a bit about your experience with drones. • Into which sectors/industries do you think this technology is best applied? Why? What are the driving factors in adopting drone technology? (Opportunities and Strengths) • Where do you see the application being very limited? Why? What are the major challenges in adopting drone technology? (Threats and Weaknesses) • From a company's perspective, what do you think will be the factors that support their decision to adopt drone technology? (Opportunities and Strengths) • From a company's perspective, what do you think will be the factors that stop their decision to adopt drone technology? (Threats and Weakness)
National level	• Tell us a bit about your vision in relation to drone technology adoption in Australia. • What are the (main) drivers that accelerate the adoption of drone technology in Australia (compared with other countries)? (Opportunities and Strengths) • What are the (main) obstacles that are potentially stopping the adoption of drone technology in Australia (compared with other countries)? (Threats and Weakness) Is now the right time for Australia to adopt drone technology? If yes, why? If no, why? • Where do you see high-volume flight paths (orientation and altitude) in 5, 10 and 20 years? Why?
Community/society level	• What has been your experience with public or community acceptance in general? • Given that some people will worry or have reservations regarding the adoption of drone technology, what are the major points of public objection to drone technologies and what reasons do they predominantly give for these objections? What do you say to those people? And what can we all do to overcome those reservations? (Threats and Weaknesses) • In what service areas and/or where do you see the strengths and opportunities in Australian society that compel the adoption of drone technology more so than in other countries? (Opportunities and Strengths) • What differences in drone use might there be from community to community, or region to region? How might the value proposition differ for different regions, communities or demographics in Australia?
Final remark	• Do you have any other comments or observations that we should consider in our report on drone technology or drone adoption in Australia?

Guide 3: Interview Questions—Existing Trials

Screening question	• What is the main business of your company/organisation? And what is your position in the company/organisation? • For how long have you been involved with drones?
About your trial (can also focus on firm level)	• Tell us a bit about your role and experience with the trial so far. • In your trial, what were the driving factors in adopting drone technology? (Opportunities and Strengths) • Where do you see the application being very limited? Why? What were the major challenges in adopting drone technology in your trial? (Threats and Weaknesses) • Do you think this technology should be applied more often in a similar fashion as in your existing trial? Why?
National level	• What are the (main) drivers that accelerate the adoption of drone technology in Australia? (Opportunities and Strengths) • What are the (main) obstacles that are potentially stopping the adoption of drone technology in Australia? (Threats and Weakness) • Tell us a bit about your vision in relation to drone technology adoption in Australia. • In what areas and where do you see the strengths and opportunities in Australian, compared with other countries, in adopting drone technology? (Opportunities and Strengths) • Is now the right time for industries to adopt drone technology? If yes, why? If no, why? • Where do you see high-volume flight paths (orientation and altitude) in 5, 10 and 20 years? Why?
Community/society level	• What has been your experience with community response to the trial? • Thinking broadly about public acceptance, we are aware of some objections. From your experience, what are the major points of public objections to drone technologies and what reasons do they predominantly give for these objections? • Given that some people will worry or have reservations regarding the adoption of drone technology, what do you say to those people? And what can we all do to overcome those reservations? (Threats and Weaknesses) • What differences in drone use might there be from community to community, or region to region? How might the value proposition differ for different regions, communities or demographics in Australia?
Final remark	• Do you have any other comments or observations that we should consider in our report on drone technology or adoption in Australia?

Appendix D-2: Questionnaire—Round 2 Delphi Method

An overview of the Australian drone sector Please indicate how much you either agree or disagree with each statement below.	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
1. Growing interest in drone technology among Australian firms has helped faster adoption of drones					
2. Increased funding for drones has helped faster adoption of drones					
3. Commercial-grade drones are readily accessible and affordable in Australia					
4. The Australian community has generally accepted drones in various applications without too many concerns					
5. The regulators in Australia are very accommodating in the development of aviation policy and regulations for drones					
6. Different states in Australia have their own policy, infrastructure or obstacles that may hinder the adoption of drones					
7. An underdeveloped market and limited supply chain options in relation to drone technology have limited the adoption of drones in Australia					
8. Technological uncertainty and the speed of technological changes have limited the adoption of drones among Australian firms					
9. A lack of drone education and training providers has limited the adoption of drones					

10. Regulation on drones in Australia has not fully matured, such as it needs to accommodate the current technological development	
11. The Australian community is still concerned with the societal impact of drones in relation to public safety and privacy	
12. Noise is still an issue for many Australian community members, which prevents them fully accepting the application of drones	
13. Negative publicity on drones and low awareness of drone applications have limited the adoption of drones by the Australian community	

Do you have any other comments regarding the current status of the adoption of drones in Australia?

____

Key benefits and challenges to increased drone uptake in Australia Please indicate how much you either agree or disagree with each statement below.	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
1. Increasing the availability of government funding will speed up the adoption of drones					
2. Increasing the availability of private investment in drones will speed up the adoption of drones					
3. Public engagement and open communication will improve the acceptance of drones by the community					

4. Public education and more exposure to drone capabilities will improve the acceptance of drones by the community	
5. More frequent reviews of regulations in various sectors will increase the adoption of drones	
6. Difficulties in gaining regulatory clearance and the extensive compliance process limit the adoption of drones	
7. Limited skills and knowledge in drone operation among Australian firms limit the adoption of drones	
8. Widespread use of drones will never be achieved across industry sectors under the current regulatory and/or technological limits (such as limited battery life for long trips)	

Do you have any other comments regarding the key benefits and challenges to increased drone uptake in Australia?

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The geographic and demographic implications for increased drone uptake in Australia Please indicate how much you either agree or disagree with each statement below.	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
1. Demonstration of successful use cases focusing on the application of drones in different sectors and regions in Australia increases the adoption of drones.					

2. Australia's innovation culture and ingenuity in applications will help to accelerate the adoption of drones in Australia	
3. The high-quality and qualified human capital in Australia will aid the adoption of drones	
4. Australia's geographical and demographical contexts, such as its strong economy, low population density and large rural areas, create opportunities for drones	
5. Drones reduce imbalances between geographical areas across Australia, especially in places where productivity and living standards are lagging	
6. As more firms employ drones, new applications and opportunities to innovate with drone technology will also expand	

Do you have any other comments regarding the geographic and demographic implications for increased drone uptake in Australia?

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Please select the sectors where the following statements apply (you can select more than one sector). You can move back and forth between statements by clicking the arrow.	Agriculture (1)	Freight and last-mile delivery (2)	Construction (3)	Public sector services (e.g. fire, medical, emergency and police) (4)	Mining (5)	Environmental management (6)	Advanced air mobility (7)	Media, recreation and entertainment (8)
1. Drones improve productivity								

Drones help to reduce the cost of production

2. Drones offer a faster, cleaner and safer alternative to current/existing technology

3. Drones create more opportunities and new applications, processes and services

4. Drones offer access to better-quality data

5. The application of drones in this sector will provide better services and access for rural and remote communities

6. Knowledge, skills and capability in this sector are still lacking to fully adopt drones

7. Government’s funding and/or grant is needed in this sector to help the adoption of drones

8. Regulation for drones in this sector needs to be reviewed to help the adoption of drones

9. The Australian community has generally accepted the application of drones in this sector without too many concerns

SECTION E: Economy-wide Impact Model

Stage IV: CGE modelling of potential and actual drone applications

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E.1 Introduction

This study uses a computable general equilibrium (CGE) model to examine potential economy-wide impact of drones in specific applications. A CGE model is based on microeconomic theory. Producers seek to minimise costs subject to resource and technology constraints. Consumers seek to maximise utility subject to a budget constraint. Among the resource constraints, national employment is exogenous in the long run. That is, scenarios such as technological gains arising from drone usage will not increase long-run national employment, although such gains may result over time in the redistribution of jobs between different sectors of the economy. Drone usage will result in net economic gains if its additional benefits more than compensate for the additional costs of investing in drones. In long-run scenarios, we also introduce a balance-of-trade constraint, which ensures that we do not exaggerate the economic impact through unaccounted borrowings.

An economic case for the uptake of drones applies in circumstances in which they can redress relative scarcity. For example, in remote regions of Australia, transport services are scarce and relatively costly. This implies that drones may have the potential to enhance transport services and decrease costs.

The following applications are modelled in this study:

- government and community services,
- advanced air mobility (AAM),
- freight and last-mile deliveries,
- agriculture,
- mining and
- construction.

An additional application is a hypothetical study in which the use of drones and other technologies reduces bushfire damage, presented with a separate summary.

In the scenario concerning government and community services, the emphasis is on emergency services, although drones have other potential applications. Emergency services comprise an estimated A$4 billion sector. A 10% net productivity gain (i.e. allowing for the annualised cost of drone inputs) is imposed on the sector to reflect the potential impact of drones in obtaining information on emergency incidents more quickly, reducing labour costs and hastening rescues. This results in a long-run increase in real gross domestic product (GDP) of about 0.022% or A$460 million in present-dollar terms. A deeper understanding of the costing of emergency services provision may lead to improved estimates of potential benefits arising from drone usage in the sector.

The AAM scenario is limited to the productivity impact of drones on transport in Outback Queensland (Outback QLD), Outback Western Australia (Outback WA) and the Northern Territory (NT). The relatively small economic gains reflect the relative size of transport services in these regions. More detailed studies may capture a wider array of direct benefit estimates that expand the estimated economic effects. In particular, these may concern time and cost savings.

The use of drones in freight and last-mile delivery services may be most important in areas other than metropolitan areas. Two sets of shocks are imposed on the model in this scenario: There are productivity gains in some health-related sectors in non-metropolitan regions, reflecting improved services, and there are small productivity gains in road freight in all regions. These result in a gain in the national real GDP of 0.016% or A$344 million. Further, gains are larger in percentage terms for non-metropolitan regions than for other regions.

In agriculture, examples of existing scarcities in production concern relatively expensive labour in horticulture and costs arising from the remoteness of cattle production in northern Australia. Drones may assist in hastening fruit picking and reducing crop losses. At present, helicopters are used routinely in cattle mustering: Drones have the potential to lower mustering costs substantially. Field trials are being conducted on the use of drones to pinpoint weeds in broadacre crops. The agricultural scenario models potential productivity effects for each of these potential uses. The modelled gain in real GDP is 0.034% or A$700 million. Moreover, if drone usage broadens to extensive use in livestock management in southern Australia, economic gains may be larger than those modelled in this study.

Mining is an area in which the use of drones is relatively advanced at present, owing to increased uptake in response to the coronavirus disease (COVID-19) lockdowns that limited the mobility of personnel to and from remote mining sites. In such scenarios, drones enable mine operations to reduce mining service inputs and improve mining productivity. A caveat on the modelled benefits of drone applications in mining is that there is substantial foreign ownership in mines. This implies that additional income from mines arising from drone-induced productivity benefits are shared between the domestic economy and foreign shareholders.

Various forms of construction activity, including building, infrastructure and civil engineering construction, account for a large share of the national economy, exceeding 8% of the GDP. Consequently, there may be substantial potential productivity benefits from the use of drones in the construction sector. Regulatory constraints concerning drone usage are less of an issue at building sites than in other spaces. Australia has experienced issues with structural materials and structural integrity in buildings in the past few years, with potentially costly remediation required. Drones may also be useful in the inspection of infrastructure, including roads and bridges, thus lowering costs and enhancing safety. The modelled gain in this study from drone usage in construction sectors is an increase in real GDP of approximately 0.19% or A$4 billion.

Regardless, even the scenarios based on relatively detailed information remain somewhat speculative. Further studies may provide more informed estimates of costs and benefits, based on growing evidence and data arising from drone usage.

E.2 Approach and Methodology

E.2.1 Preparing productivity shocks

The preparation of shocks for the CGE study requires judgements based on the scope of possible drone applications within a given industry and the industry size and location. The ascribed shocks are speculative: Even if drones are being used increasingly in particular industrial applications, estimates of their contribution to productivity may become available only after many years. Moreover, prospective drone usage may not materialise if, for example, competing technologies ultimately play a larger role in lowering industry costs. Yet, some drone applications may result in economic gains that far exceed those modelled in this study, whereas the early promise of other applications may not materialise. The magnitude of shocks depends in part on known input cost shares for a given industry, and in part on judgement.

E.2.2 Relating productivity shocks to background productivity growth

The Australian Bureau of Statistics (ABS) produces regular estimates of multi-factor (i.e. primary factors plus intermediate inputs) productivity across industries.[3] In some years, productivity growth in a particular sector is negative. This was so for mining in 2021–2022

[3] See https://www.abs.gov.au/statistics/industry/industry-overview/estimates-industry-multifactor-productivity/latest-release#productivity-growth-cycles

because of the impact of floods. In a typical year, productivity may grow by about 1%. Note that the modelling undertaken in this study includes a combination of intermediate input productivity gains and primary factor productivity gains. The productivity improvement of services to mining as an input to the mining sector is an example of the former, and the primary factor productivity shock to the mining sector is an example of the latter.

Productivity studies remind us that potential drone applications are but one possible source of productivity gains. Some of the shocks ascribed in the CGE modelling of this study may be equivalent to a few months of ongoing, typical multi-factor productivity growth. Larger shocks may be equivalent to several years of typical multi-factor productivity growth.

We used two versions of a multi-regional CGE model to examine the impact of drones. One version is a comparative static version of TERM, or The Enormous Regional Model (Horridge, 2012; Horridge et al., 2005). Another is a dynamic version of TERM (Wittwer & Verikios, 2012). Section A9 provides more information on the model. The comparative static version of TERM is used in all but one of the applications presented here to examine the prospective impact of the use of drones on different sectors. The exception concerns the application of drones in mining, where drones are already in relatively advanced use. In the mining scenario, the study presents preliminary estimates of the realised effects of drone usage.

Last, this study presents a hypothetical scenario, in which the drones and other technologies reduce the extent of bushfire damage. Since much of the economic damage of a catastrophic event is measured by estimating the destruction of capital stocks and infrastructure, with subsequent restoration costs, the model used in this study is dynamic. Dynamic models contain formal links over time between investment flows and capital stocks, and between balance-of-trade flows and stocks of debt.

E.2.3 The model

The model used for six of the seven scenarios is a comparative static version of TERM, a multi-regional CGE model of the Australian economy. The master database of TERM depicts 216 sectors in 334 SA4 regions. For convenient computation and presentation, the model was aggregated to 33 sectors and 15 regions. Table E.1 shows the sectors of this aggregation and Table E.2 the regions. The comparative static CGE database in this study is based on the 2017–2018 input–output table prepared by the ABS.[4] However, using national accounts data, it was updated to 2021–2022. In the final scenario, we used a dynamic version of TERM for analysis. Table E.1 lists the sectors and Table E.2 the regions in the comparative static aggregation of TERM.

Table E.1: Sectors in comparative static TERM aggregation

Sector	Description
OthCrops	Crops other than grains & fruit tree crops
TreeFruit	Tree crops—fruit
OthrLivstock	Livestock other than beef cattle
BeefCattle	Beef cattle
Grains	Wheat, barley, oats & other cereals
HayCerealFod	Hay from cereal crops; fodder
ForestFish	Forestry & fishing

[4] Details of the CGE database preparation are outlined in https://www.copsmodels.com/archivep.htm TPGW0196.

TCFs	Textiles, clothing & footwear
Mining	Mining
MiningSrvces	Services to mining
FoodProds	Food and beverage products
HumPharmac	Human pharmaceuticals
Fuel	Fuel
BasicChemicl	Basic chemicals
OthManufact	Other manufactures
Utilities	Electricity, water & gas distribution, waste
ResidBuildng	Residential building construction
OthConstruct	Other construction
CivilEngCnst	Civil engineering construction
ConstrucSrvc	Services to construction
Trade	Wholesale and retail trade; hotels & restaurants
OtherService	Other services
RoadPassngr	Road passenger transport
RoadFreight	Road freight transport
RailTranspor	Rail transport
OthTransport	Other transport & storage
AirTransport	Air transport
PostCourier	Postal services and couriers
OwnerDwellng	Ownership of dwellings
ArchEngScSvc	Architectural, surveying, engineering & scientific services
EmergncyServ	Fire brigades & other public order
OthHealth	Health excluding pathology services
PathologySvc	Pathology services

Table E.2: Regions in comparative static TERM aggregation

Regions	Description
RoNSW	Rest of NSW
SydneyNSW	All Sydney SA4 regions
RoVic	Rest of Victoria
MelbourneVic	All Melbourne SA4 regions
SEQld	Brisbane, Gold Coast, Sunshine Coast & Toowoomba
RoQld	Rest of Queensland
OutbackQld	Outback Queensland SA4 region
AdelaideSA	All Adelaide SA4 regions
RoSA	Rest of South Australia
FarmWA	Rest of Western Australia

PerthWA	Perth SA4 regions
OutbackWA	Outback North & Outback South SA4s
TAS	Tasmania
NT	Northern Territory
ACT	Australian Capital Territory

E.2.4 Model closure

The choice of exogenous and endogenous variables in a model is known as the closure. In a CGE model, each equation solves for a single variable, but a typical CGE model has more variables than equations. Therefore, to ensure equal numbers of equations and endogenous variables, some variables are defined to be exogenous. The comparative applications presented here use a long-run closure.

In the long run, capital stocks adjust so as to restore the pre-simulation rates of return on capital. There is a caveat: National aggregate capital is assumed to be exogenous. This is to ensure that there is no ‘free gift’ of capital. A comparative static model consists of flows. There is no formal linkage between investment stocks and capital flows as in a dynamic model. Although the percentage change in investment is set equal to the percentage change in capital stocks in each sector, this maintains rather than builds up new capital. The assumption in the labour market at the national level is that national employment in the long run is driven by demography and immigration patterns. Therefore, scenarios in this study have no assumed impact on national employment, which is fixed.

The long-run effects that our scenarios have on the national labour market are real wage impacts. The multi-regional model includes a theory of imperfect labour mobility between regions, so that a scenario in which the labour market is strengthened in one region relative to others will see it increase its share of national employment. Real wages also adjust, but not sufficiently to equalise percentage wage changes across all regions relative to base.

E.2.5 Modelling net benefits

The direct effects imposed on the model in each scenario, with the exception of the bushfire scenario, are productivity shocks. We interpret these as net direct productivity gains. The purchase and use of drones entails upfront costs. We can think of these as annualised costs in a comparative static framework. Therefore, productivity gains are net of these costs. In some cases, the annualised capital costs of using drones may be lower than the costs of alternative capital inputs. In other cases, they may displace labour or material inputs. Each of the scenarios presented here is speculative. Even if we had accurate and detailed cost information for drones in each scenario, they would provide a guide only. This is because with technological developments over time, the costs of drones will fall. Indeed, the uptake of drones will depend in part on productivity gains.

Some aspects of productivity are not straightforward to measure. For example, if the use of drones raises the quality of industrial outputs, price premiums rather than the quantity of output may reflect the gains. If drones enhance industry safety, data such as recorded reductions in industrial accidents and workers’ days off may reflect the gains. Studies of estimated productivity gains rely on historical data on inputs and outputs. In the case of this study, which quantified the future impact of drones, there were very limited data with which to calibrate the productivity shocks. Some shocks are based on numbers in the literature review, while others are more speculative.

Emerging technologies complicate the marginal impact of drones. In some cases, other technologies will be complementary to drones. In others, competing technologies may diminish the role of drones. There is reasonable confidence that some applications presented in this study will entail growing drone usage. In other potential applications, there is much less confidence. For example, regulatory barriers or public resistance may prevent potential applications from being realised. Some applications, such as AAM, may have a growing role in remote areas but not in metropolitan areas. It is quite possible that some of the scenarios presented here are likely to overestimate the eventually realised economic impacts of drones in a particular application, while other scenarios may underestimate the impacts.

E.3 Preparing productivity shocks of drones in various sectors

The scope of modelled applications is based on information available in the rest of this report. The task of estimating impacts at the sectoral level relies heavily on activity levels within the CGE database, combined with judgments on potential productivity gains arising from the use of drones. This study examines potential economy-wide effects arising from the possible applications of drones listed next.

E.3.1 Emergency services (within government sector)

The ascribed shock was determined using an estimate of the size of the emergency services sector within the model, combined with the researchers' judgement about the scope of drones to reduce costs. Search and rescue efforts without drones may involve many personnel and the use of expensive helicopters in a single mission. Drones may lower costs considerably and, via quicker resolutions, improve health outcomes for those who are rescued. A 10% productivity improvement was based on these considerations.

E.3.2 Advanced air mobility

The application of AAM is excluded from metropolitan areas, owing to existing regulatory constraints and limited public acceptance (Sah et al., 2021). In theory, AAM applications may lower travel costs in relatively inaccessible areas in which roads are poor, distances long and seasonal conditions likely hinder or prevent land transportation. At present, remote regions rely on relatively expensive air transport connections.

A 30% productivity shock imposed on road passenger transport in Outback QLD and Outback WA reflects the possibility that AAM may provide considerable cost savings, in part via reduced travel times. The smaller shock given to the NT (5%) reflects the inclusion of metropolitan Darwin in the NT region, in which AAM is unlikely to be applicable.

In addition, there is a 10% productivity shock to rail transport in Outback QLD. This reflects the possibility that AAM use from railway stations to final destinations may lower travel costs while also increasing rail patronage.

E.3.3 Freight and last-mile delivery

Section B includes numerous examples of freight and last-mile delivery applications of drones. Trials cited include one in Vanuatu (Snoufer, 2002) and another in Goondiwindi (Goondiwindi Regional Council, 2022). Away from metropolitan areas, the delivery of goods may be relatively slow and expensive. The scenario modelled in the CGE application excludes metropolitan areas from the productivity shock.

Section B cites that Deloitte (Deloitte Access Economics, 2020) estimate that there may be between 46 million and 65 million medical delivery trips by 2040. The 0.75% productivity shock imposed on the other health and pathology services sectors implies a cost saving of A$2.40 to A$3.40 per trip.

The productivity shock ascribed to road freight to depict last-mile deliveries was based on an A$3 cost saving per trip on 50 million trips per annum. Potential gains may be in the form of lower freight costs in non-metropolitan areas and more timely delivery of medical items. Modelled national gains of A$344 million in real GDP are concentrated in non-metropolitan areas.

E.3.4 Agriculture

The CGE model includes the following sectors: tree crops; beef cattle; grains; hay, cereal and fodder; other crops; and other livestock. By representing tree crops separately, the model enabled us to separate the potential benefits of drone use to pick crops from the benefits of other drone applications. The direct benefit of using drones to pick crops is limited to this sector, which is based on regional data on crop output. A 10% shock to output enhancement was based on the potential contribution of drones to reducing spoilage and losses in crop picking.

The costs of weed spraying may fall in broadacre crop production if drone technologies eventually supersede the aerial spraying method used currently. This presupposes that drone technologies will target weeds, thereby reducing herbicide usage, and will lower the overall costs of spraying. Spraying costs are captured by a 30% reduction in the basic chemical inputs for grain production. Basic chemicals account for 7% of the intermediate input costs and 4.8% of the total costs of grain production. Herbicide costs are an ongoing concern for farmers.[5]

In beef cattle production, the replacement of helicopter mustering with drones will be limited mainly to rangeland production. Helicopter mustering is used in remote regions on large holdings. Drones will have less of a role in higher-intensity production in southern regions, which were excluded from the productivity shocks. The multi-regional model used for CGE analysis in this study enabled us to distinguish between rangeland and other production by depicting beef cattle production in different regions.

The potential examples modelled are drone use in cattle mustering, fruit picking and weed spraying. The modelled effects from these applications are a real GDP gain of A$700 million.

E.3.5 Mining

The present mining technologies include some inputs that are quite expensive. For example, mining in remote regions relies heavily on a fly-in, fly-out workforce. The use of drones may expand to redress the high costs arising from the remoteness of mines.

Given that the future of coal, oil and gas will be limited by the global efforts to transition away from fossil fuels, it may be reasonable to exclude fossil fuels from the scope of productivity improvements in future studies. A growing understanding of how drones may contribute to the extraction of precious metals used in renewable technologies, including batteries and solar panels, may result in studies that examine precious metals production specifically.

A primary factor productivity shock of 0.5% was ascribed to the mining sector. In addition, a 5% shock to the services to mining sector reflects the growing role of drones and their potential to lower costs in the services sectors.

[5] See https://www.abc.net.au/news/rural/2021-07-20/glyphosate-ban-could-cost-farmers-hundreds-of-thousands-/100307322

The lockdowns related to COVID-19 accelerated the uptake of drone usage in mining in remote regions. The benefits of drones to mining productivity may be substantial. However, these will be distributed between foreign shareholders, Australian shareholders and government revenue.

E.3.6 Construction

There is considerable scope for drones to lower the costs of inspections of multistorey buildings, civil engineering construction and other construction such as pipelines. The productivity shock of 5% ascribed to the services to construction sector reflects the cost-lowering possibilities of drones in construction.

Various forms of construction activity account for more than 8% of Australia's GDP. Regulatory constraints concerning drone usage are less of an issue at building sites than in public spaces. In this scenario, productivity gains arising from drone usage results in an increase in real GDP of about A$4 billion.

E.3.7 Bushfires

An earlier study (Wittwer & Waschik, 2021) itemised estimated direct losses from bushfires, including the destruction of property and infrastructure, and harm to human health. These inputs were used in a dynamic CGE analysis. In the hypothetical scenario of the present study, the assumption is that drones and other technologies provide early information on fires and enable firefighters to respond while blazes are still relatively small. The assumption of the hypothetical scenario is that direct losses are halved. The modelled A$8 billion welfare gain from hypothetical responses to the extreme example of the 2019–2020 bushfires may translate into a possible A$1 billion gain in a more typical year.

E.4 Drones in government and community services

The emphasis in possible drone usage is on emergency services, an estimated A$4 billion sector. Drones may hasten information gathering and search and rescue efforts. The illustrative impact of drone use is an A$460 million increase in the annual real GDP.

Section B lists several activities in which drones could enhance delivery of public services. These include policing, border control, firefighting, disaster management, coastline patrols and environmental protection. The economic impact of some of these could be examined in more detail in case studies. Section E.10 provides a hypothetical example of the case of bushfires, in which successful early intervention with drones and other technologies alleviates disaster to some extent. The bushfire scenario uses a dynamic version of TERM to estimate the impact on the flow of economic transactions and stocks of capital and debt. Stocks are not modelled in a comparative static CGE model. A large proportion of the economic benefits of drones and other technologies in the hypothetical scenario arise from the reduced destruction of stocks of housing, farm capital, communications infrastructure and commercial buildings.

Drones have a potentially vital role to play in search and rescue efforts. They can trace missing people more rapidly than on-the-ground searches. There are benefits in terms of reduced personnel required to undertake searches, and, given the likelihood of finding the missing people earlier, in terms of reduced injury and dehydration. Section B notes the potential role that drones may play in the provision of emergency medicine in future, including the delivery of medical equipment to relatively inaccessible locations.

In emergency incidents, drones will become vital in establishing early lines of communication. During flood events, drones have a potentially important role to play in locating people stranded by floodwater. Section B lists many examples of the roles of drones in emergencies in addition to those listed above. Some of these are traffic emergencies, building inspections and beach hazards.

For illustrative purposes, this section includes a comparative static CGE scenario, in which drones lower the costs of emergency services provision by 10%. Future studies using more detailed information on personnel required and costs in search and rescue operations may improve modelling inputs.

- The annual costs of emergency services provision in Australia

Tracing the costs of emergency services provision in Australia is not straightforward. The ABS input–output product details table[6] includes the sectors ‘fire protection’ and ‘other emergency services’, whose total sales in 2017–2018 were A$3.7 billion and A$9.0 billion, respectively.

Nassios and Giesecke (2022) compiled fiscal data from the Commonwealth Government and state governments. Only two states, New South Wales (NSW) and Tasmania, collect an emergency services levy. In other states, emergency services revenues are embedded in other taxes. Inferences from NSW levy collections, plus additional revenues collected by local councils via land taxes, imply that in 2017–2018, the annual activities of the nationwide emergency services sector were worth A$3.5 billion. Allowing for updates to 2021–2022, emergency services is depicted as an A$4 billion industry in value-added terms.

Next, we used a back-of-the-envelope[7] calculation to measure the impact of a 10% productivity gain in emergency services on national real GDP. Real GDP is a measure of aggregate output:

$$GDP = f(K,L,1/A)$$

GDP is a function of capital (K), labour (L) and technological change (1/A). K and L are both fixed nationally by assumption. This implies that national real GDP can increase only via technological change: If drones can improve the productivity of emergency services by 10%, this is equivalent to an A$400 million boost.

Table E.3 shows the macro-economic impact of the emergency services productivity improvement, realised with the use of drones. National real GDP increases by 0.022% or $460 million relative to base. This is larger than the direct $400 million productivity boost, despite national aggregate employment and capital being exogenous in the long run setting. The difference between the direct and modelled results reflects additional indirect tax income, excluded from the simplified GDP formula above but included in the CGE model. In the base data, indirect taxes account for around 10.4% of GDP.

[6] See https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-input-output-tables-product-details/latest-release

[7] ‘Back-of-the-envelope’ refers to a calculation based a simplified version of the model, in this case, a simplified GDP equation. This checks that the modelled results and the simplified equation align reasonably.

Table E.3: Macro-economic impact of emergency services productivity improvement (change from base case)

Region	Real GDP		Real Consumption		Employment		Real Wage	Capital Stock
	(%)	(A$m)	(%)	(A$m)	(%)	FTE	(%)	(%)
RoNSW	0.025	55	0.037	50	−0.001	−7	−0.016	0.004
SydneyNSW	0.025	112	0.037	91	−0.001	−21	−0.017	0.004
RoVic	0.023	23	0.052	33	0.007	40	−0.009	0.008
MelbourneVic	0.029	107	0.046	105	0.004	71	−0.012	0.010
SEQld	0.024	68	0.038	62	−0.001	−8	−0.016	0.001
RoQld	0.010	12	0.036	21	−0.001	−7	−0.017	−0.011
OutbackQld	0.026	2	0.061	2	0.011	3	−0.005	0.019
AdelaideSA	0.028	27	0.039	24	0.000	0	−0.016	0.006
RoSA	0.021	6	0.052	8	0.006	10	−0.009	0.009
FarmWA	0.008	4	0.044	9	0.003	5	−0.013	−0.010
PerthWA	0.009	19	0.036	35	−0.001	−10	−0.017	−0.015
OutbackWA	−0.009	−3	0.030	3	−0.004	−3	−0.020	−0.025
TAS	0.030	10	0.048	11	0.005	9	−0.011	0.013
NT	0.011	3	0.027	3	−0.006	−5	−0.022	−0.013
ACT	0.028	15	0.007	2	−0.016	−30	−0.031	−0.021
National	0.022	460	0.040	459	0	..	−0.016	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

The assumption in this long-run scenario is that real government consumption is unchanged. This results in government consumption of emergency services remaining the same, even though these services are now cheaper relative to base. In Table E.3, we see that increases in real household consumption account for virtually all of the increase in real GDP.

Table E.4 shows a combination of the sectors in which emergency services have relatively high dollar inputs into industry activity and sectors with relatively large percentage increases in output. Although the effect of cheaper emergency services on the mining sector is positive, the relative cost advantage is higher in other sectors. Consequently, the sector's share of national labour and capital decreases. As shown in Table E.4, the mining sector's output decreases by 0.019% and its price increases by 0.008%, the latter due to movement up the export demand curve as the export volume decreases.

The remaining sectors shown in Table E.4 are beneficiaries of cheaper emergency services inputs relative to base. For most, a fall in input costs reduces overall production costs. The exception is OwnerDwellng (ownership of dwellings), sold mainly to households and one of the most income-elastic of sectors. The reason the sector's output price increases relative to base is because the national capital constraint raises the rate of return on capital relative to base uniformly across all sectors. About 63% of the total costs of ownership of dwellings are capital costs.

Table E.4: Selected national industry impact, emergency services productivity improvement (change from base case)

Sector	Output (%)	Price (%)	Value ($m)
EmergncyServ	0.306	−2.890	−374
Mining	−0.019	0.008	−26
BasicChemicl	0.047	−0.012	6
OthManufact	0.045	−0.012	76
ResidBuildng	0.044	−0.011	37
OtherService	0.025	−0.011	254
HumPharmac	0.056	−0.034	2
OthTransport	0.014	−0.006	6
ArchEngScSvc	0.018	−0.026	−6
ConstrucSrvc	0.011	−0.015	−9
OwnerDwellng	0.042	0.028	162

The benefits of reduced injuries and shorter hospital admissions owing to more rapid search and rescue operations are not modelled in this scenario.

E.5 Drones in Advanced Air Mobility

The AAM scenario is limited to the potential productivity impact of drones on transport in Outback QLD, Outback WA and the NT. In addition to potentially cheaper transport between destinations and airports, there may be significant time and cost savings.

The use of drones for personal transport appears to remain somewhat speculative and relatively far in the future, in particular, owing to the difficulties of persuading regulators and potential passengers of their safety. There are several plans and trials for uncrewed air taxis or similar operations. These include Vertical Aerospace in London, Volocopter in Singapore and EHang in Linz. However, to the best of our knowledge, no uncrewed air taxi service has begun regular operations. Therefore, in the context of the effects we are discussing for the other use cases, in which benefits can be realised in the coming years with technology already available or available in the near future, any benefits of uncrewed passenger aircraft in a similar timeframe are likely to be small.

Studies on personal transport by drones, for example, Mualla et al. (2019) and Goyal et al. (2021) cited in Section B, largely focused on their performance and cost-effectiveness, and paid little attention to the challenges of having them accepted. The research we conducted in this project, in particular, the survey of community members, will add to current knowledge about perceptions of the risks of using drones for passenger travel and concerns about using them for travel.

Once the technology is developed and proven, drones may be used for a range of types of passenger transport. Drones of different designs could substitute for private cars, taxis, buses, private jets, ambulances and sightseeing helicopters, or provide types of transport not permitted by any existing vehicles. However, given the current state of technology and plausible concerns about adopting drones for passenger travel, those uses appear still to be some way in the future.

In the Australian context, the greatest potential for AAM is in relatively remote regional areas. Remoteness raises the potential benefits of such usage. In remote regions, potential users are likely to be saddled with less regulation than in relatively congested urban settings. A potentially important use may be to transport people from regional airports to their destinations. For example, in relatively remote parts of QLD, roads are poor and may be inaccessible when it is wet. AAM may become cheaper than cars for transport in such conditions, particularly after accounting for significant potential time savings. In cities, regulation to manage air space makes the potential use of drones for passenger transport more problematic, although, in less congested cities, productivity gains are expected to be smaller as time savings are most likely much smaller.

The productivity shock to road passenger transport in this scenario is 30% in Outback QLD and Outback WA, and 5% in the NT. In addition, there is a 10% productivity shock to rail transport in Outback QLD. The latter shock reflects the relative importance of rail passenger transport in the region—the shock is proportionally smaller than for the road sector, because rail transport includes a substantial freight component that is excluded from the shock. All of the above assume that drones for passenger transport eventually fall in price so that they are not an order of magnitude more expensive than motor vehicles. The productivity shocks also reflect time-saving benefits for people who live in these regions. The shock to the NT is proportionally smaller than to the Outback regions because NT includes Darwin, in which AAM is less likely to be applicable, owing to air space management challenges and reduced cost–benefit advantages. As with other productivity shocks imposed in this study, refined estimates may emerge in future studies as costings and benefits are examined in more detail, with the benefit of emerging data.

Table E.5: Macro-economic impact of advanced air mobility scenario (change from base case)

Region	Real GDP		Real Consumption		Employment		Real Wage	Capital Stocks
	(%)	(A$m)	(%)	(A$m)	(%)	FTE	(%)	(%)
RoNSW	−0.001	−2	0.002	2	0.000	−4	−0.001	−0.002
SydneyNSW	−0.001	−3	0.002	4	0.000	−7	−0.001	−0.002
RoVic	0.000	0	0.002	2	0.000	0	0.000	−0.001
MelbourneVic	0.000	−1	0.002	5	0.000	−3	−0.001	−0.001
SEQld	−0.001	−3	0.002	3	0.000	−7	−0.001	−0.003
RoQld	−0.001	−1	0.003	2	0.000	2	0.000	−0.002
OutbackQld	0.163	11	0.033	1	0.015	5	0.015	0.042
AdelaideSA	0.000	0	0.003	2	0.000	0	0.000	−0.001
RoSA	0.002	1	0.006	1	0.002	3	0.001	0.003
FarmWA	0.000	0	0.002	0	0.000	0	−0.001	0.000
PerthWA	−0.001	−3	0.000	0	−0.001	−11	−0.002	−0.001
OutbackWA	0.063	22	0.038	4	0.018	12	0.017	0.044
TAS	−0.001	0	0.002	0	0.000	−1	−0.001	−0.002
NT	0.027	9	0.008	1	0.003	3	0.002	0.013
ACT	0.000	0	0.003	1	0.000	1	0.000	0.000
National	0.001	29	0.002	28	0	..	0.000	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

Table E.5 shows the macro-economic impact of the scenario. The national real GDP increases by A$29 million. The relatively small national increase reflects the relatively small base values of the regional transport sectors shocked in the scenario. This is one example that may underestimate the potential benefit of drones. This is because the TERM database used for modelling does not capture regional details concerning transport costs perfectly. In particular, differences in transport subsidies between regions are not embedded in the model. Therefore, the model likely underestimates the true economic cost of transport in remote regions, and in turn, may underestimate the net benefits of potential enhancements that AAM may bring.

Table E.6: Selected national industry impact, advanced air mobility (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
Mining	0.006	0.000	14
OthManufact	−0.001	0.000	−1
ResidBuildng	0.002	0.001	4
OtherService	0.001	0.001	32
RoadPassngr	0.010	−0.101	−17
OwnerDwellng	0.002	0.004	14

Table E.6 shows selected sectoral results of the scenario at the national level. These are relatively small, reflecting that the imposed effects are small relative to national economic activity.

E.6 Drones in Freight and Last-mile Deliveries

Potential gains may be in the form of lower freight costs in non-metropolitan areas and more timely delivery of medical items. Modelled national gains in real GDP of A$344 million are concentrated in non-metropolitan areas.

Section B provides different examples of drone usage for freight and last-mile deliveries. One example is a trial in Vanuatu in which drones delivered vaccines to remote villages and communities. For a potential Australian example, distances between communities and remoteness on Cape Yorke Peninsula in QLD, for example, make the region a candidate for the use of drones to deliver medical supplies. Given that air and road transport services are there in the region, although relatively infrequent, one possibility is the delivery of medical supplies from airports and truck stops to destinations within several dozen kilometres. This would improve the timeliness of delivery.

Another possibility is that the development of logistics, including the use of drones, enables them to become complementary to the provision of the Flying Doctors service. This would entail delivery of emergency supplies from bases such as hospitals, primary health sites and community health centres within the Cairns and Hinterland Hospital and Health Service. Alternatively, it may be that the Flying Doctors service within Australia renders less valuable the use of drones as in the Vanuatu trial. A basic economic concept is that a new service will bring relatively high economic benefits in circumstances or regions in which existing services are relatively scarce. No modelling of a complementary role to Flying Doctors is presented here, although such a role remains a possibility for drones.

Another trial cited in section B is the Goondiwindi drone trial, in which medical supplies can be delivered within a 40-km radius of the airport. The adoption of drone technologies across rural regions has the potential to lower the costs and improve the timeliness of medicine delivery to households. The modelling exercise depicts the widespread adoption of drones for medical service delivery as a 0.75% improvement in the productivity of medical services outside metropolitan areas. This reflects the current high costs of medical provision for people living some distance from medical facilities and the role of drones in reducing these costs.

The value-added of the health sector in this version of TERM in regions excluding Sydney, Melbourne, South East QLD, Adelaide, Perth, Tasmania and ACT is A$20.6 billion. A productivity improvement of 0.75%, as modelled in this scenario, would imply a gain of A$155 million. Section B notes that Deloitte (Deloitte Access Economics, 2020) estimated that 46 million and 65 million trips may be made using drones for medical deliveries by 2040. This would imply that each trip entailed a productivity benefit of between A$2.40 and A$3.40 per trip.

Section B discusses the use of drones for the last leg of a freight delivery. It cites the Deloitte (Deloitte Access Economics, 2020) estimate of 37 million to 67 million such deliveries by 2040. Assuming an A$3 productivity enhancement per trip on 50 million deliveries per annum, an A$150 million productivity gain would equate to a productivity gain of 0.702%: the primary factor costs of the national road freight sector are A$21.3 billion (0.702% = 150/21300 × 100).

Real GDP at the national level increases by A$344 million relative to base (Table E.7)—A$305 million from productivity shocks and the remainder from indirect tax revenue increases.

Table E.7: Macro-economic impact of freight and last-mile deliveries via drones (change from base case)

Region	Real GDP		Real Consumption		Employment		Real Wage	Capital Stocks
	(%)	(A$m)	(%)	(A$m)	(%)	FTE	(%)	(%)
RoNSW	0.041	91	0.029	39	−0.001	−6	−0.006	0.006
SydneyNSW	0.005	22	0.030	74	0.000	−8	−0.005	−0.005
RoVic	0.051	52	0.033	20	0.001	7	−0.004	0.014
MelbourneVic	0.007	28	0.032	73	0.001	13	−0.004	−0.002
SEQld	0.007	21	0.031	51	0.000	1	−0.005	−0.005
RoQld	0.037	44	0.033	19	0.001	5	−0.004	0.007
OutbackQld	0.059	4	0.065	2	0.017	5	0.012	0.039
AdelaideSA	0.008	7	0.027	17	−0.002	−9	−0.007	−0.003
RoSA	0.048	13	0.040	6	0.005	7	0.000	0.020
FarmWA	0.040	19	0.041	9	0.005	9	0.000	0.018
PerthWA	0.004	8	0.028	27	−0.001	−10	−0.006	−0.007
OutbackWA	0.017	6	0.034	3	0.002	1	−0.003	−0.001
TAS	0.058	19	0.035	8	0.002	4	−0.003	0.021

NT	0.033	11	0.023	3	−0.004	−3	−0.009	0.007
ACT	−0.001	−1	0.023	5	−0.004	−7	−0.009	−0.008
National	0.016	344	0.031	356	0	..	−0.005	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

There are small benefits to all regions in terms of aggregate consumption. The ACT's small real GDP loss is offset by a slight improvement in the region's terms of trade (i.e. the price of a region's exports divided by the price of its imports), resulting in an increase in consumption relative to base. As the last-mile delivery shock is imposed on all regions, no single region increases substantially its share of national employment.

At the sectoral level, gains are spread thinly over most sectors (Table E.8). Health (divided into pathology services and the rest of health) output increases slightly with slightly lower prices, reflecting the productivity enhancement arising from the use of drones. Road freight's productivity enhancement from last-mile drone uptake also results in an increase in output and decrease in price. Other services benefit from cheaper health inputs and an increase in aggregate consumption: the sector's income elasticity is close to 1.0. The increase in output of the ownership of dwellings sector is driven entirely by the increase in aggregate consumption.

Table E.8: Selected national industry impact, freight and last-mile productivity improvement (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
OtherService	0.01	0.00	313
RoadFreight	0.07	−0.33	−126
OwnerDwellng	0.03	0.03	130
OthHealth	0.04	−0.14	−115
PathologySvc	0.01	−0.13	−15

In non-metropolitan regions, the modelled real GDP gain is approximately 0.4%. For example, in the Rest of NSW, the largest of the non-metropolitan economies, the real GDP gain is 0.41%. As seen in Table E.9, showing selected sectoral results for Rest of NSW, the direct modelled productivity gains are larger than the output gains in road freight (0.750% v. 0.086%), other health (0.702% v. 0.231%) and pathology services (0.702% v. 0.278%). This result implies that the demand for each of these services is relatively inelastic. It also implies that labour and capital are moved in the long run towards other activities, enabling other sectors to increase output.

Table E.9: Selected Rest of NSW industry impact, freight and last-mile productivity improvement (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
OtherService	0.035	−0.008	49
RoadFreight	0.086	−0.335	−15
OwnerDwellng	0.021	0.021	11
OthHealth	0.231	−0.500	−32
PathologySvc	0.278	−0.498	−3

E.7 Drones in Agriculture

The potential examples modelled are drone use in cattle mustering, fruit picking and weed spraying. The modelled effects from these applications are a real GDP gain of A$700 million.

Section B cites Islam et al. (2021) in outlining the productivity enhancement potential of drones in agriculture. The report also notes the potential of drones as an integral component in the automation of productive processes in agriculture.

Several years ago, there was optimism that drones would become much more widely used in Australian agriculture. UVAIR (2017) predicted that a relatively rapid uptake of drones was about to commence.[8] Since then, growth in drone use has fallen below these expectations. This is not unusual for new technologies. In some applications, drones may be valuable, whereas in others, they may not warrant the capital outlay.

One of the promises of drones has been in gathering high-resolution images of farmland. In reality, as noted in Section B, satellite imagery is a serious competitor to drones. One specific task in which drones have proven useful is in detecting the colour of fruit in citrus plantations. To date, they have not been helpful in providing information on citrus yields, although section B cites crops for which yield estimates are possible.

A possibility is to use drones in irrigation management. However, they are competing against sophisticated irrigation technologies already utilised by farmers and, for many, remain too costly for routine use. As regards broadacre cropping, there is an expectation that drones will play a larger role in spraying, but farmers seeking to minimise costs may be reluctant to abandon established practices. An aircraft pilot may spray crops for several dozen farmers in a day, keeping down costs to individual farmers. Therefore, farmers will not be motivated to switch to drones for crop spraying until there are demonstrable cost savings from the switch. Further, farmers make decisions on whether the additional costs of new equipment, including drones, are more than compensated by the additional benefits. Among the costs is learning to use drones, which may be non-trivial.

About a decade ago, the Commonwealth Scientific and Industrial Research Organisation was optimistic that drones could play a significant role in the detection of weeds.[9] One possibility was that drone images could help farmers target weed outbreaks. The accuracy of the available images does not appear to be sufficient yet for widespread broadacre application.[10] However, as noted in Section B, field trials are being conducted (Hobba et al., 2021).

[8] See https://uavair.com.au/drones-australian-agriculture-hype-reality/

[9] See https://www.gizmodo.com.au/2014/08/the-csiro-is-using-drones-to-hunt-weeds/

[10] Applied Agricultural Remote Sensing Centre, University of New England, personal communication.

Technological advances and further trials may eventually lead to the widespread use of drone imaging to assist targeted weed spraying.

In addition, drones may play an increasing role in detecting feral animals, which maim and kill farm livestock, in farming areas. The vulnerable areas account for a small percentage of national livestock output. Section B notes that in the UK, drones assist police in detecting livestock theft. Further, in rangeland in northern Australia, drones may play an increasing role in cattle mustering. This requires relaxation of the line-of-sight restriction on drone use, which is occurring gradually.

The 2022 mango harvest in the NT has been hindered by a shortage of workers due to COVID-19 and visa restrictions.[11] There are drones that can pick fruit. There may be little in terms of labour saving from the use of drones, but a significant increase in the harvest owing to reduced wastage.

The modelled scenario

The scenario modelled here includes:

- cost savings from replacing helicopters with drones in cattle mustering,
- herbicide savings in broadacre crops from the use of drone imagery during spraying to target weeds and
- productivity increases in fruit tree crops owing to assistance in picking from drones.[12]

The output of Australian beef cattle sector in the updated database is approximately A$16.5 billion (A$5.7 billion in value-added terms, which excludes the costs of intermediate inputs). Of this, the estimated output in Outback WA is A$670 million (A$230m value-added), in the NT is A$780 million (A$270m value-added) and in Outback QLD is A$2000 million (A$680m value-added). The sum of the estimated output in these rangeland regions is about A$1.4 billion (A$1180m value-added).

The cost shocks imposed on the model are a 20% decrease in fuel inputs and a 5% decrease in capital inputs arising from replacing helicopters with drones, based on judgements concerning possible cost savings with a switch to drones. The fuel input reduction concerns on-property fuel savings and does not include the costs of cattle transportation. The latter is represented separately by the road transport margin used to move beef cattle to the point of sale. The shocks are confined to these three outback regions where helicopters are in common use in mustering. Fuel costs in the base data for beef cattle production in the three regions sum to A$180 million, and the corresponding capital cost sums to A$242 million. Therefore, the imposed costs savings are A$48 million (= −20% × $180m + −5% × $242m).

The assumed saving in farm chemicals used in broadacre food crops and hay production is 30%, based on field studies reported in the main text. Chemicals account for about 7% of the intermediate input costs in grain production or approximately 4% of total costs with the CGE database. A key assumption is that the resolution of drone imaging is sufficient to target weeds effectively. The cost saving applies to broadacre food crops and hay in all regions.

The value of chemical inputs into wheat, barley, oats, other grains and legumes, and hay and cereal fodder in the base year nationally totals A$678 million. Therefore, the assumed national cost saving will be equal to about A$203 million annually (= −30% × $678m).

[11] https://www.abc.net.au/news/2022-11-06/bumper-year-for-northern-territory-mangoes-despite-early-rain/101618766

[12] https://www.dronesinsite.com/drone-news/tevel-drone-fruit-pickers/

The assumed direct impact of the use of drones to assist in fruit picking is harvest increase of 10%. This arises through a combination of reduced spoilage owing to the timeliness of picking and more complete picking owing to drone assistance. The annual value of the output of the relevant tree crops is about A$4.27 billion. The direct impact is therefore equivalent to an increase in annual tree crop output of A$427 million.

Table E.10: Macro-economic impact of agricultural scenario (change from base case)

Region	Real GDP		Real Consumption		Employment		Real Wage	Capital Stocks
	(%)	(A$m)	(%)	(A$m)	(%)	FTE	(%)	(%)
RoNSW	0.059	130	0.069	93	0.007	85	0.064	0.011
SydneyNSW	0.006	28	0.047	116	−0.004	−74	0.053	0.018
RoVic	0.165	167	0.062	39	0.004	24	0.061	0.015
MelbourneVic	0.014	51	0.056	127	0.001	14	0.058	0.023
SEQld	0.015	47	0.051	95	−0.002	−29	0.055	0.000
RoQld	0.017	14	−0.005	−2	−0.030	−93	0.027	−0.065
OutbackQld	0.707	36	0.600	15	0.272	57	0.329	0.098
AdelaideSA	0.033	32	0.069	42	0.007	40	0.064	0.031
RoSA	0.331	91	0.118	18	0.032	48	0.089	0.040
FarmWA	0.202	97	0.128	27	0.037	67	0.094	−0.024
PerthWA	−0.019	−41	0.028	27	−0.013	−109	0.044	−0.040
OutbackWA	0.007	3	0.056	5	0.001	1	0.058	−0.101
TAS	0.104	34	0.062	14	0.004	7	0.060	0.026
NT	0.037	12	0.064	8	0.005	4	0.061	−0.035
ACT	0.004	2	0.048	10	−0.003	−6	0.054	0.020
National	0.034	701	0.055	635	0	..	0.057	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

Table E.10 shows the macro-economic effects of these drone-related changes in either input costs or output in agriculture. The national results, shown in the bottom row of the table, indicate an increase in real GDP of 0.034% or A$701 million (2022 dollars). If the uses of drones in agriculture broaden, in particular in livestock management in southern Australia, economic gains may be larger than those modelled in this study. The back-of-the-envelope calculation is that real GDP should increase by A$678 million (= $48m + $203m + $427m). The discrepancy between the back-of-the-envelope calculation ($678m) and the modelled solution ($701m) arises mostly from a simplification in A2: it excludes the (positive) contribution of indirect taxes to real GDP.

The biggest winner among the regions in Table E.10 is OutbackQld, which reflects the large share of beef cattle production in its income base. The region increases its shares of both employment (an increase of 0.272% or 57 jobs FTE relative to base) and capital (0.098%). It also has the largest increase in real wages relative to base (0.329%).

SydneyNSW, with an employment decrease and capital stock increase relative to base, and OutbackWA, with a very small employment increase and capital decrease relative to base, have the opposite sign on aggregate employment and aggregate capital. In each case, the movement from base is relatively small and is attributable to changes in industry composition. Factor intensities differ between sectors. In the case of OutbackWA, the direct contribution of capital saving in beef cattle production results in an aggregate decrease in capital relative to base.

Table E.11: Selected national industry impact (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
TreeFruit	4.9	−10.2	−227
BeefCattle	0.2	−0.3	−21
Grains	2.2	−1.1	125
HayCerealFod	0.6	−0.8	−6
Mining	−0.1	0.0	−226
FoodProds	0.2	−0.1	108

Table E.11 shows the national impact for industries that are directly shocked (TreeFruit, BeefCattle, Grains and HayCerealFod) and selected industries that are indirectly affected. The output price of fruit shows a significant decline, reflecting inelastic total demand as output grows. Similarly, the nominal value of beef cattle output declines slightly relative to base. In each case, the gains from productivity improvements are shared between the industry and downstream users or consumers. The elasticity of total demand for grains is greater than for fruit or beef cattle, reflecting a relatively high share of exports in total sales. Within the model, export demands are more price elastic than household or downstream demands.

The food products (FoodProds) industry benefits from lower costs of beef cattle and grain inputs. This induces a movement of capital and labour in the sector over time. Mining loses out slightly because of higher real wages, which affects the sector’s international competitiveness.

It is possible that the use of drones in agriculture will broaden far beyond those modelled in this scenario. If so, productivity gains will be correspondingly larger, with increased movements of labour and capital to non-metropolitan regions.

E.8 Drones in Mining

The lockdowns related to COVID-19 accelerated the uptake of drone usage in mining in remote regions. The benefits of drones on mining productivity may be substantial. However, these will be distributed between foreign shareholders, Australian shareholders and government revenue.

Section B’s information on drones in mining and resources indicates that drone use in mining in Australia has reached a more advanced phase than in other sectors. The COVID-19 restrictions accelerated the use of drones for visual inspections of mining site and equipment, owing to lockdowns and prolonged state border restrictions. The benefits from the drone use include cost savings plus environmental benefits. Section B lists many ways in which drones could contribute to cost savings. They reduce the costs of mining service inputs to mining in areas such as mapping applications. Section B notes that drones may be many times faster than competing technologies in compiling data and images from fields. Improved mining worker safety arising from the use of drones enhances productivity. Since much labour is associated with the use of heavy machinery, we could depict this through total factor productivity gains rather than labour productivity gains.

The environmental and safety benefits associated with drone monitoring of old mines are not depicted in the present CGE modelling exercise. Since the use of drones in mining is relatively more advanced than in other fields, the scenario modelled in this section is a depiction of the possible realised impact on drones in mining. The value of mining services inputs into mining in the CGE database at the national level is A$15.8 billion. In this exercise, without more precise information, we imposed a saving of 5% on mining services inputs to mining, equivalent to A$790 million (= 0.05 × $15,800m). In the database, labour inputs to mining total A$23.6 billion out of total primary factor costs of A$141.3 billion. The assumed total factor productivity gain imposed in this exercise is 0.5%, equivalent to A$706.5 million (= 0.005 × $141,300m).

A caveat on the modelled benefits of drone applications in mining is that there is substantial foreign ownership in mines. The increase in real GDP of A$1,711 million is slightly smaller than the modelled dollar increase in real consumption (A$1,742 million; see Table E.12). The distribution of a significant share of additional income to foreign shareholders would reduce the additional income available for domestic consumption. This would be reflected in the smaller impact in relatively income-elastic sectors, such as ownership of dwellings.

Table E.12: Macro-economic impact of mining productivity increases (change from base case)

Region	**Real GDP**		**Real Consumption**		**Employment**		**Real Wage**	**Capital Stocks**
	(%)	**(A$m)**	**(%)**	**(A$m)**	**(%)**	**FTE**	**(%)**	**(%)**
RoNSW	0.195	432	0.224	300	0.036	421	0.009	0.164
SydneyNSW	−0.058	−258	0.081	200	−0.035	−696	−0.063	−0.128
RoVic	0.010	10	0.143	89	−0.004	−24	−0.032	−0.083
MelbourneVic	−0.041	−153	0.101	232	−0.025	−488	−0.052	−0.112
SEQld	0.040	113	0.143	237	-0.004	-60	-0.032	-0.046
RoQld	0.463	550	0.338	198	0.093	464	0.066	0.300
OutbackQld	0.413	28	0.352	13	0.100	31	0.072	0.238
AdelaideSA	−0.013	−12	0.123	76	−0.014	−76	−0.041	−0.087
RoSA	0.143	39	0.214	33	0.031	47	0.004	0.046
FarmWA	0.334	161	0.259	55	0.054	98	0.027	0.180
PerthWA	0.208	454	0.167	160	0.008	64	−0.020	0.052
OutbackWA	0.790	282	0.455	44	0.152	105	0.124	0.366
TAS	0.084	28	0.213	48	0.031	61	0.003	0.015
NT	0.115	37	0.166	21	0.008	7	−0.020	−0.041
ACT	0.004	2	0.173	36	0.011	21	−0.017	−0.043
National	0.082	1711	0.150	1742	0	..	−0.028	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

OutbackWA accounts for a significant share of national mining activity. Since much of the industry is in remote regions, it relies heavily on fly-in, fly-out workers. For this reason, PerthWA is a substantial beneficiary of productivity enhancements arising from the use of drones in mines. These workers, by assumption, spend much of their income in a region other than the region in which they work. For this reason, much of the labour associated with mining in OutbackWA is treated as being located in PerthWA. The effects of mining booms and busts or mining investment slowdowns are observable in Perth. During the investment boom from around 2005 to 2013, housing prices and the prices of services, such as dining out, soared in Perth. Thereafter, prices fell as the investment boom waned. FarmWA also has substantial mining activity. Therefore, its real GDP percentage gain (0.334%) is larger than the national gain (0.082%).

Table E.13 shows selected sectoral effects. A large percentage of mining products are exported. The demand for is exports is more elastic than that for domestic sales. Consequently, mining expands output by 0.95%, with a decrease in the quantity of mining services. The latter arises from the direct input savings brought about by the increased use of drones.

Export-oriented sectors other than mining, notably food products, other manufactures and grains plus beef cattle (an input to food products in addition to having some export sales), all suffer small output losses relative to base. The productivity improvements in mining draw in additional labour and capital at the national level (0.56% for labour, 0.45% for capital) because the output effect on factor demand is larger than the factor-saving effect of the productivity improvement. This reduces factors available for other sectors. In addition, the relatively income-elastic ownership of dwellings increases output in the long run: aggregate consumption increases by 0.15%. That ownership of dwellings increases by a smaller percentage, 0.11% (despite having an income elasticity of about 1.7), than the percentage increase in aggregate consumption (0.15%) reflects a small choking off due to its output price rising relative to base. As aforementioned, distributing more of mining income to foreign shareholders would reduce the gain in aggregate consumption and the consequent increase in the output of the ownership of dwellings sector.

Other export-oriented sectors in agriculture and food processing lose to a small extent from mining productivity improvements. The resource squeeze on some sectors due to additional labour and capital moving to mining is reinforced by spending effects. These raise demand for the ownership of dwellings and associated residential building construction.

Table E.13: Selected national industry impact—mining productivity increases (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
OthrLivstock	−0.28	0.17	−37
BeefCattle	−0.29	0.13	−26
Grains	−0.38	0.11	−33
Mining	0.95	−0.34	1477
MiningSrvces	−2.56	0.13	−507
FoodProds	−0.25	0.16	−106
OthManufact	−0.22	0.07	−348
Utilities	0.03	0.20	299
ResidBuildng	0.11	0.15	291
OthConstruct	−0.01	0.15	99

CivilEngCnst	0.00	0.18	216
ConstrucSrvc	0.06	0.14	456
Trade	−0.04	0.18	357
OtherService	−0.02	0.18	2850
OwnerDwellng	0.11	0.34	1040

E.9 Drones in Construction

Various forms of construction activity account for more than 8% of Australia's GDP. Regulatory constraints concerning drone usage are less of an issue at building sites than in public spaces. In this scenario, productivity gains arising from drone usage results in an increase in real GDP of about A$4 billion.

Construction activities account for a large share of GDP. Within the TERM database, the factor income for residential buildings is A$22.3 billion, for other construction A$17.8 billion, for civil engineering construction A$46.1 billion and for construction services A$70.3 billion. In turn, construction services account for large shares of the commodity inputs to the construction sectors: 43% for residential buildings, 49% for other construction and 34% for civil engineering construction.

There appears to be considerable scope in the use of drones to improve building inspections. For example, Clayton (2022) detailed weaknesses in regulation in Victoria's residential building sector and cited a government review that identified the need for improvements to comply with building standards. Drones may be an invaluable tool for inspecting multistorey buildings. Drone usage on building sites is unlikely to face regulatory hurdles that apply elsewhere. Furthermore, drones have the potential to reduce the costs of inspections in civil engineering applications. They may become increasingly used in inspections of roads and bridges and may thus lower the costs of inspection and maintenance and enhance safety.

In this scenario, a productivity shock of 5% is ascribed to construction services. The relatively large shock reflects the potential of drones to improve productivity across an array of construction activities, as presented in section B. The productivity shock is equal to a contribution of A$3,515 million to real GDP. Table E.14 shows that real GDP increases by A$4,045 million, with an activity-related positive contribution from indirect taxes. The dollar increase in national aggregate consumption, A$3,184 million, is smaller than the dollar increase in real GDP. This is because international export volumes increase by 0.129% at the national level. Export demand curves slope downwards: the export price index falls by 0.032, implying an average export demand elasticity of −4 (= 0.129/−0.032). We assume that international import supplies are infinitely elastic. Therefore, the price of imports is unchanged while the price of exports falls. The term-of-trade loss (i.e. a fall in the price of exports relative to the price of imports) reduces the disposable income available for consumption.

Table E.14: Macro-economic impact of construction productivity increases (change from base case)

Region	Real GDP		Real consumption		Employment		Real wage	Capital stocks
	(%)	(A$m)	(%)	(A$m)	(%)	FTE	(%)	(%)
RoNSW	0.213	469	0.306	410	0.016	187	−0.079	0.029
SydneyNSW	0.208	929	0.328	814	0.027	538	−0.068	0.054
RoVic	0.186	188	0.278	173	0.002	12	−0.094	−0.020
MelbourneVic	0.190	702	0.313	714	0.019	381	−0.076	0.023
SEQld	0.185	521	0.192	318	−0.041	−590	−0.136	−0.068
RoQld	0.097	115	0.217	127	−0.028	−141	−0.124	−0.103
OutbackQld	0.213	14	0.398	14	0.062	19	−0.034	0.113
AdelaideSA	0.213	201	0.315	193	0.021	113	−0.075	0.033
RoSA	0.174	48	0.326	51	0.026	39	−0.070	0.022
FarmWA	0.194	93	0.119	25	−0.077	−141	−0.173	−0.048
PerthWA	0.203	442	0.133	127	−0.070	−577	−0.166	−0.037
OutbackWA	0.088	31	0.229	22	−0.022	−15	−0.118	−0.030
TAS	0.227	75	0.356	80	0.041	82	−0.054	0.076
NT	0.289	92	0.151	19	−0.061	−55	−0.157	0.019
ACT	0.224	124	0.453	96	0.090	170	−0.006	0.113
National	0.193	4045	0.274	3184	0	..	−0.096	0

Note: Regional employment FTE (full-time equivalent) regional changes may not sum to 0 as the national constraint is imposed using value-weights rather than FTE-weights.

Table E.15: Selected national industry impact—construction productivity increases (change from base case)

Sector	Output (%)	Price (%)	Value (A$m)
OthCrops	0.142	−0.014	27
TreeFruit	0.139	−0.013	5
OthrLivstock	0.093	−0.001	31
BeefCattle	0.150	−0.059	15
Grains	0.218	−0.069	18
HayCerealFod	0.121	−0.015	3
ForestFish	0.025	0.122	14
TCFs	0.164	−0.022	13
Mining	0.050	0.006	135
MiningSrvces	0.015	0.024	8
FoodProds	0.149	−0.017	149
HumPharmac	0.037	0.029	7
Fuel	−0.099	0.091	−2
BasicChemicl	0.118	−0.002	20
OthManufact	0.181	−0.026	350
Utilities	0.145	−0.093	67
ResidBuildng	0.521	−0.788	−297
OthConstruct	0.008	−0.822	−573
CivilEngCnst	0.019	−0.459	−539
ConstrucSrvc	0.561	−2.336	−3894
Trade	0.122	−0.056	169
OtherService	0.171	−0.072	1791
RoadPassngr	0.164	−0.062	19
RoadFreight	0.121	−0.053	33
RailTranspor	0.151	−0.248	−18
OthTransport	0.108	−0.027	60
AirTransport	0.166	−0.020	42
PostCourier	0.197	−0.071	16
OwnerDwellng	0.493	−0.126	851
ArchEngScSvc	0.159	−0.101	48
EmergncyServ	0.097	−0.100	0
OthHealth	0.103	−0.085	20
PathologySvc	0.041	−0.087	−6

In the long-run closure, government spending (G) and aggregate national capital stocks are fixed, which limits the change in aggregate investment (I), and the balance of trade at the national level is exogenous. From this, we can use back-of-the-envelope calculations to explain the dollar gap between real GDP and aggregate consumption at the national level. In dollar terms, the terms-of-trade loss and the export volume increase required for the balance-of-trade constraint to hold is equal to the base level of exports multiplied by the additional quantity minus the price. The export base is A$511 billion, so that our estimate of the value of GDP increase not available for consumption is A$823 million (= 511,000 × [0.129% – (−0.032%)]). The gap between the change in real GDP ($4045m) and the change in consumption ($3184m) is A$861 million, close to the back-of-the-envelope calculation of the terms-of-trade impact.

Table E.15 shows the sectoral effects for all industries in the aggregation used in this study. The pattern is that the output of almost all sectors increases. Export-oriented agriculture and mining expand as construction inputs become cheaper, with export volumes increasing. The residential building sector expands more than the other construction sectors because the sector is an input into the relatively income-elastic ownership of dwellings sector, which expands with the increase in aggregate consumption. The services to construction sector has the largest percentage increase in output relative to the base case, but the increase (0.56%) is only a fraction of the productivity increase (5%): the benefit to other users is via a price fall of 2.34%.

E.10 A Hypothetical Study: Potential Effects of Drones and Other Technologies in Reducing Bushfire Damage

Summary of hypothetical study

This study is a hypothetical exercise to examine the reduction in economic losses that may have been possible had drones been widely deployed in conjunction with timely use of imaging technologies to counter the 2019–2020 bushfires. This was an extreme event: the bushfire damage was unprecedented, in terms of the area burnt out and the nature of fire damage. The potential benefits of drones and other technologies in response to this event may have been extraordinary, much greater than the potential routine use of drones in search and rescue ventures or in less extreme fire conditions.

We assume in this study that some of the regulations concerning drone use are eased in emergencies, notably the line-of-sight restriction on their use. Another key assumption is that the drones deployed had sufficient range to undertake the surveillance of relatively inaccessible mountain regions, notably around Gospers Mountain where a fire was ignited by lightning in October 2019 and grew into a megafire that burned 500,000 ha and took three months to contain.

This scenario assumes that many of the 2019–2020 fires were brought under control much earlier than these were in reality. Drones are not solely responsible for the earlier control in this scenario. They are used in conjunction with satellite imagery in a timely manner to ensure that ignition points are identified early. We could speculate that ‘mule’ drones assist in firefighting operations by entering areas in which it would be hazardous to fly crewed firefighting aircraft. Therefore, this scenario reflects a vision of how drones and other technologies could contribute to firefighting in the future.

This study draws on an existing modelling and analysis of the effects of the 2019–2020 bushfires and the accompanying prolonged drought. The existing study used a dynamic CGE model of the regions of Australia for analysis (dynamic TERM). It used an economic welfare calculation to summarise the effects. This calculation includes the effects of an economic event on nationwide spending over time, while also accounting for the effects of destroyed capital and infrastructure and consequent recovery costs. The estimated welfare losses from bushfires and drought were A$63 billion. A repeat of this exercise assumes that drones could contribute to a halving of direct fire impact. This results in welfare losses falling to A$55 billion. The reduced impact includes reduced property, crop and infrastructure losses; reduced smoke-related deaths and health impact; and reduced post-traumatic stress disorder (PTSD) among firefighters. Drought and bushfires together reduce employment nationally, drive down real wages relative to a business-as-usual baseline and result in some temporarily idle capital.

At the macro-economic level, the apparent differences between the drought and bushfire disaster scenarios with and without drones are small. The differences are most obvious in the welfare calculation, which accounts for destroyed capital and infrastructure. With these losses included in the welfare calculation, the hypothetical use of drones and improved surveillance methods may have reduced nationwide economic losses by A$8 billion.

The benefits from the use of drones in response to other extreme events would be much smaller, because it is not possible for drones to reduce the magnitude of adverse events such as floods, storms or earthquakes in the same way that the extent of damage from a bushfire can be reduced with better and more timely intervention. However, regardless of the type of disaster, there is potential to use drones in response to such events, and drones are increasingly used in search and rescue operations arising from adverse events.

Given that the scenario concerns an extreme event, the welfare impact does not reflect the annualised expected benefit that drones may contribute to bushfire management in a typical year. Some fraction of the welfare benefit calculated in this study would be a more appropriate estimate of the economic benefits of drone use. An A$1 billion benefit may be closer to the magnitude of the expected benefit for a typical year.

In this hypothetical scenario, drones and other technologies provide early information on fires and enable firefighters to respond while blazes are still relatively small. The modelled A$8 billion welfare gain from hypothetical responses to the extreme example of the 2019–2020 bushfires may translate into a possible A$1 billion gain in a more typical year.

E.10.1 Introduction: How could drones contribute to a bushfire response?

The catastrophic bushfires in south-eastern Australia in 2019–2020 arose from a prolonged severe drought and record heat events. The question explored in this study is the extent to which drones and other technologies might have alleviated economic losses and loss of life.

The use of drones and satellite imaging technology during the 2019–2020 bushfires was quite limited. Since then, there has been rapid uptake of drone usage by emergency services in Australia. Wittwer and Waschik (2021) have estimated the economic losses arising from bushfires. The hypothetical case modelled here uses a CGE approach to examine the extent to which drones, in playing a significant role in the surveillance of, and the response to, bushfires, could alleviate economic losses.

In our hypothetical scenario, in a time of serious drought-stricken conditions over much of the Great Dividing Range in south-eastern Australia, online surveillance of emerging fires in the wake of lightning strikes from satellite imagery may enable firefighters to devise an early response. Once other sources have detected a fire, drones could be used to obtain more precise information on the location, direction and size of fires using thermal imaging.

Lightning ignited the Gospers Mountain fire on 26 October 2019. Eventually, five fires joined together on 6 December. An ABC journalist, Nyugen (2020), used a German-based weather service Blitzortung to identify lightning strikes that occurred along the Great Dividing Range and combined it with information from Metraweather to examine the timeline of the spreading fire.

How could drones have helped in this fire, which took many weeks to merge into a megafire? Currently, CASA regulations restrict the use of drones, not permitting out-of-sight drone surveillance. In emergency situations, there is a case for making regulation more nimble, enabling the use of out-of-sight drones in response to an emerging serious incident. Another issue is that the range of many drones used in emergency services at present is 10 km. For surveillance of fire outbreaks in relatively inaccessible regions, drones with a longer range would be necessary. At present, military drones have longer ranges but may be more expensive. However, given the potential benefits in firefighting, the additional cost to the government of longer-range drones for emergency service use may be easy to justify.

An early response to the Gospers Mountain fire may have had a dramatic effect on the associated economic damage, duration and health effects. Had drones and other imaging technologies, such as those reported by Nyugen (2020), been used for surveillance in the early stages of the fire, a better understanding of the situation could have been gained and resources better allocated. With the danger accurately assessed, aircraft water bombers could have reduced the eventual extent of the blaze.

'Mule' drones—designed to carry heavy payloads—may eventually play a role in firefighting. Firefighting can be hazardous for personnel in aircraft and on the ground. Turbulent wind conditions contribute to the loss of lives in firefighting. The option to deploy 'mule' drones in some circumstances may enhance the safety of emergency services personnel. Moreover, early intervention to prevent bushfire damage from worsening and different fires coalescing to form an unmanageable blaze will have a further benefit. It will increase the resources available to fight subsequent or concurrent fires elsewhere. In addition, the terrain mapping capability of drones will also be useful in the aftermath of a catastrophe, be it a fire or flood. It may assist with relief work or verification for insurance. After the bushfires of 2019–2020, many local victims felt frustrated by the slow pace of recovery, worsened because recovery efforts were hindered by pandemic restrictions (Lazzaro, 2020).

The benefits of earlier intervention in the Gospers Mountain fire extend beyond economic accounting. The prolonged megafire resulted in hazardous air quality in Sydney, Canberra and various towns in a large area for many weeks on end. Given that Arriagada et al. (2020) reported over 400 deaths and over 1,100 hospital admissions resulting from poor air quality in this time, the social returns from better firefighting tools in inaccessible areas, in terms of improved air quality alone, are potentially high. Furthermore, the fires destroyed vast areas of conservation land. There was widespread habitat destruction and substantial native fauna losses.

E.10.2 Estimating direct bushfire losses in South-Eastern Australia in 2019–2020

We chose the bushfire example because we can base it on a detailed study of economic losses (Wittwer & Waschik, 2021). In analysing the marginal impact of drones on economic events, such as a bushfire catastrophe, the emphasis is on the alleviation of damage. Since we have estimates of the economic losses of bushfires, including an estimate of the impact on national welfare, it is a relatively straightforward task to rerun the scenario with an assumed halving of bushfire damage. The assumption that drone technologies halve bushfire losses is based on an understanding that satellite surveillance combined with drone surveillance will hasten responses to fires. In the extreme events of 2019–2020, a halving of damage may even be an underestimate of the potential benefit of the hypothetical use of drones and other technologies.

The single number that describes the benefit of drones in this scenario is the welfare calculation. Section 8 explains the calculation of the welfare impact.

Severe bushfires were widespread in the Great Dividing Range in south-eastern Australia in the summer of 2019–2020. Fires started in southern QLD and northern NSW in early September 2019. Outbreaks occurred further south over the following weeks and months. Lightning ignited the Gospers Mountain (north-west of Sydney) fire on 26 October 2019. The megafire formed by coalescing fronts, including this fire, burned through 512,000 ha before being contained in mid-January. In this regard:

> Deep into the mountains, in country fractured by creeks, chasms and vertiginous escarpments, it was virtually inaccessible by land, and the bush had never been so brittle. After 10 years of below-average rainfall, the soil had become so dry that gum trees were keeling over and stacking up like a giant bonfire waiting to be lit. (Alexander & Moir, 2019)

The eventual destruction in south-eastern Australia included more than 3 million ha of conservation land, 1.5 million ha of forests and plantations and 820,000 ha of agricultural land. NSW losses included more than 2.5 million ha of conservation land, 750,000 ha of forests and plantations and 559,000 ha of farmland. Fires destroyed more than 2,400 houses in NSW out of more than 3,000 nationally. Further, about 10,500 sheep and 3,440 cattle were lost in fires in NSW, and national losses exceeded 63,000 sheep and 8,400 cattle.[13]

Wittwer and Waschik (2021) estimated that owing to national farmland destruction of more than 820,000 ha, 67,000 km of fencing were destroyed, with a replacement cost of A$600 million, based on A$7,500 per km for fence replacement plus A$1,500 per km for clean-up costs. Other capital replacement costs include around 3,000 homes at A$1.2 billion, 5,800 other buildings at A$870 million, 14,000 cars at A$210 million and 3,000 items of farm machinery at a replacement cost of A$180 million.

On the basis of the limited information available, damage to telecommunication towers amounted to A$33 million and the total damage to electricity infrastructure was A$110 million. Smoke damage to a large proportion of the grapes in the Lower Hunter and Yass-Young regions made them unsuitable for wine production. Vineyards in Victoria and South Australia also suffered from smoke damage.

E.10.3 Costs arising from health, injury and trauma

The capital losses from fires over 2019–2020 may amount to about A$3 billion, leaving aside native flora and fauna losses, but the costs of bushfires extend far beyond capital losses. In the absence of data on the number of firefighting injuries, we assume that there were 1,800 injuries, each with associated medical costs of A$5,000 and labour productivity losses of A$5,000. These costs total A$18 million.

Firefighters suffer a high rate of PTSD.[14] There are approximately 20,000 professional and more than 150,000 volunteer firefighters in Australia. We assume that the trauma of firefighting efforts results in PTSD in one-fourth of professional firefighters and one-fifth of volunteers, and that it has adverse effects on their wellbeing for three months. A disruption equivalent to

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[13] Online sources used to compile estimates include: https://www.agriinvestor.com/agricultural-land-comprises-14-of-total-area-burned-by-australian-bushfires/

https://www.abc.net.au/news/2020-01-05/fire-bushfire-dead-livestock-farmers-agforce-animal-carcasses/11841868

https://www.begadistrictnews.com.au/story/6580090/telstra-faces-biggest-disaster/?cs=509

https://www.beefcentral.com/news/bushfire-livestock-loss-estimates-downgraded/

https://www.macleayargus.com.au/story/6504487/the-devastating-toll-of-the-carrai-east-fire-becomes-clear-more-than-50-homes-destroyed/

[14] https://www.verywellmind.com/rates-of-ptsd-in-firefighters-2797428

40% of wages for three months, based on earning capacity of A$80,000 per annum, would be A$280 million. Additional counselling costs for PTSD sufferers, at A$1,000 per person, would amount to A$35 million.

Furthermore, the health costs due to smoke pollution are high. For months, large populations around Sydney, Newcastle, Wollongong and Canberra suffered from air quality reported at hazardous levels by the NSW Department of Planning, Industry and Environment.[15] Hazardous levels were recorded for up to 60 days after the fires started. For the calculations used in this study, we assumed that one-tenth of the population suffered from asthma and lost half of their labour productivity on hazardous days. This calculation amounts to labour productivity losses of A$1.6 billion, although it may understate the number of days that adversely affected health.

Arriagada et al. (2020) estimated that the effects of the bushfires included 417 additional deaths, 1,124 additional hospital admissions for cardiovascular cases, 2,027 additional hospital admissions for respiratory cases and 130 emergency department attendances for asthma. These median estimates may result in additional medical costs exceeding A$30 million (based on A$10,000 per admission). Calculations of the value of human life could be deducted directly from the welfare calculation from CGE modelling. The estimate of smoke-related deaths provided by Arriagada et al. far exceeds the number of direct deaths (34) in the fires. Each of the above effects is ascribed to the dynamic TERM as a temporary deterioration in labour productivity in fire-affected regions.

E.10.4 Alleviating bushfire damage

First, we note that given the severity of the numerous fires, the fact that only 34 deaths were directly caused by the fires of 2019–2020 was a relatively good outcome. This contrasts with the Black Saturday fires of 7 February 2009, which killed more than 190 people in Victoria. Firefighters across Australia did a remarkable job with the resources they had and learned from previous catastrophes. Nevertheless, there is evidence that the Commonwealth Government paid little heed to warnings in 2019, notably from former NSW fire chief Greg Mullins, that there would be the threat of catastrophic bushfires in the impending summer (Offer, 2019).

There was a widespread perception that firefighters worked with avoidably limited resources. Better equipment may have assisted in earlier control of some fires over the summer, thereby limiting property losses, saving human lives and reducing trauma. Notably, the uptake of drones has increased since 2019–2020. This modelling of the hypothetical impact of drones and other technologies assumes that their deployment could have halved the eventual damage from fires. This may be a conservative estimate of the potential savings, given that extinguishing the Gospers Mountain fire, for example, before it expanded into a megafire, would have resulted in a marked improvement in air quality in smoke-affected cities and towns. This would have reduced smoke-related hospitalisations and deaths, reduced the threat to settlements near the megafire and freed resources for other firefighting efforts.

The assumption in this scenario is that damage from all fires across south-eastern Australia could have been halved in 2019–2020 through drone use. It is based on the expectation that early information on, and intervention in, fires would have lessened the related damage significantly. The effective uptake of drones would have expanded firefighting resources. That is, with the same firefighting personnel and equipment, combined with investment in drones, fires would have been extinguished earlier with a consequent reduction in the damage to property, infrastructure and conservation reserves.

[15] https://www.dpie.nsw.gov.au/air-quality/current-air-quality

E.10.5 Hypothetical modelling of marginal effects of improved firefighting including drone use

The assumption in this scenario is that the effective use of drones, combined with data from satellites, would reduce fire damage by 50%. In this scenario, drones provide early verification and location of fires and are deployed in remote and inaccessible locations, such as Gospers Mountain. The scenario is identical to that of Wittwer and Waschik (2021), who modelled the combined effects of drought and bushfires in south-eastern Australia relative to a business-as-usual base. The drought shocks are unchanged, but the fire damage is halved.

Table E.16 shows the modelled deviations in national macro-economic variables from base in each year from 2018–2019 to 2021–2022, and the final year of the reported scenario, 2025–2026. The deviations include the impact of prolonged drought, with real GDP in 2018–2019 already 0.809% below base. Given that agriculture normally accounts for less than 3% of the national GDP, this effect arises from the substantial output losses in agriculture. In 2019–2020, a combination of a worsening drought and bushfires results in real GDP falling almost 1% below base. In addition, bushfire destruction results in capital losses: national capital was only 0.088% below base in 2018–2019 but fell to 0.237% below base in 2019–2020.

Capital destruction has a lasting impact on national welfare. The prolonged impact, and the additional investment and consequent debt built up in financing the recovery, are not fully reflected in the snapshot for a single year, as shown in each column in Table E.16.

Table E.16: National macro drought and bushfire impact without drones and other technologies (% deviation from base)

	2018–2019	2019–2020	2020–2021	2021–2022	2025–2026
Real GDP	−0.809	−0.997	−0.151	−0.047	−0.097
Employment	−0.681	−0.671	0.130	0.230	0.063
Capital	−0.088	−0.237	−0.328	−0.299	−0.141
Real wages	−0.393	−0.717	−0.637	−0.510	−0.254
Consumption	−1.004	−1.319	−0.318	−0.078	−0.117
Investment	−1.347	−1.708	−0.075	0.273	0.070

Table E.17: National macro drought and bushfire impact with use of drones and other technologies (% deviation from base)

	2018–2019	2019–2020	2020–2021	2021–2022	2025–2026
Real GDP	−0.809	−0.932	−0.038	0.041	−0.033
Employment	−0.681	−0.671	0.214	0.276	0.069
Capital	−0.088	−0.237	−0.320	−0.274	−0.095
Real wages	−0.393	−0.717	−0.595	−0.446	−0.159
Consumption	−1.004	−1.274	−0.193	0.020	−0.045
Investment	−1.347	−1.594	0.088	0.378	0.103

Table E.17 shows the bushfire and drought scenario relative to base with an assumed effective use of drones and other technologies.[16] At first, there appears to be little difference between the scenarios. Closer inspection shows that real GDP is closer to base in Table E.17 from 2019–2020 onwards. Without the use of drones and other technologies, national real GDP is 1.0% or A$19.2 billion below base in 2019–2020 (2020 dollars). With the use of drones, national real GDP is 0.93% or A$18 billion below base. The effective use of drones reduces the amount of capital destroyed by fires and alleviates smoke-induced labour productivity losses. It reduces both insurance claims and the increase in insurance premiums in fire-affected regions. That is, in the no-drone version, victims of fires receive higher insurance payouts but must also pay higher insurance premiums in the future.

In summary, the economic losses in the year of the bushfires (2019–2020) only account for a part of the overall economic losses. This is because labour, capital and infrastructure earn income over many years.

E.10.6 National welfare effects of drought and bushfires with and without effective drone use

In the context of the present study, fire destroys property, reflected in capital stocks, and has the potential to increase foreign debt, as borrowing for investment to replace lost property proceeds in the aftermath of fires. In the short-to-medium term, fire disrupts business-as-usual economic activity. There are labour productivity losses due to disruptions, plus longer-term effects, such as PTSD. Lost income implies that spending power also falls, such that household spending declines.

In the no-drone case, the aggregate consumption falls to 1.32% or A$15.1 billion (2020 dollars, Table E.16) below base in 2019–2020. In the drone case, the fall in consumption is 1.27% (Table E.17), a fall of A$14.6 billion relative to base.

The economic concept of welfare concerns the household and public consumption of goods and services. However, given the destruction of capital and infrastructure, and the subsequent costs of rebuilding, we need to account for the scenario's impact on the net foreign debt and capital stocks. We do so by including the change in debt and in capital stocks in the final year of the simulation run. We measure welfare at the national level. The net present value of the deviation in welfare (*dWELF*) at the national level is:

$$dWELF = \sum_{d}\sum_{t}\frac{dCON(d,t) + dGOV(d,t)}{(1+r)^{t}} - \frac{dNFL(z)}{(1+r)^{z}} + \frac{dKstock(z)}{(1+r)^{z}}$$

where *dCON* and *dGOV* are the deviations in real household expenditure and government spending in region *d* and year *t*; dNFL is the deviation in real net foreign liabilities in the final year (*z*) of the simulation; *dKstock* is the deviation in the value of capital stock in the final year (*z*) of the simulation; and *r* is the discount rate.

In this hypothetical scenario, the use of drones and other technologies reduces welfare losses by about A$8 billion. This occurs in part through the smaller negative temporary effects on labour productivity: these arise from a combination of air quality effects on health, and PTSD and injuries among firefighters. Capital destruction is smaller and the subsequent impact on foreign debt is smaller in the drone scenario.

[16] An NSW Government news release indicated the purchase of two drones in 2016: https://www.nsw.gov.au/news/drones-to-assist-firefighters-emergencies. These appear to indicate an experimental rather than a routine stage of drone use.

These measures of economic welfare do not include all of the losses arising from bushfires. Beyond some labour productivity shocks, the human trauma in the scenario may be underestimated. The effects not modelled include the reduced destruction of conservation land and native fauna. Studies that have accounted more carefully for human effects and placed a value on burnt-out conservation land would measure much greater welfare losses due to bushfires, and potentially enlarge the marginal benefits of the effective use of drones.

The modelled improvement in welfare owing to the role of drones and other technologies in reducing bushfire damage does not include the costs of increased drone uptake. These are likely to be in the hundreds of millions of dollars, rather than billions, and are therefore small relative to the estimated benefits.

This scenario concerns an extreme event. Therefore, the estimated welfare impact of A$8 billion does not reflect the annualised expected benefit of drones in bushfire management. Some fraction of the welfare benefit calculated in this study would be a more appropriate estimate of the economic benefit of drone use. An A$1 billion benefit may be closer to the magnitude of the expected benefit for a typical year. The annualised costs of drone usage should be subtracted from this estimate. Even with a relatively modest expected benefit, the annualised costs of drones are likely to justify their increased uptake in bushfire management. However, other technologies are likely to be used in conjunction with drones.

E.10.7 Discussion

The fall in deaths between the Black Saturday 2009 fires and that of 2019–2020 may indicate, in part, changes in practices such as the evacuation policy. There may also have been changes in technologies to improve firefighting in the absence of the widespread use of drones.

In the scenario presented here, we assumed that drones play an important role in the surveillance of emerging fires. There is also the possibility that 'mule' drones will be used in firefighting, sparing pilots from hazardous conditions. We do not know with precision the extent to which the contribution of drones could have alleviated the damage of the unprecedented bushfires of 2019–2020, but any innovations would have had large marginal effects. It may be decades before a fire hazard as widespread as in 2019–2020 occurs again. However, in most summers in Australia, there is some degree of bushfire hazard. Drones could be put into regular use in managing both fires and controlled burns. Relative to the potential damage to human lives, flora, fauna, property and infrastructure, there may be substantial net benefits from investments in drones and training to utilise integrated software associated with their use.

With climate change, bushfire hazards may worsen in extreme years. This will increase the social benefits in adversity from any interventions to respond as early as possible to fires. More generally, climatic change may worsen the severity of other extreme weather events, including floods and cyclones. As potential catastrophes unfold, drones may become indispensable in relaying important information that improves early responses. In the aftermath of adverse events, drones may help locate people in need of rescue. They may pinpoint breaks in transmission lines or other damage to infrastructure. Where there are concerns about land slippage after heavy rain, drones may relay rapid information.

Slow recovery worsens economic outcomes, leaving people unable to resume at former productivity. For example, in communities in far eastern Victoria, some victims of bushfire remained without homes a year or two after the catastrophe. In summary, in extreme events such as bushfires, floods and cyclones, drones may become an increasingly valuable tool in emergency responses.

E.11 TERM: Depicting Small Regions in Computable General Equilibrium Framework

E.11.1 What is a computable general equilibrium model?

A CGE model can be an economy-wide model. In the context of the current project, it is an economy-wide model that also includes small-region representation. Another sort of model is an input–output model, but it solves either for quantities or for prices but not for both together, unlike a CGE model that solves for both together.

E.11.2 Comparative static computable general equilibrium modelling

CGE models are based on microeconomic theory. Each industry has a production function, based on cost minimisation subject to a technological constraint. Households seek to maximise utility subject to a budget constraint. An input–output database details the intermediate (commodity) and primary inputs into industries, and the commodity demands of final users, namely households, investment, the government and exports. Dixon et al. (1982) explained the theory of a CGE model.

In comparative static CGE modelling, economic shocks are imposed on exogenous variables within the model. The economic changes arising from these shocks to macro-economic and sectoral variables are depicted relative to the base case. Although there is no time dimension, different closures, or combinations of endogenous and exogenous variables, apply to short run and long-run settings.

In the short run, capital in each industry is fixed, as there is insufficient time for adjustments to stocks, even though investment levels in each industry change, driven by changes in the rate of return on capital. Real wages are also fixed. National employment can vary from base: that is, all adjustments at the industry and macro-economic levels occur via quantity rather than price adjustments.

In the long run, capital stocks adjust so as to restore the pre-simulation rates of return. An exception arises if aggregate capital is exogenous: all industry rates of return will move by a uniform percentage from the initial rates of return to accommodate the constraint. In the labour market, national aggregate employment is assumed to be exogenous. Real wages adjust to accommodate changes in labour market conditions. In a multi-regional model, there is imperfect mobility between regions, so that there may be some variation in both employment and real wage percentage changes between regions relative to base.

E.11.3 Dynamic computable general equilibrium modelling

Dynamic models trace the effects of ascribed direct effects across periods. The theoretical basis of dynamics is in linkages between investment and capital across time, and the balance of trade and net foreign liabilities. Investment and balance-of-trade outcomes are flows that a comparative static model includes. Capital and net foreign liabilities are stocks that require a dynamic model.

The importance of these dynamic linkages is evident in a disaster scenario. Comparative static models measure changes in flows relative to a base case. A dynamic model includes links between stocks and flows. In a disaster, in addition to disruption to business-as-usual activities, there may considerable destruction of capital and infrastructure. A dynamic model is able to capture the effects of an event on such destruction and also capture the changes in stocks of debt necessary to rebuild in later periods.

Dynamic TERM combines much of the theory of dynamic national models (see Dixon & Rimmer, 2002) with bottom-up, regional representation. That is, each region in TERM has its own production functions, household demands, input–output database and interregional trade matrices. This enables us to model relatively local issues.

TERM was originally developed by Mark Horridge at the Centre of Policy Studies, Victoria University (see https://www.copsmodels.com/term.htm). Since then, Glyn Wittwer has developed a dynamic version of the model, and Wittwer et al.'s (2005) study is an example of its application.

In dynamic TERM, we use an underlying forecast. This may be based on the macro forecasts of other agencies. The underlying forecast or baseline gives us a year-by-year 'business-as-usual' case. The typical variables to be reported in the policy scenario relative to a baseline forecast are regional real GDP, employment and aggregate consumption. Industry-level results are also available.

Production technologies

TERM contains variables describing primary-factor and intermediate-input-saving technical change in current production; input-saving technical change in capital creation; and input-saving technical change in the provision of margin services (e.g. transport and retail trade).

TERM's unique treatment of transport

The supply of margins originating in one region can lower the costs of moving goods between regions further afield. Previous multi-regional models (e.g. Naqvi & Peter, 1996) assigned the margin supply of a sale either to the origin or destination of the sale.

GEMPACK software

Dynamic TERM uses GEMPACK software for implementation (Horridge et al., 2019).

References

Alexander, H., & Moir, N. (2019, 20 December). ‘The monster’: A short history of Australia's biggest forest fire. *The Age*. https://www.theage.com.au/national/nsw/the-monster-a-short-history-of-australia-s-biggest-forest-fire-20191218-p53l4y.html

Arriagada, N., Palmer, A., Bowman, D., Morgan, G., Jalaludin, B., & Johnston, F. (2020). Unprecedented smoke-related health burden associated with the 2019-20 bushfires in eastern Australia. *Medical Journal of Australia*, *213*(6), 282–283 https://doi.org/10.5694/mjA3.50545

Clayton, R. (2022, 9 November). *Building review panel finds systemic issues with Victoria's regulatory system*. ABC News. https://www.abc.net.au/news/2022-11-09/victoria-building-regulation-report-leak-shows-unsafe-homes/101613026

Deloitte Access Economics. (2020). *Economic benefit analysis of drones in Australia, Final Report*. Department of Infrastructure, Regional Development and Communications. https://www.infrastructure.gov.au/sites/default/files/documents/economic-benefit-analysis-of-drones-to-australia-final-report.pdf

Dixon, P. B., Parmenter, B., Sutton, D., & Vincent, D. (1982). *ORANI: A multisectoral model of the Australian economy.* Contributions to Economic Analysis. North-Holland.

Dixon, P. B., & Rimmer, M. T. (2002). *Dynamic general equilibrium modelling for forecasting and policy: A practical guide and documentation of MONASH.* Contributions to Economic Analysis (Vol. 256). North-Holland. https://doi.org/10.1108/S0573-8555(2001)256

Goondiwindi Regional Council. (2022). *Goondiwindi region is first regional place in Australia to deliver rural medications by drones*. https://www.grc.qld.gov.au/news/article/486/goondiwindi-region-is-first-regional-place-in-australia-to-deliver-rural-medications-by-drone

Goyal, R., Reiche, C., Fernando, C., & Cohen, A. (2021). Advanced air mobility: Demand analysis and market potential of the airport shuttle and air taxi markets. *Sustainability*, *13*(13), Article 7421. https://doi.org/10.3390/su13137421

Hobba, B., Akinci, S., & Göktogan, A. H. (2021). Efficient herbicide spray pattern generation for site-specific weed management practices using semantic segmentation on UAV imagery. In *Proceedings of the Australian Robotics and Automation Association* (p.10).

Horridge, M. (2012). The TERM model and its database. In G. Wittwer (Ed.), *Economic modeling of water,* Global issues in water policy (Vol, 3). Springer. https://doi.org/10.1007/978-94-007-2876-9_2

Horridge, M., Jerie, M., Mustakinov, D., & Schiffmann, F. (2019). *GEMPACK manual*. GEMPACK Software. https://www.copsmodels.com/gpmanual.htm

Horridge, M., Madden, J. & Wittwer, G. (2005). Using a highly disaggregated multi-regional single-country model to analyse the impacts of the 2002-03 drought on Australia. *Journal of Policy Modelling*, *27*, 285–308. https://doi.org/10.1016/j.jpolmod.2005.01.008

Islam, N., Rashid, M. M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021). A review of applications and communication technologies for Internet of Things (IoT) and unmanned aerial vehicle (UAV) based sustainable smart farming. *Sustainability* (Switzerland), *13*(4), 1–20, Article 1821. https://doi.org/10.3390/su13041821

Lazzaro, K. (2020, 29 August). *Taxpayer funded bushfire clean-up in Victoria complete*. ABC News. https://www.abc.net.au/news/2020-08-29/government-funded-bushfire-clean-up-invictoria-complete/12601938

Mualla, Y., Najjar, A., Daoud, A., Galland, S., Nicolle, C., & Shakshuki, E. (2019). Agent-based simulation of unmanned aerial vehicles in civilian applications: A systematic literature review and research directions. *Future Generation Computer Systems*, *100*, 344–364. https://doi.org/10.1016/j.future.2019.04.051

Morgan, E. (2007). A ‘fare’ go for regional communities: *The challenge of providing accessibility to regional and remote communities* [Paper presentation]. International conference series on competition and ownership in land passenger transport, Hamilton Island, QLD. http://hdl.handle.net/2123/6099

Naqvi, F., & Peter, M. (1996). A multiregional, multisectoral model of the Australian economy with an illustrative application. *Australian Economic Papers*, *35*, 94–113. https://doi.org/10.1111/j.1467-8454.1996.tb00040.x

Nassios, J., & Giesecke, J. (2022, June). Property tax reform: Implications for housing prices and economic productivity (Working Paper G-330). Centre of Policy Studies. https://www.copsmodels.com/elecpapr/g-330.htm

Nyugen, K. (2020, 2 August). *How the ABC located the tree which started the Gospers Mountain bushfire and the Sydney 'mega-blaze'*. ABC News. https://www.abc.net.au/news/2020-08-02/how-we-found-tree-which-sparked-the-sydney-mega-blaze-bushfire/12510960

Offer, K. (2019, 10 April). Ex-emergency chiefs sound climate alarm. *Canberra Times*. https://www.canberratimes.com.au/story/6014638/ex-emergency-chiefs-sound-climate-alarm/?cs=14231

Sah, B., Gupta, R., & Bani-Hani, D. (2021). Analysis of barriers to implement drone logistics. *International Journal of Logistics Research and Applications*, *24*(6), 531–550. https://doi.org/10.1080/13675567.2020.1782862

Snouffer, E. (2022, 13 April). Six places where drones are delivering medicines. *Nature Medicine*, *28*, 874–875. https://doi.org/10.1038/d41591-022-00053-9

Wittwer, G., & Verikios, G. (2012). Introducing Dynamics to TERM. In G. Wittwer (Ed.), *Economic modeling of water: The Australian CGE experience*. Springer. https://doi.org/10.1007/978-94-007-2876-9

Wittwer, G., & Waschik, R. (2021). Estimating the economic impacts of the 2017–2019 drought and 2019–2020 bushfires on regional NSW and the rest of Australia. *Australian Journal of Agricultural and Resource Economics*, *65*(4), 918–936, https://doi.org/10.1111/1467-8489.12441

SECTION F: Report Synthesis

Stage V: Synthesis

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F.1 Status of Australian Drone Industry

Uncrewed aerial vehicles (UAVs), or drones, have developed over time to be high-tech sophisticated tools and vehicles with a wide variety of potential use cases. There are many different types of drones with different systems and capabilities. Drones equipped with advanced navigation systems, collision avoidance and environment detection systems can operate as autonomous systems with artificial intelligence and machine learning capabilities built in (Gupta et al., 2021). However, autonomous flight is currently not permitted in Australia, but automatic flights are, as long as the remote pilot can take control at any time, visual line of sight is maintained and a Global Positioning System is available. The development and application of drone technology for civilian use has accelerated in recent years, and drones are used not only for recreational purposes but also in a wide range of industries. However, this study has shown that the market for some industries, such as mining and agriculture, is well established while that for other sectors, such as advanced air mobility (AAM) and freight and last-mile delivery, are still at infancy (see Figure F.1). Consequently, the potential benefits of drone technology are yet to be fully realised.

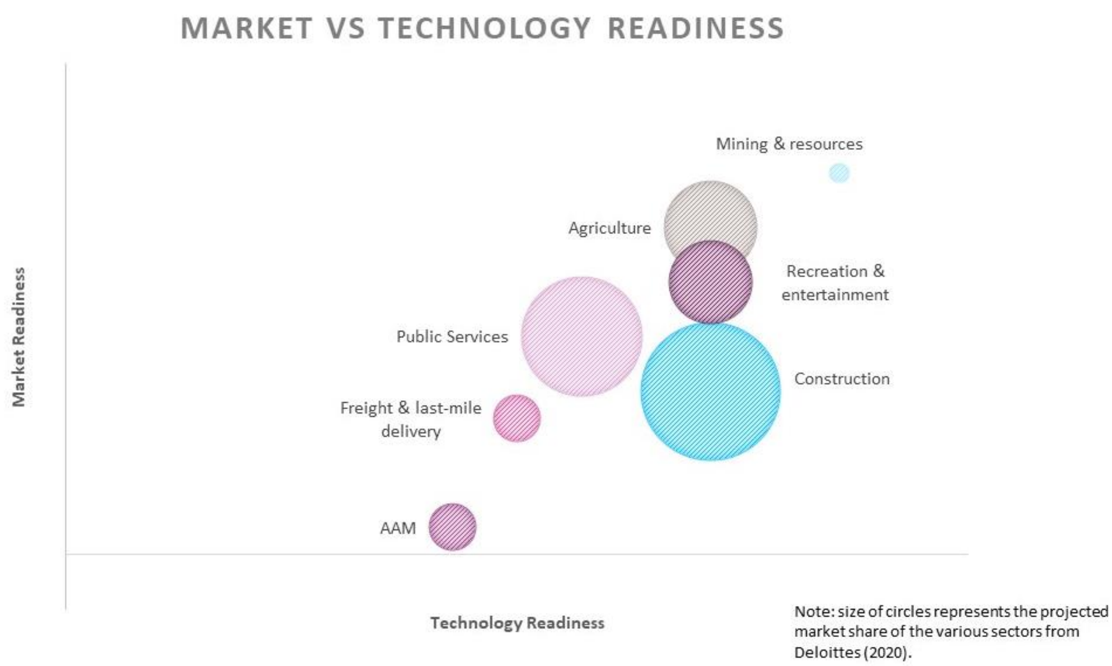

Figure F.1: Market and technology readiness

Drone technology is currently being tested and trialled across a wide variety of use cases, and the regulation is undergoing development and review. Prominent ongoing trials include the use of drones for the inspection of bridges in NSW, last-mile delivery of medical equipment in Queensland, parcel delivery in major cities across Australia, health service transport in the Northern Territory (NT) and tracking endangered elusive species (rock-wallabies) in the NT. More recently, the Commonwealth Government approved funding of up to A$32.6 million, as part of the Emerging Aviation Technology Partnerships (EATP) Program, for a new round of trials to further evaluate the benefits of this emerging technology. Trials, both new and completed, will reveal whether the technology, with the right amount of regulation, can scale to offer significant benefits to Australia's economy.

In the following sectors in Australia, there have been significant applications of drone technology, and the literature review presented in Section B finds that the state of technology development and adoption appears at least on par with that of other international markets in such sectors as (1) agriculture, (2) freight and last-mile deliveries, (3) public sector services, (4) mining and resources and (5) media, recreation and entertainment. For example, in agriculture, drones are being used for crop spraying, mapping of farms, crop inspection and monitoring, stock management and other high technology applications, commonly referred to as precision agriculture or smart farming. Similarly, drones are increasingly being used for the delivery of retail goods as well as essential supplies, such as medicines and medical devices. In public sector services, drones are being used for firefighting and emergency services, police work, customs and border control, disaster management, monitoring of ports, urban traffic management and shark patrols among many others.

Other sectors have seen fewer applications in Australia than in some other countries, namely construction and AAM. For instance, in the construction industry, drones offer promising applications across planning, design and building-related activities, but usage appears to be very much in its infancy in Australia. AAM could offer affordable transport alternatives for both short and medium-distance travel, particularly in regional and remote Australia, but AAM services are not yet trialled in Australia, and nor does a manufacturing or supply chain exist; further, neither has regulation been formulated yet. Numerous other countries, such as Singapore, the United Arab Emirates and Germany, are at a more advanced stage of drone adoption than Australia, given that they have more developed AAM policies and have trials underway.

F.2 Geographic and Demographic Considerations

Australia's geographic and demographic profile, such as its strong and open economy, low population density and large rural areas, create opportunities for drones. Australia has vast open spaces that can be utilised for trialling and testing of new applications. As more firms employ drones, new applications, and opportunities to innovate with drone technology, will also expand. This will be further supported by the innovative culture and ingenuity in applications across different sectors in Australia.

With respect to application, according to industry experts, drones are expected to be more useful for regional areas than urban areas, by reducing isolation. The rural areas of Australia offer new opportunities to utilise drones. For example, delivery services will have more impact in remote corridors and between major capital cities and regions, such as Melbourne and regional Victoria, and between Sydney and regional New South Wales. The participants in the survey administered to the general public indicated that if they were to consider using flying cars, they would be more likely to use it for longer distances. Hence, drone uptake will most likely be higher in the transport sector to help those people living in regional and remote areas. Consequently, drone use can reduce the inequities between geographical areas across Australia, especially in places where productivity and living standards are lagging.

Our findings suggests that the most feasible higher-volume flightpaths are between regional cities and regional communities owing to the higher demand from regional communities. However, ensuring connectivity between metropolitan areas and other regions is probably one of the most useful long-term applications of the technology but involves air traffic management challenges. Geography may also influence the sectoral uptake of drone technology. For example, the public services sector may experience a higher uptake in the coastal areas than inland because of its wider applications to spot sharks and monitor crowds. However, finding missing people in remote bushland or evacuating or supporting injured people in remote areas is one of the use cases that has high value in a vast and relatively sparsely populated land, such as Australia. High-volume use cases, such as agriculture and mining, also suggest a higher volume in more regional and remote areas in the near future. Once the AAM ecosystem has matured and air traffic management and regulatory hurdles have been resolved, higher volumes in metropolitan areas can be expected because of increased freight and passenger transport.

In sum, in the short-to-medium term, higher volumes are expected in regional and remote areas as well as in urban areas away from the no-fly zones of controlled airports. In the long term, once the technology matures and current challenges have been addressed, more volume is possible in Australia's metropolitan areas.

F.3 Determinants of Drone Uptake in Australia

The uptake of drone technology in Australia will depend upon the rate and scale of technology development and readiness, as well as numerous other factors (see Figure F.2). The inner segments of Figure F2 provide examples of how the core determinants can be classified being issues of 'Technology', the proliferation of 'Use cases', and public awareness of new and current 'Trials'. We can further identify areas where the 'Socio-Economic' implications of drone technology can either positively or negatively affect drone technology uptake as will the perceived 'Value Proposition to Industry Stakeholders'. Even so, the issues are many and varied overlapping and interconnecting across any attempt at classification as may be seen by the 'Challenges' segment.

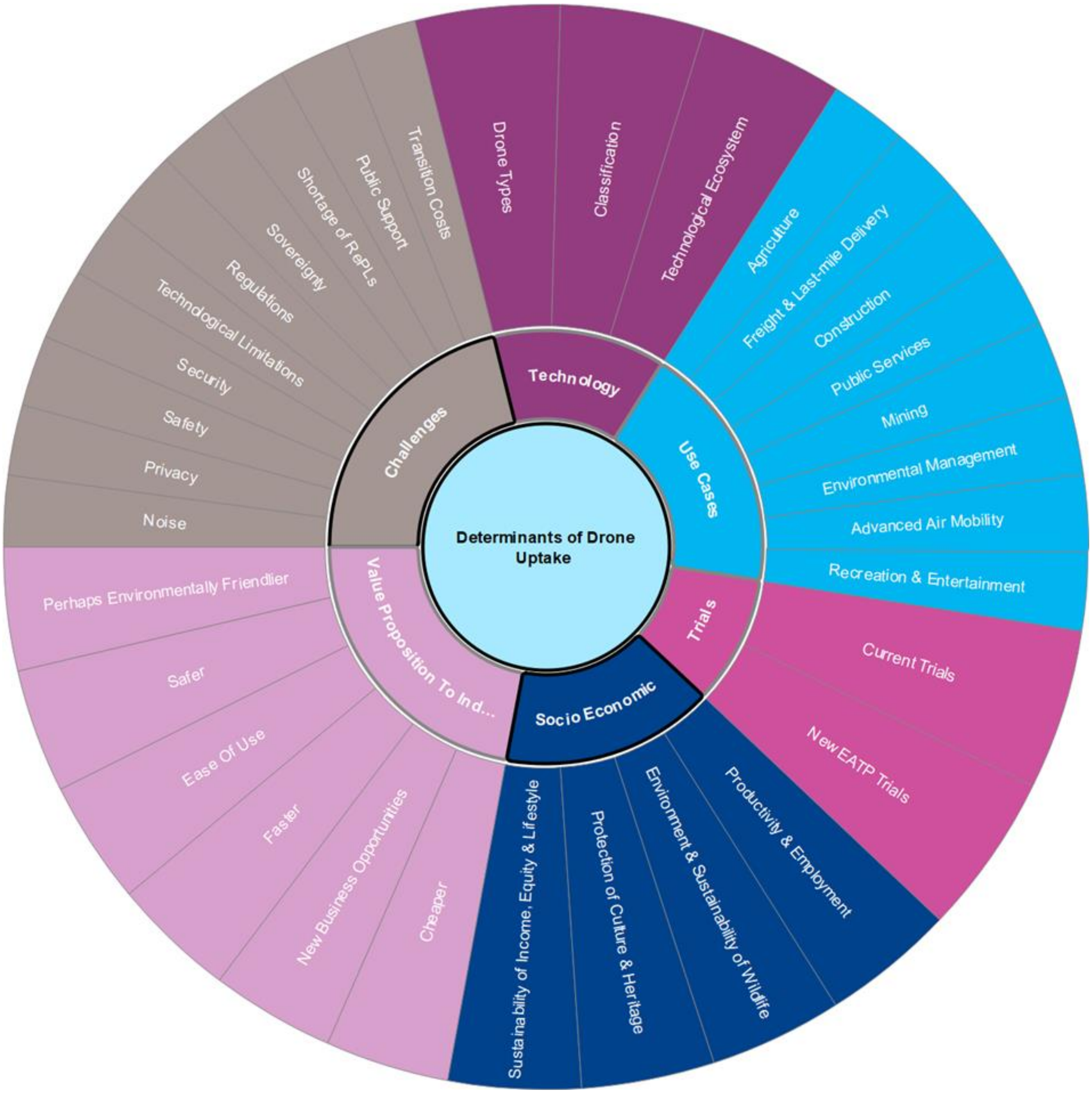

Figure F.2: Determinants of drone uptake

Drone technology is more developed for some use cases, such as sensing and surveying applications, and less developed for others, such as those requiring the movement of large goods or of people (see Figure F.1). Many technological challenges remain to be resolved. For example, battery life, performance in inclement weather, constraints on payloads and transition costs continue to be limiting factors to drone applications. There are national issues to consider and address with respect to national sovereignty in manufacturing supply chains, along with data collection, storage and distribution risks. Further, there are operational challenges. For example, many of the surveyed experts identified a greater need to educate and train remote pilots to enable higher uptake. Greater investment from both the private and public sectors could help expedite the process of technology development and overcome some of these technical and operational challenges. A consistently supportive regulatory environment across states, territories and federal jurisdictions with regard to testing and trialling would further help the process.

Uptake will further depend on market readiness. For drone technology to gain widespread application, a clear and compelling value proposition must be identified to potential end-users. In most cases, the direct benefits of drone technology can be understood in terms of cost and time savings. For example, Kitjacharoenchai et al. (2019) and She and Ouyang (2021) highlighted the potential of drones to reduce travel costs in logistics by reducing the use of land vehicles powered by fuels. In search and rescue operations, where time is of the essence, drones can often be deployed much quicker than crewed helicopters (Said et al., 2021). Moreover, drones can also offer safety benefits. For example, in the construction and mining industries, drones are being used to improve site inspection and monitoring and to enforce safety protocols more effectively (Vanderhorst et al., 2019; Zhou & Gheisari, 2018). Furthermore, drones could enable new business opportunities that are not otherwise technologically possible, such as sensing and surveying of otherwise inaccessible environments.

Last, public acceptance and support will be essential to the widespread adoption of drone technologies. Drone technologies pose concerns through their broader effects on safety and security, noise, privacy and the natural environment. Even if the technology addresses a clear market need, if the general public is opposed to its use, this could hinder uptake. Government regulations and public information campaigns will have a major role to play in safeguarding the interests of the broader public, addressing their concerns and communicating the value of the technology. The current public opinion in Australia on drone technology is outlined and detailed in Section F.5.

F.4 Wider Effects of Drone Technology

The direct benefits of drone technology, such as time and cost savings and improved safety, could translate into productivity benefits at the national level. The results of the computable general equilibrium (CGE) model of the national economy estimated the macro-economic impact of drone technologies across a subset of use cases. In the case of emergency services, a 10% net productivity gain from the use of drone technologies could result in a long-run increase in the national real GDP of 0.022%, or A$460 million in present-dollar terms. The use of drones in freight and last-mile delivery services could lead to productivity gains in some health-related sectors in non-metropolitan regions, reflecting improved services, as well as small productivity gains in road freight in all regions. We estimate these cumulative gains to be 0.016% of the national real GDP, or A$344 million, with greater benefits accruing in non-metropolitan regions. Similarly, productivity benefits are estimated to be 0.034% of the national real GDP, or A$700 million, to the agricultural sector; 0.19% of the national real GDP, or A$4 billion, to the construction sector; and 0.082% of the national real GDP, or $1.7 billion, to the mining sector.[17]

However, drone technologies are also likely to lead to several externalities. They could displace some existing jobs across sectors where they find widespread application. For example, there are currently roughly 90,000 delivery drivers in Australia, and drone freight and delivery services could displace a proportion of these jobs, imposing added welfare and/or re-training costs on the economy. In terms of environmental effects, drones may offer some emissions savings when compared with ground transport vehicles (Elsayed & Mohamed, 2020; Persson, 2021), but the noise generated by drones could have a negative impact on the wellbeing of people and prove disruptive to wildlife (Mulero-Pázmány et al., 2017; Rebolo-Ifrán et al., 2019). Privacy remains a major concern for the general population (see Figure F.4), and it is possible that this concern will increase with the increased uptake of drones. There is also the risk of mission creep in all fields, paparazzi abuse of authorisation given to journalists, checks on illegal immigrants being used for other law enforcement purposes and

[17] However, substantial foreign ownership of mines may not lead to commensurate domestic benefits that could be gained by greater domestic consumption if profits are primarily channeled overseas.

other infringement of privacy rights by enforcement authorities (Wright & Finn, 2016). Last, the risks of technical and/or operator failure and of malicious attacks by hackers or terrorists pose a possible threat to the safety of local residents and risk damage to public and private property.

While the increased uptake and application of drone technologies can be positive and beneficial to some community groups, the economy and industrial sectors, there are also significant risks, both known and unknown. To address known risks, development work on legislation and community education is required. To address unknown risks. further research is necessary to better understand the risk–benefit equation.

F.5 Public Attitudes and Social Acceptance of Drone Technology

To understand public attitudes and perceptions towards drone technology, 1,000 Australians aged 18 years and above were surveyed, and a group of experts were interviewed and surveyed. While awareness around drones has been increasing recently, interviews with experts and the demand survey with consumers suggest that the public still has concerns regarding drones, mainly on the topics of noise, privacy and safety. These concerns can be, in part, attributed to the negative publicity about drones and the low awareness of their benefits among people. Experts mentioned that positive public attitudes towards drones were increased especially where stakeholders had been engaged before commencing drone operations and when drones were used for the public good, such as for shark patrol.

The surveyed sample of the Australian general public revealed a surprisingly high level of familiarity with drone technology. Roughly 84% of the sample reported being at least slightly familiar with the technology, 28% reported having flown a drone themselves at least once and 26% indicated moderate to strong interest in purchasing a drone. The survey respondents were also asked to assess different drone technology use cases in terms of value to their community and society at large (see Figure F.3). They saw the greatest value of the technology for emergency services and disaster recovery, such as to assist with search and rescue operations and emergency response coordination and to provide emergency deliveries. Security services, with applications in police response coordination, crime scene investigation, and criminal surveillance and tracking, were rated second. Environmental management, with applications in environmental hazard assessment, wildlife and habitat monitoring and protection, and scientific research, was rated third. Agriculture, with use cases such as crop and yield management, pest and disease detection and treatment, and water and asset management, was rated fifth. Respondents did not perceive as much value in applications of drone technologies in other industries, such as business, entertainment and recreation. However, approximately 80% of the industry experts who took part in the Round 2 survey of the Delphi study agreed that the Australian community has generally accepted the application of drones in mining without too many concerns. The same appears true to some extent for media, recreation and entertainment, with 66.6% agreement, although perhaps a bit less so in agriculture with only 53.3% agreement, from among the participating industry experts. This is in contrast with the survey results of public support (Figure F.3). This finding suggests that much more engagement and dialogue between different stakeholders is necessary to reach agreement about where efforts into Australia's drone industry should be concentrated. It is possible that early use cases, such as recreation and entertainment, although accepted as widely used, are not the use cases where the greatest benefits can be achieved for Australia or have the highest political support.

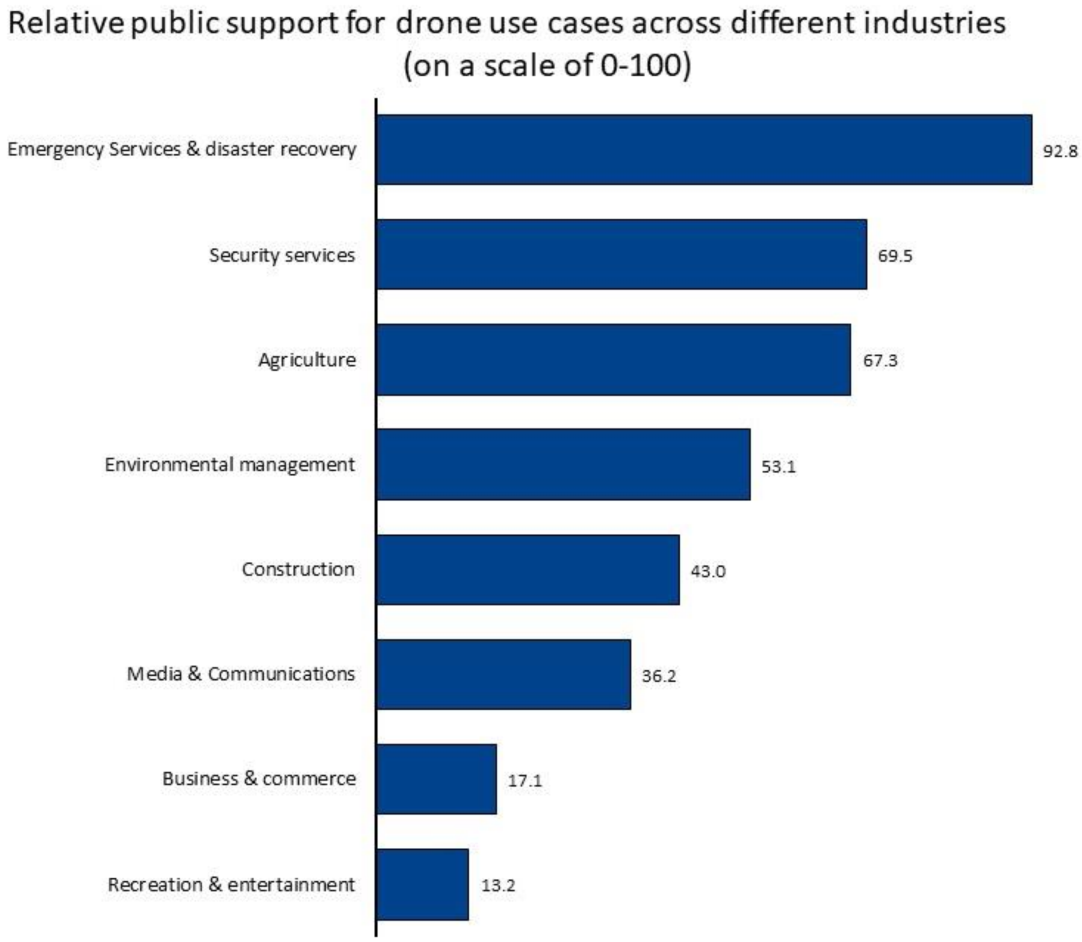

Figure F.3: General public's relative support for drone technologies by industry sector

From the list of potential effects of small-scale drones explored in the survey, respondents reported being most concerned about 'invasion of privacy', 'disturbance to wildlife' and 'safety risks to the general public', and perhaps surprisingly, being least concerned about 'noise pollution', 'disturbance to cultural sites' and 'reduce the beauty of the sky'. Considering the general positive public attitude towards drones, and the mitigation strategies described by experts, it seems that public education and stakeholder engagement are key when drone uptake increases over time to ensure that those concerns do not become more salient.

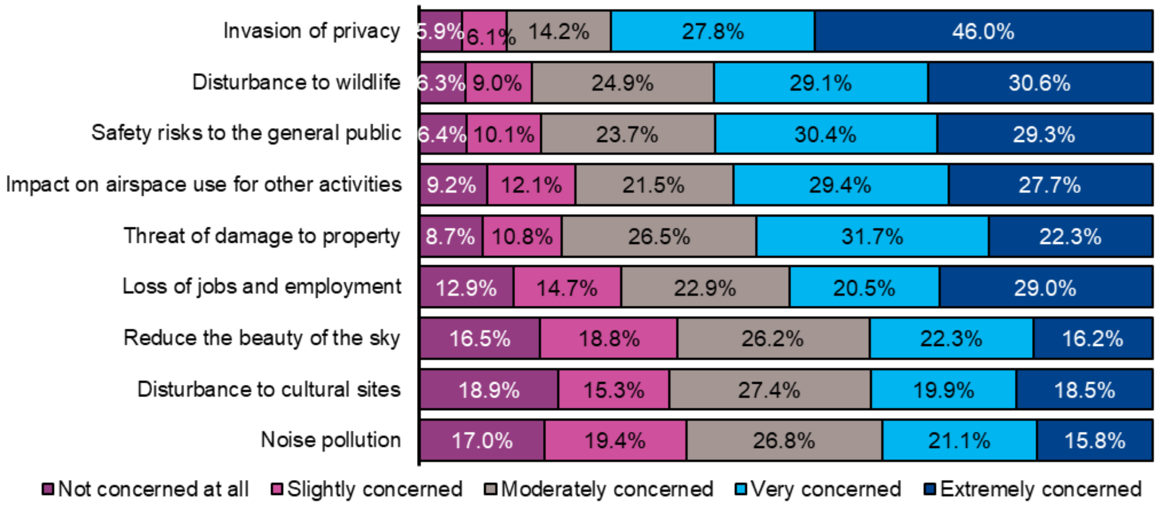

Figure F.4: Major concerns of the general public about drone technology

The findings from interviews with experts and from the consumer survey revealed that society, in terms of business and the general public, has started to perceive the benefits of drones over earlier concerns about drone noise. Likely, the latest technology advancements that make drones much quieter than in early years have helped this perspective, but also engaging and educating people about the benefits of drones has helped to clear some of the negative image of the 'noisy' drones of the early years. Drones can be now more widely accepted: 63% of the respondents to the survey on consumers were either strongly supportive or overall supportive of drones being deployed in practice wherever they offer value to the public; 79% indicated a willingness to accept drone use in specialised use cases where they offer high value; and only 21% indicated that they do not want to see drones commercially deployed in practice at all. The sampled survey respondents find drones of most value in the delivery of goods, emergency, traffic management and general services to the public sectors. Roughly half of the sample indicated some desire to use drones for delivery, while a quarter indicated no desire to use such a service. Trust in the service varied across the sample. Roughly 30–35% of the sample indicated they are willing to use flying cars (AAM), and 25% indicated they would purchase a flying car when it becomes available. In general, the respondents are much more likely to use flying cars for long-distance intercity travel than short-distance intracity travel. However, most of them are still sceptical of the technology and wary of entrusting their safety to an UAV at this point, for any type of travel.

F.6 Potential Role of Government in Supporting Development and Uptake

If governments are inclined to take a more proactive role in supporting the uptake of drone technologies, the findings from our study offer four broad directions through which they could pursue these aims (see Figure F.5).

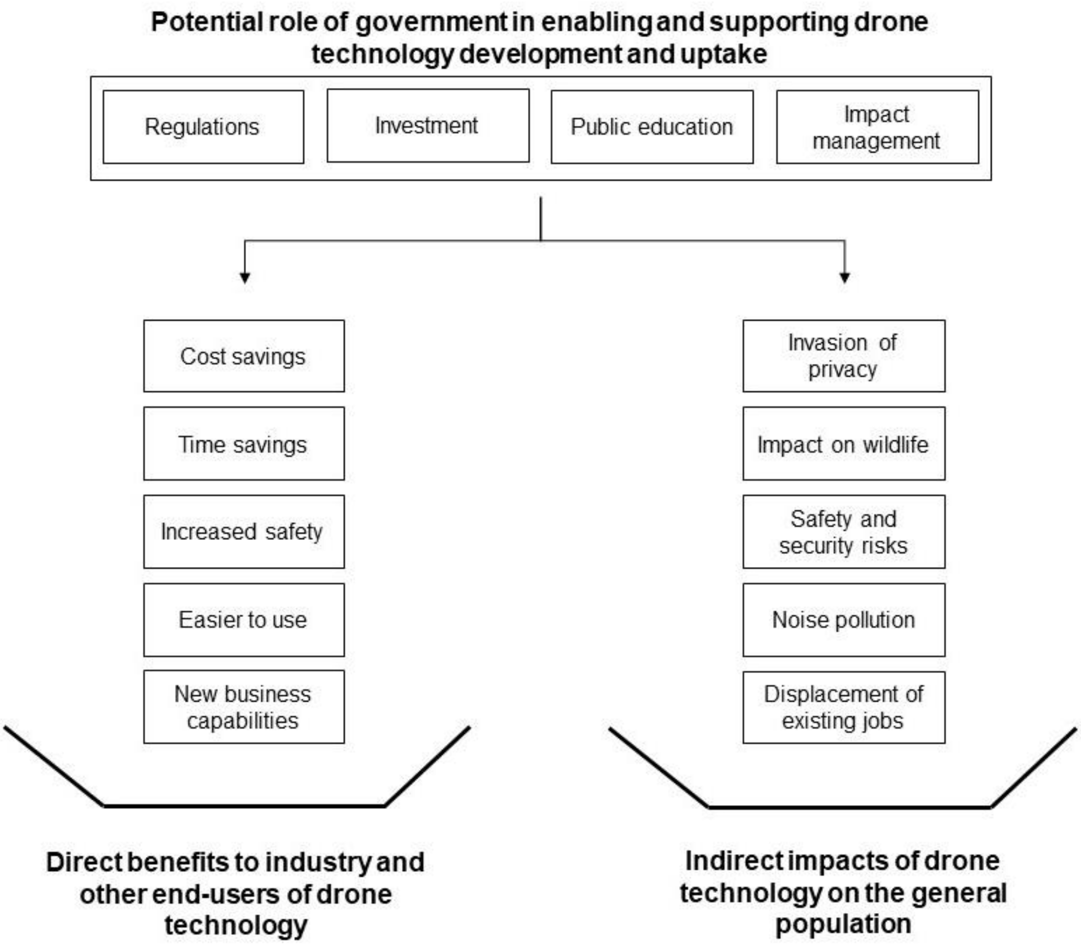

Figure F.5: Potential role of government in supporting drone technology uptake

First, government regulations on the operations of drones, licensing, flight paths and flight priorities are all important aspects of managing public safety. A comparative study of drone regulations showed that there is much to be resolved in this space (Tsiamis et al., 2019). While Australia has a relatively mature set of regulatory frameworks to govern drone technology, the rapid pace of technological developments could pose a challenge for regulators to ensure that regulations and infrastructure are in place to manage and meet future changes. Many of the experts interviewed in this study indicated that difficulties in gaining regulatory clearance and the extensive compliance process for the various industries where they employ drones across different states and territories has limited the adoption of drones in particular sectors across Australia. Government regulations—regarding not only the usage of drones but also the various industries that commonly use this new technology—will be essential to get the balance right between safety, security and innovation. Given the federal nature of the Australian political system, the harmonisation of government regulations across different states and territories could also support the development and uptake of this technology.

Second, public sector investment in drone technology and the broader ecosystem could expedite its rate of development and adoption. State and federal governments have already funded many trials across Australia. Given the potential for drone technologies to be used across different public services, such as emergency services, disaster relief, and security and surveillance, technology development and uptake could be driven by government procurement processes that incentivise the use of drones within these use cases. A strong local drone industry would also be important from the perspective of national security and sovereignty. Tax incentives, subsidies and other financial instruments could be used as further incentives to spur such development and uptake.

Third, governments could have a role to play in educating and informing the public about the process of technology development and deployment. For example, public information campaigns could be used to share news about ongoing and planned future trials and deployments. Information dissemination could target segments identified previously as being more resistant to these new technologies in order to help allay their concerns, as well as those who are most enthusiastic about these technologies in order to help build greater support. Potential campaigns should emphasise key benefits to the community and address key concerns in terms of safety, security, privacy and environmental impact.

Fourth, governments may also need to help manage the negative effects of drone technologies. For example, these technologies could displace a proportion of existing jobs in the transport and logistics sector, and from a public policy perspective, governments will have a major role to play in supporting and assisting displaced workers. Drone technologies also pose concerns in terms of their potential impact on privacy, noise and the environment. Given that many of these effects are not fully understood, governments will need to keep abreast of ongoing developments, as well as support further research, as discussed in greater detail in Section F.8.

F.7 Overall Sector-wise Economic Benefits and Social Acceptance Profiles

In the interests of providing a snapshot summation of the depth and range of this study, the research team pooled their collective knowledge and insights gained across the project to formulate a high-level and subjective summary profile of the sectors and their application readiness and benefits captured in Table F-1. For the detailed analysis of these sectors, we referred to the prior sections of the report. However, this summative assessment is based upon a low to high relative level among the selected sectors, as judged by the research team by concatenating all the results of this study. For instance, the security services and other studied sectors have adopted the technology at relatively low levels when compared with agriculture, mining and resources, and the recreation and entertainment sectors, but the emergency relief and disaster management, and the environmental management sectors are relatively somewhere in between low and high adoption levels.

The potential direct benefit pertaining to each industry sector is generally quite high, although this appears to be relatively less so in the mining and construction sectors where either the gains have already been largely exploited, or the applications will provide fewer benefits compared with other potential gains that may be made in the industry sectors. However, the direct benefits in the environmental management sector are unclear, where productivity benefits may be wiped out by intangible costs to humans and wildlife. Thus, more research on this sector is required.

With respect to the broader macro-economic effects, we sought to project the extent to which the uptake of drones within the sectors will affect Australia's national real GDP and therefore social consequence. In this regard, and relative to the other sectors, our analysis showed that the mining and resources and the construction sectors potentially offer the highest returns. Still positive, but not as impactful, are the potential real GDP gains in the agriculture and freight and last-mile delivery services sectors, and hence, we assess these as moderate. The emergency relief and disaster management services sector is also assessed as potentially providing a relatively moderate economic gain. Currently, and considering the complexities related to AAM, the potential real GDP gains are assessed as low in any near-term future scenario. However, we hasten to add that the benefits in sectors such as emergency relief and disaster management and AAM are not confined to economic gains, and other factors, such as the safety and wellbeing of the Australian population and the service equities to remote regions, need to be considered in national and sector investment decisions.

Last, as regards public support, we suggest a relative qualitative assessment on the perceptions of the public about the technology and their level of preparedness to, if not proactively support, be more accepting of, drone uptake in the different sectors. In this category, public support for the sector applications in the security, environment, and emergency services is generally high, where public good is most obvious. Where uncertainties are large, for example, in the safety aspects of AAM and privacy concerns in recreation and entertainment, support is relatively low. The moderate level of support represents the sectors where there is potential for mixed reactions between those who may be clearly advantaged by the sector application and those who perceive a negative impact from drone adoption.

Table F.1: Profile of economic benefits and social acceptance across sectors

Sector	Use cases	Relative level of adoption	Potential direct benefit to industry	Broader macro-economic benefits	Public support
Emergency relief and disaster management	Emergency deliveries, search and rescue operations, disaster prevention monitoring, relief operations, post-disaster management	Moderate	High	Moderate	High
Security services	Surveillance, tracking, response coordination, crowd control and management	Low	High	unclear	High
Environment management	Hazard assessment, pest control, wildlife and habitat monitoring and protection, scientific research	Moderate	unclear	unclear	High
Agriculture	Livestock monitoring and herding, crop and yield management, water and asset management, surveying and planning	High	High	Moderate	Moderate
Mining and resources	Surveying, inspection and monitoring	High	Moderate	High	Moderate
Construction	Surveying, inspection and monitoring	Low	Moderate	High	Moderate
Freight and last-mile deliveries	Urban deliveries, postal services, cargo freight	Low	High	Moderate	Moderate
Advanced air mobility	Urban and regional air services	Low	High	Low	Low
Recreation and entertainment	Photography and filming, advertising and marketing, journalism, gaming	High	High	unclear	Low

F.8 Future Research Opportunities

The present study provides a number of opportunities for future research. First and foremost, this study concentrated on certain sectors in which there is a wide range of drone applications as indicated in the prior literature. These sectors are AAM, environmental management, freight and last-mile delivery, public services, agriculture, mining and resources, construction and recreation and entertainment. The value proposition for drone adoption in many other sectors has been excluded, particularly for the maritime, health services, manufacturing and insurance sectors, largely because of limited evidence and/or because the technology is in its infancy in these sectors. It would be useful to assess the benefits and costs of drone applications in these industries in the future as more data becomes available from existing and future trials.

The literature review discussed various classifications of drones over time, according to size, weight, operational functions and type of wings (Alghamdi et al., 2021; Arjomandi et al., 2006; Chan et al., 2018; Hassanalian & Abdelkefi, 2017). In Australia, the classification of drones is provided by CASA, which defines drones by their intended use, flight technology and weight. CASA classifies drones by size, into micro (up to 250 gm), very small (between 250 gm and 2 kg), small (between 2 kg and 25 kg), medium (between 25 kg and 150 kg) and large (more than 150 kg) drones. Given the large variation in sizes, regulators could conduct a thorough analysis on the comparison of the noise level, safety, security, and associated regulations of these drones. Since a drone can weigh anything between 250 gm and more than 150 kg, the public and societal acceptance of drones is most likely not going to be the same between a small and a large-sized drone (e.g. a micro drone as against a very large-sized drone). More research is required to understand how societal and public acceptance can change when different size drones are adopted in trials.

The demand survey and the qualitative Delphi study both suggest that noise is perhaps less of a concern among community groups currently. While nearly 47% of the experts from the second round of the Delphi study agreed that noise is still an issue for many Australian communities, which prevents them from fully accepting the application of drones, about 40% were neutral and another 13.3% disagreed with this statement. In the consumer demand survey, only 15.8% of the consumers strongly felt that noise pollution can limit the potential uptake of small-scale drone technology. Further, the experts commented that noise is prevalent in all flightpaths in big cities and communities do not always complain about it. With reductions in noise levels, and as society understands better the greater benefits of this new technology, drone noise concerns will possibly become less and less of an issue over time. Thus, an interesting research question is to what extent is noise still a concern for drone adoption, particularly in urban and rural areas? Furthermore, does the concern about noise among the public increase with the size of drones? How do the flightpath and use case influence the perception of noise? How do the context (busy urban environments v. calm countryside) and the duration of drone noise exposure influence the perception of, or actual, noise annoyance, physical hearing loss or emotional disturbance? How does the perception change when it is clear that the mission is, for example, a search and rescue one (e.g. through a different colour coding scheme of drones)?

Another important area of future research is the environmental impact of drones as the technology matures and goes to scale. This includes life cycle assessment, cost–benefit analysis and analysis of the impact on wildlife. The literature review and the CGE modelling discussed some of the benefits and costs of using drones on environment and wildlife conservation. Although there is some evidence that drone noise can disrupt the breeding season of birds, research also shows that wildlife preservation can be enhanced by monitoring the heart rate of wildlife and their other vital signs of health in a non-invasive, non-intrusive way. Thus, future research can focus on comparing the costs and benefits of both wildlife conservation and the environmental assessment of drones.

This also leads to the topic of utilising drone technology to battle climate change. Drones are increasingly used to monitor the effects of climate change, including deforestation and the melting of glaciers; of wildlife conservation; and of urbanisation.[18] For example, in the city of Rochester, Minnesota, in the United States, a series of drone trials were undertaken recently to better understand how a temperature rise caused by climate change can affect the densely populated areas of the city.[19] Thus, with the maturity of the technology, public acceptance of

[18] https://social-innovation.hitachi/en-eu/stories/technology/drones-new-heights-climate-change/

[19]https://www.preventionweb.net/news/city-rochester-use-drones-collect-data-climate-change-impacts

its application can also change, which has a broader impact on society and the environment. More research is needed to fully understand the societal acceptance and environmental effects, benefits and challenges of drone applications.

Last, several EATP Program trials are currently being conducted in various states in Australia in collaboration between governments and private industries. One of the main objectives of these programs is to provide Australian businesses with a stable ecosystem to incorporate drone use in their day-to-day operations with increased technical complexity. Thus, the EATP Program is a strategic move towards taking drone trails to the next level of achieving scale and production. This program aims to evaluate the contributions of drones towards achieving a net zero carbon emissions goal and supporting regional communities in improving their health and transport services. Once these EATP Program trials are completed, future research can focus on assessing the results from these trials, their benefits, challenges and socio-economic impact.

Overall, the adoption of drone technologies has a long way to go to substantiate the estimates about the added value to the economy and society. However, there are some sectors and communities that currently benefit and others that clearly can experience substantial gains, particularly in rural and remote communities. The development of the technology is largely dependent on overseas manufacturing, and there is an opportunity to ramp up private and government investment in funding capability development and national capacities in provisioning, servicing and adopting drone technologies. Just like any new and emerging technological area, the uptake of drone technologies presents concurrent risks that are known, such as overcrowding of a poorly controlled air space; or known unknowns, for instance, the effects of drone operations on wildlife habitats; and unknown unknowns, where we have no idea about unanticipated or unintended consequences that may emerge in either the short or long term. For this reason, vigilance and careful steps are required, but at the same time, this should not dampen the enthusiasm for a technology that enhances Australians’ wellbeing, addresses social inequities and increases the wealth-creating capacity of Australia’s important industrial sectors.

References

Alghamdi, Y., Munir, A., & La, H. M. (2021). Architecture, classification, and applications of contemporary unmanned aerial vehicles. *IEEE Consumer Electronics Magazine*, *10*(6), 9–20. https://doi.org/10.1109/MCE.2021.3063945

Arjomandi, M., Agostino, S., Mammone, M., Nelson, M., & Zhou, T. (2006). Classification of unmanned aerial vehicles. *Report for Mechanical Engineering class.* University of Adelaide, Australia, 1–48.

Chan, K., Nirmal, U., & Cheaw, W. (2018). Progress on drone technology and their applications: A comprehensive review. *AIP Conference Proceedings*, *2030*(1), Article 020308. https://doi.org/10.1063/1.5066949

Elsayed, M., & Mohamed, M. (2020). The impact of airspace regulations on unmanned aerial vehicles in last-mile operation. *Transportation Research Part D: Transport and Environment*, *87*, Article 102480. https://doi.org/10.1016/j.trd.2020.102480

Gupta, A., Afrin, T., Scully, E., & Yodo, N. (2021). Advances of UAVs toward future transportation: The state-of-the-art, challenges, and opportunities. *Future Transportation*, *1*(2), 326–350. https://doi.org/10.3390/futuretransp1020019

Hassanalian, M., & Abdelkefi, A. (2017). Classifications, applications, and design challenges of drones: A review. *Progress in Aerospace Sciences*, *91*, 99–131. https://doi.org/10.1016/j.paerosci.2017.04.003

Kitjacharoenchai, P., Ventresca, M., Moshref-Javadi, M., Lee, S., Tanchoco, J. M., & Brunese, P. A. (2019). Multiple traveling salesman problem with drones: Mathematical model and heuristic approach. *Computers & Industrial Engineering*, *129*, 14–30. https://doi.org/10.1016/j.cie.2019.01.020.

Mulero-Pázmány, M., Jenni-Eiermann, S., Strebel, N., Sattler, T., Negro, J. J., & Tablado, Z. (2017). Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. *PLoS ONE*, *12*(6), Article e0178448. https://doi.org/10.1371/journal.pone.0178448

Persson, E. (2021). *A systematic literature review on drones' application in last-mile delivery* [Master's thesis, University of Gavle]. DiVA. https://www.diva-portal.org/smash/get/diva2:1577765/FULLTEXT01.pdf

Rebolo-Ifrán, N., Grilli, M. G., & Lambertucci, S. A. (2019). Drones as a threat to wildlife: YouTube complements science in providing evidence about their effect. *Environmental Conservation*, *46*(3), 205–210. https://doi.org/10.1017/S0376892919000080

Said, K. O., Onifade, M., Githiria, J. M., Abdulsalam, J., Bodunrin, M. O., Genc, B., Johnson, O., & Akande, J. M. (2021). On the application of drones: A progress report in mining operations. *International Journal of Mining, Reclamation and Environment*, *35*(4), 235–267. https://doi.org/10.1080/17480930.2020.1804653

She, R., & Ouyang, Y. (2021). Efficiency of UAV-based last-mile delivery under congestion in low-altitude air. Transportation Research Part C: Emerging Technologies, 122, Article 102878. https://doi.org/10.1016/j.trc.2020.102878

Tsiamis, N., Efthymiou, L., & Tsagarakis, K. P. (2019). A comparative analysis of the legislation evolution for drone use in OECD countries. *Drones*, *3*(4), Article 75. https://doi.org/10.3390/drones3040075

Vanderhorst, H. R., Suresh, S., & Renukappa, S. (2019). Systematic literature research of the current implementation of unmanned aerial system (UAS) in the construction industry. *International Journal of Innovative Technology and Exploring Engineering*, *8*(11S), 416–428. https://doi.org/10.35940/ijitee.K1073.09811S19

Wright, D., & Finn, R. (2016). Making drones more acceptable with privacy impact assessments. In Custers, B. (Ed.) *The future of drone use* (pp. 325–351). Information Technology and Law Series (Vol. 27). TMC Asser Press. https://doi.org/10.1007/978-94-6265-132-6_17

Zhou, S., & Gheisari, M. (2018). Unmanned aerial system applications in construction: a systematic review. *Construction Innovation*, *18*(4), 453–468. https://doi.org/10.1108/CI-02-2018-0010