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Improving small area population projections

From the AHURI Inquiry: Inquiry into projecting Australia's urban and regional futures: population dynamics, regional mobility and planning responses

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AHURI

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AHURI's mission is to deliver high quality research that influences policy development and practice change to improve the housing and urban environments of all Australians.

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Acronyms and abbreviations used in this report

AHURI	Australian Housing and Urban Research Institute Limited
ABS	Australian Bureau of Statistics
ARIMA	Autoregressive Integrated Moving Average
ERP	Estimated Resident Population
GCCSA	Greater Capital City Statistical Areas
IPC	Indicative Planning Council
LGA	Local Government Areas
MAPE	Mean absolute per cent error
Median APE	Median absolute per cent error
PE	Per cent error
SA1	Statistical Area Level 1
SA2	Statistical Area Level 2
SA3	Statistical Area Level 3
SA4	Statistical Area Level 4
SME	Standard mean error

Executive summary

Key points

- Demographic factors are vital components to understanding future population, economic, environmental and social change.
- Projections are utilised in a broad range of ways, but the scale of decision-making tends to dictate the type and source of projection used.
- Projection accuracy degrades over time, with five to 10 years generally regarded as the usable timeframe.
- To improve decision-making there is a need to make error and uncertainty in the available projections more explicit.
- The report highlights the need, not for a single solution, but many solutions (top-down and bottom-up), to meet the very different requirements of a diversity of users.
- Overall this work reinforces the need for consistency, including agreed methods, definitions, shared datasets, accepted and explicit error boundaries.
- The use and creation of projections in Australia was more conservative than anticipated – with more limited uptake of novel datasets than we expected (such as the Geocoded National Address File (GNAF)).
- This research has highlighted a shared and generous concern. Across government, policy and industry stakeholders there is a need to work together on improving the projection landscape in Australia.

Key findings

The key to successful planning is the utilisation of good information. Quality population projections provide us with the ability to plan for the short and long term, while making explicit the underlying assumptions, data, and potential for error (Wilson and Rees 2005; Rayer 2008). Demographic factors are vital components to understanding future population, economic, environmental and social change.

Data describing births, deaths, migration flows (international, interstate and intrastate) and land availability form the basis of most population projection methodologies (Wilson and Rees 2005). Typically, these variables are drawn from the preceding five to 10 years of data, a practice often referred to as 'walking backwards into the future' (Klosterman 2013). Other components that can influence (both positively and negatively) the assumptions applied to population projections include (but are not limited to) proposed land developments, building infrastructure availability and capacities (such as power, water, and so on), perceived job and educational opportunities, and broader housing and population targets set by state and territory governments.

Several different population projection methodologies are utilised by the Australian Bureau of Statistics (ABS) and state and territory planning authorities, upon whose data local government and other public agencies depend (Wilson 2012). However, there is a paucity of recent published evidence on how these projections have been developed and how their associated assumptions compare over time with actual population change. Existing Australian reviews acknowledge that error margins increase with distance from real data (Wilson and Rowe 2011; Wilson 2015; Wilson 2016). Consequently, while available population projections may provide a long term view of 20—50 years into the future, the reliable time span is generally five to 10 years. This means that even if a long term view is provided, projections will still usually be updated at least every five years in line with the national Census of Population and Housing (and more often if a significant change is evident).

Local government planning and resourcing depend on accurate population data. Therefore, concerns are often expressed over discrepancies between projections and actual outcomes, or the transparency and accuracy of baseline assumptions. As highlighted in recent AHURI research, these concerns are particularly evident in local government areas experiencing rapid growth, such as those in metropolitan greenfield locations where population increases can lead to infrastructure lags (Sarkar, Moylan et al. 2021). Concerns about the accuracy of population projections have also long been expressed by local councils in non-metropolitan regions. In particular, those with smaller base communities, where transitory peaks and ongoing churns associated with visitors or fly-in/fly-out workers can be difficult to capture via traditional methods and data sources (Hugo and Harris 2013; Hugo, Barrie et al. 2019).

Although population projections have an established role in policy and planning, the substantial shifts in migration, population and mobility brought about by the COVID-19 pandemic have initiated a widespread rethink on the reliability, accuracy, scale and applicability of the population projections that inform policy.

Our aim in this report is to critically assess the population projection resources available to Australian decision-makers and planners in this time of change, examining:

- how projections are used to inform policy decision-making
- the types of decision-making supported by current projection datasets
- the relative trade-offs made around reliability and certainty
- what opportunities exist for methodological and data improvement, and future innovation.

In order for future policy to be based on solid and reliable estimates of how many and what people are where in Australia, this project suggests that we prioritise:

- consistent approaches and shared information sources
- good quality, reliable and timely data

- better methods (especially for estimating small area populations)
- a more widespread understanding of error and accuracy.

Overall, this work reinforces the need for consistency, including agreed methods, definitions, shared datasets, and accepted and explicit error boundaries.

Policy development options

While the need for consistency is reinforced in this report, we also acknowledge and highlight the diverse uses (and users) of population projections. This means that one package of projections cannot meet the diversity of applications required. Different scales, error tolerances, and foundational data, for example, are necessary to meet the decision-making needs of local governments versus Australian Government agencies. Perhaps a less expected finding of this project was the value placed on more responsive, detailed bottom-up generated estimates. Looking more broadly to the characterisation of what projections Australia should have in its decision-making support armoury, there is a place for strong top-down projections, and more flexible and targeted bottom-up ones.

The data landscape for population projections has almost certainly changed in recent years, and we should be considerate of these changes in our future planning. Traditionally the data components of projections were tied to national Censuses and large-scale agency collections. Recent (and potential) developments in technology have almost certainly expanded the depth and diversity of data that can form the basis of reliable population projections. Many of our expert panel participants, for example, referred to the usefulness of a diversity of residential dwelling data, such as from sales, land development applications or the planning system.

Finally, projections should be seen as well-informed estimates of what our population will look like in future, and so it is no surprise that considerations of error are an important finding of this work. In terms of future policy, a certain amount of 'error tolerance' in projections is implicit. However, better decision-making comes from making the error more explicit, and therefore a component of the decision process.

This project has also revealed a population projection landscape in Australia that is slightly different to the one we anticipated. Firstly, it is a more conservative landscape than anticipated, with a very limited uptake of novel datasets (such as GNAF, Geoscape, and the Survey of Tourist Accommodation) than expected. Secondly, this research responded to an assumption posed by the policy community, that there was the potential for a one-size-fits-all solution to undertaking projections better in Australia. Our assumptions as researchers, also reflected that assumption in the design of the project. What clearly came through, however, was the need, not for a single solution, but many solutions to meet the very different requirements of a diversity of users, who are using projections for a very wide set of decision-making purposes.

The study

Given the value of population projections to inform the future housing, infrastructure and service needs of urban and regional communities, it is important to review the methods and data sources used by planning authorities across Australia. This project is one of four in the *Inquiry into projecting Australia's urban and regional futures; population dynamics, regional mobility, and planning responses*, which address this need by responding to the overall Inquiry research question:

How effective are local area population projections; and how can a best practice, nationally consistent program of local area population projections be implemented?

Within the broader Inquiry, this project focuses on understanding, and critically assessing, the population projection resources available to Australian decision-makers and planners. It is structured around four Research Questions:

1. How valid are the Australian population projections examined in this study – when considering spatial scales, time spans, strengths and weaknesses, and metropolitan and rural differentiations?
2. What are the opportunities for future data components for pragmatic, more responsive, tailored, or more accessible population projections (housing supply, international migration proxies, and so on)?
3. How do stakeholders use population projections to inform decision-making?
4. What recommendations should be made for a national program for local area population projections, and how could these recommendations be implemented?

This project supports the broader Inquiry's aim by offering a critical review of population projection modelling in Australia. Informed by consultations with key stakeholders from Australian Government, state, territory and local agencies, as well as private sector experts, the project will assess existing and new options for a nationally consistent approach to small area population projections and planning.

1. Introduction

- **Demographic factors are vital components to understanding future population, economic, environmental and social change.**
- **Data on births, deaths, migration (international, interstate and intrastate) and land availability forms the basis of the majority of population projection methodologies.**
- **There is a paucity of recent published evidence on how population projections have been developed, and how their associated assumptions compare over time with actual population change.**
- **It is critical to recalibrate the methods and data sources used by planning authorities across Australia to better project population changes.**
- **While population projections are typically 20—50 years into the future, the realistic time span for reliable use is five to 10 years.**

The key to successful planning is the utilisation of good information. Quality population projections provide us with the ability to plan for the short and long term, while making explicit the underlying assumptions, data, and potential for error (Wilson and Rees 2005; Rayer 2008). Demographic factors are vital components to understanding future population, economic, environmental and social change.

Data describing births, deaths, migration flows (international, interstate and intrastate) and land availability form the basis of most population projection methodologies (Wilson and Rees 2005). Typically, these variables are drawn from the preceding five to 10 years of data, a practice often referred to as 'walking backwards into the future' (Klosterman 2013). Other components that can influence (both positively and negatively) the assumptions applied to population projections include (but are not limited to) proposed land developments, building infrastructure availability and capacities (power, water and so on), perceived job and educational opportunities, and broader housing and population targets set by state and territory governments.

Several different population projection methodologies are utilised by the Australian Bureau of Statistics (ABS) and state and territory planning authorities, upon whose data local government and other public agencies depend (Wilson 2012). However, there is a paucity of recently published evidence on how these projections have been developed and how their associated assumptions compare over time with actual population change. Existing Australian reviews acknowledge that error margins increase with distance from real data (Wilson and Rowe 2011; Wilson 2015; Wilson 2016). Consequently, while available population projections may provide a long term view of 20—50 years into the future, the reliable time span is generally five to 10 years. This means that even if a long term view is provided, projections will still usually be updated at least every five years in line with the national Census of Population and Housing (and more often if a significant change is evident).

Local government planning and resourcing depend on accurate population data. Therefore, concerns are often expressed over discrepancies between projections and actual outcomes, or the transparency and accuracy of baseline assumptions. As highlighted in recent AHURI research, these concerns are particularly evident in local government areas experiencing rapid growth, such as those in metropolitan greenfield locations where population increases can lead to infrastructure lags (Sarkar, Moylan et al. 2021). Concerns about the accuracy of population projections have also long been expressed by local councils in non-metropolitan regions. In particular, those with smaller base communities, where transitory peaks and ongoing churns associated with visitors or fly-in/fly-out workers can be difficult to capture via traditional methods and data sources (Hugo and Harris 2013; Hugo, Barrie et al. 2019).

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1.1 Policy context

Understanding both the broad and fine-grained details of population size, distribution and composition is crucial to the actions of government and industry. Population projections enable planners to look to the future and estimate, based on current circumstance, who, where, and how many Australians will need housing, transport, feeding and assisting.

Projections are an important requirement for planning and decision-making across jurisdictions. Population projections underlie policy in various direct and indirect ways. Quality projections enable governments to 'better align Australia's infrastructure planning, housing, and service delivery' (Chalmers 2022: iv) and provide knowledge to make decisions about the future (Forecast.id 2023). Furthermore, quality projections allow state and territory governments to plan for land use and development, infrastructure, services and programs (e.g. Victorian Department of Environment, Land, Water and Planning 2019).

Although population projections have an established role in policy and planning, the substantial shifts in migration, population and mobility brought about by the COVID-19 pandemic have initiated a widespread rethink on the reliability, accuracy, scale and applicability of the population projections that inform policy. The COVID-19 pandemic significantly altered international, interstate and intrastate movement, and was an unexpected but dramatic influence on the traditionally predictable flows of population into and out of Australia.

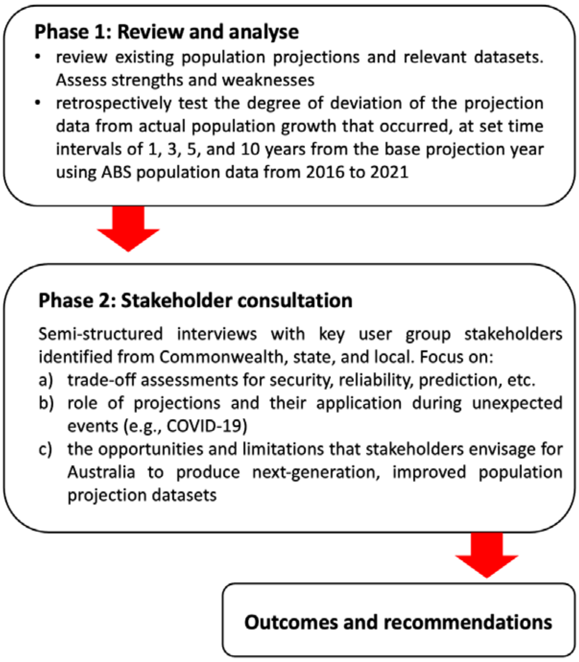
Our aim in this report is to critically assess the population projection resources available to Australian decision-makers and planners in this time of change, examining:

- how projections are used to inform policy decision-making
- the types of decision-making supported by current projection datasets
- the relative trade-offs made around reliability and certainty
- what opportunities exist for methodological and data improvement, and future innovation.

1.2 Research methods

This project combines quantitative spatial and statistical analysis, with qualitative semi-structured interviews and a research evidence review.

Figure 1: Improving small area population projections research phases



Source: Authors

Phase 1: Examine the available population projection datasets, assessing the comparative characteristics, strengths and weaknesses, including underlying datasets. New and emerging datasets are considered alongside the key components of population projections (demographic change, mobility, and urban development and change).

Analyse key projection datasets to test the degree of deviation of the projection data from actual population growth from the base projection year using ABS population data from 2016 to 2021.

Phase 2: Undertake consultations with Australian Government, state and territory and local jurisdictions, and private organisations tasked with the development and use of population projections. The consultation explored the ways that projections are applied for decision-making purposes, comprehension of the degree of reliance placed on these projections, and whether there are disparities between the reliance attributed to projections by those calculating the data.

Finally, based on the analysis and consultations, we will make recommendations for national small area projections that are amenable to the needs and requirements of local, state and territory and Australian governments. Recommendations will include suggested implementation strategies which can be applied locally, regionally and nationally.

2. Projection methods and resources

- **As there is no agreement across the projection agencies on the provision of small area projections, they differ on a state-by-state basis and may not be available in some jurisdictions.**
- **Projection accuracy degrades over time, with five to 10 years generally regarded as the usable timeframe.**
- **Due to the demographic nature of most projections, smaller geography projections are not supported by state projection agencies.**
- **Five-year projections are generally reliable, although reliability was most variable for very young and young adult age cohorts.**

The terms 'forecasts' and 'projections' are often used interchangeably. The ABS defines forecasts, or estimations, as a 'more likely' outcome of the future population, whereas projections indicate a future value if the set of underlying assumptions were to occur (ABS 2022). The same holds true for projection datasets, which often include several series ranging from low to high probability (the middle of which is considered most likely, or the 'forecast'). Two different probability series could include (a) no net overseas migration, versus (b) a certain value or percentage of overseas migration for the coming years. For example, the ABS publishes high, medium, and low projection series, of which, the low projection series is based on different, lower assumptions of fertility, mortality and migration.

Projections can range from the national scale to small areas. For Australia, the geographical hierarchy progresses from the national to the state level, and then to a diverse range of statistically and administratively defined sub-regional geographies. While statistical area definitions by the ABS largely follow the functional-social-economic definition of small areas, and echo more reliably how populations are distributed, administrative area definitions are also important as most policy and decision-making is performed at the administratively defined levels. Thus, projections are calculated for Greater Capital City Statistical Areas (GCCSA), Local Government Areas (LGAs), postcodes and suburbs, and ABS Statistical Area Levels 4 to 1 (SA4 to SA1). The LGA and SA2 levels are of primary importance as other data, such as the data from all Census variables, are most completely available at the SA2 level, and the LGAs are the seat of decision-making at the local government level.

Another issue that is important in population projecting is the concept of a top-down or bottom-up model. A top-down model is one where larger spatial units are used to control the smaller area projections. For example, the Australia projection is used as a control total for the state and territory projections and, in turn, these are used to control the SA4 projections. In these cases, the total population for Australia is used to constrain the sum of the state and territory projections and so on through the smaller spatial units. In this modelling, the sum of the parts can never exceed the total of the controlling spatial unit. In the bottom-up model, the smaller area projections can be summed to form the larger spatial units. There are arguments to support both examples, the demographic inputs for larger spatial units (Australia and States for example) are better and therefore more reliable, whereas as the population (and spatial units) gets smaller, demographic data may be less reliable due to small numbers or missing data. However, small area projections will have better input of local policy, land availability and development data, which in turn provides a realistic base for population growth (demography may overestimate growth trends when the land development driving historic growth is no longer available). Both are valid approaches, and a hybrid model that incorporates top-down and bottom-up projections may well provide a better outcome.

Across Australia, many different agencies and organisations are involved in the preparation of population projections. The following table (Table 1) summarises key providers, their respective sector (public or private), the projection type they produce, and the available spatial scales.

Table 1: Summary of organisations and agencies that provide population projections

Agency or organisation	Sector	Projection Type	Spatial scale
Australian Bureau of Statistics, National level	Public	Population projections, national level	National
Australian Bureau of Statistics, National, state and territory population	Public	Statistics about the population and components of change (births, deaths, migration) for Australia and its states and territories	National and state and territory
Australian Bureau of Statistics, Regional Population Methodology	Public	Projections at the SA2 and LGA levels	Small area (SA2, LGA)
Australian Government Centre for Population Projections	Public	Population projections at the national, state and territory, and capital city and balance of state (using the Australian Bureau of Statistics' Greater Capital City Statistical Area definitions) levels	Various
NSW Department of Planning and Environment	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
VIC State Department of Planning	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
Government of WA	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
QLD Government, QLD Treasury	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
SA Government	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
NT Government	Public	Population projections at the state, rest of state, GMR, LGA and SA2 levels	Various
REMPLAN	Private	Identifying local drivers of demographic and housing change to model future scenarios over a 20-year period	Small area projections, LGA, sub-LGA
Forecast.id	Private	Population forecasts, projections, and demographic analytics	Australia, states and territories, LGA and sub-LGA small areas

Source: Authors

2.1 Main projections methods

The literature on population projections is vast, and many standard methods are employed including simple extrapolations, more refined probabilistic methods, social and time-series analysis methods, and detailed component-based methods (Wilson 2005). This section presents an overview of the standard methods identified from international and Australian literature considering evaluations of forecasts versus projections, the inclusion of probabilistic methods into traditional models, inclusions of projections of migrations into traditional models, scenario modelling (or 'what-if' scenarios), and additional variables and dimensions (in addition to age, sex or region). We will exclude the discussion of some models such as Autoregressive Integrated Moving Average (ARIMA) models, regression methods and microsimulation methods, which were reported in the literature to have had poor performance and low reliability and accuracy (Wilson 2011).

2.1.1 The cohort component method

The cohort component method is arguably the most widely used projection method both nationally and internationally, and is the preferred method for national, state and regional level projections. While the set of methods under the head of cohort-component method is very large, and many variations are applied, sensitive to the local context in which they are being applied, and for the specific purpose for which they are being applied, the method can be summarised as having two major components: (a) the whole population of an area at a given time is divided into cohorts, and (b) demographic components of change, fertility, mortality and migration are modelled over these cohorts. A set of equations can be used to describe the method:

$$P_{t+n} = P_{t,t+n} + B_{(t,t+n)} + M_{t,t+n},$$

Where P_{t+n} is the projected population for time period $(t+n)$, where usually, n is five years. $P_{t,t+n}$ then represents the survived population upto this time from five years ago, $B_{t,t+n}$ represents the births in this time period, and $M_{t,t+n}$ represents the total net migration into the area in this time period. Computing the survived population and births requires assumptions on fertility, survival and mortality rates, and computing net migration requires either high quality data on actual migration numbers or assumptions on migration rates. The model is computed for five year cohorts separately for male and female populations. For example, for every age cohort other than the 0—5 cohort (where births occur),

$$P^x_{s,t+n} = P^x_{s,t,t+n} + M^x_{s,t,t+n},$$

$P^x_{s,t+n}$ represents the projected population for age cohort x for sex s (male or female), and takes into account the surviving population from the previous five year cohort $P^x_{s,t,t+n}$ and the number of net migrations in age cohort x for sex s. A frequent barrier is that migration estimates are difficult to define for finer demographic groupings (such as migrations in the 20—25 age cohort of females), and therefore, each component in the above model must be modelled carefully and consider the context of application. For full details of methods, the reader is referred to the large body of literature by Wilson (Wilson 2005; 2011; 2012; 2015; 2016; 2022).

The method is used by the ABS at the national level, and by the State Planning Departments at state and sub-state spatial units (SA3, SA2, Local Government Area levels) in modified or refined forms. In the cohort component method, assumptions are made on rates of demographic components of change: the fertility, mortality and migration of different age-based cohorts of the population, which are then applied to a base population for each sex by age (single year, cohorts), and advanced year by year. This process is repeated for each year nationally, and for each spatial unit (state and territory, each capital city, and rest-of-state geographic region within each state and territory).

The ABS applies this method for national and state projections, and the results for each state and territory by year are adjusted to the national level figures, and similarly the outcomes from the capital city and rest-of-state regions are adjusted to the respective state and territory figures (total and age and sex).

The strength of this approach is the detailed use of demographic data and detailed age and sex. While this is its strength, it is also a weakness because it does not include details on land and dwellings, and while at the very broad scale this has less influence, as the spatial unit decreases in size the need for land constraints increases. As stated by Bell et al. (1997), at the regional level, demography drives the housing market, but at the local level it is the housing stock that shapes the demography. Consequently, what is a strength at the small scale is a weakness at the large scale as land availability and dwelling type are significant constraints on what can occur. Historic rates of change in demography can project beyond an area's carrying capacity if not constrained by land and housing availability. This is why most of the states have developed mixed models that use both the cohort component model and varying degrees of land availability.

All state and territory governments employ the cohort component method, like the ABS, for state, territory and regional (large area) projections. A further suite of sub-regional projection methods are then employed to project small area populations at the SA4, SA3, SA2, SA1 and LGA levels. Of these, the SA2 and LGA projections are the most relevant (as discussed above).

For sub-regional areas, a range of cohort-component models can be applied. These differ in how they model migration and the types of migration variables that they use. Commonly used variables include net migration numbers, net migration rates, out-migration and in-migration rates and shares, and bi-regional or multi-regional migration flows. A specific difficulty is that when age-based cohorts are considered, there may be poor data available for these variables, considering that the number of origin-destination pairs increase along with sparsity and instability of data, especially for small areas.

Within the family of component methods, there are simple component methods, which project total populations in terms of aggregate demographic components of change without age and sex breakdown. Although this is a simple model, it can perform well for total population projections as it is data sparse and can overcome issues with separating complex migration patterns. However, while this simplicity can be attractive for generating total populations over time, it could also be considered a negative; it does not detail the age and sex distributions that are so important for the planning of services and facilities.

Another variation is shortcut cohort methods. These are similar to cohort component methods, but aggregate the demographic components of change. While these methods reliably address the change of population in cohorts, they are not ideal for the aggregation of mortality, or for modelling migration into net rates. There is added risk of generating run-away growth in some cohorts. While conceptually simple to apply, the methods can require many adjustments, making their generality of applications poor.

A special section of the cohort-component method is how migration is modelled and projected. Cohort component methods require assumptions to be made about future fertility, mortality and migration. Of these, fertility and mortality rates may be relatively stable over longer periods of time, but migration is the most volatile and most affected by policy, social, economic and other kinds of unforeseen events (such as the recent impacts of large-scale work from home during COVID-19, which resulted in large rates of out-migration from larger metropolitan areas to smaller regional towns). Thus, a suite of methods exists to project migration numbers and rates and flows between pairs of origins and destinations. These may include conventional migration rates and probabilities, or rates and probabilities with some change assumptions in-built, net in/out migration to/from an area, the share of migration to/from a small area in relationship to a larger area, ratios of rates, and building from these basic variables, a range of other more complex mathematical or functional forms.

If good data on migration are available, then these can be valuable and reliable inputs to cohort component models. However, generally, the data requirements are too high, and the mathematical applicability too complex. For example, consider that actual data on migration flows is only available once every five-year census period, and that it is difficult (or even impossible) to find records of any intermediate volatility of movement occurring between this time.

Despite some known issues, the cohort component model is still the most widely applied projection method. It requires the modeller to delve into what has happened with birth rates (both total and age-specific fertility) and survival rates, as well as the complexity of overseas, interstate and intrastate migration flows. The cohort component method prompts modellers to question what could happen to these variables over time and space, and to consider what these trends tell us about population change now and in the future.

2.1.2 Trend exploration methods

Trend exploration methods are simple mathematical functions that extend a trend observed over a specified base period into the future. This method uses polynomial forms such as linear, quadratic, cubic functions, power functions, hyperbolic functions, or exponential functions, and then fits these data to the chosen functional form. While this family of methods is easy to use and requires minimal inputs (since only past populations and some upper/lower constraints are needed), the outcomes will be more or less reliable, and this is often a function of the type and level of change used to project the population.

An area experiencing very little population change over time might perform quite well with this method, whereas an area experiencing significant growth or decline may perform very poorly. However, in areas with little absolute population change over time this method provides no information on the changes occurring to the age sex profiles. Consequently, while they might be useful in some circumstances, trend exploration methods are typically unreliable unless used in conjunction with cohort component models.

2.1.3 Comparative methods, or ratio-share models

Comparative methods, or ratio-share models, use larger area projections to create smaller, sub-regional area projections using relationships such as the share of population, the share of growth, or the growth difference. Share of population methods simply assign a portion of the larger region's population to the smaller component areas.

Similarly, share of growth models add a share of the parent region's projected population growth to the jump-off year population of the local area. Growth difference models assume a specified difference in growth between a local area and its parent region, so apply this difference to a past year to project into the future. More complex versions of this method also apply shares across the age and sex variables of component areas, while also adjusting the share over time to reflect changing circumstances.

These models are often used in conjunction with a top-down cohort model, and bottom-up view of land availability. Outputs of comparative or ratio-share models are generally more useful in the short term.

2.1.4 Economic base methods

Economic base methods use exogenous projections of labour and employment numbers (or other economic indicators) to derive population projections by applying a population/employment ratio of a local area to a total employment number. They assume that economic change is a primary driver of demographic and social change, and are most frequently employed in circumstances where the introduction of a large-scale project is likely to result in large socio-economic and demographic shifts in the population.

These methods are particularly relevant for resource driven areas (such as mining in Western Australia), where the economic sector dominates all other sectors. As a result, these methods may be most appropriate for highly specialised areas. However, these methods are inappropriate for more diverse areas where other factors such as housing, family requirements of education or leisure, climate and other amenity driven growth or changing commuting patterns (such as the relationships of satellite towns to metropolitan areas) are important.

2.1.5 Housing unit methods

Housing unit methods project total population based on the approvals, completions, demolitions, and projections of the number of new and existing stock of housing units in an area. These calculations include estimations, or future scenarios, of occupancy rates (proportions of units occupied on a usual residence basis), vacancy rates (proportions of units not occupied on a usual residence basis), and other factors such as average household size.

One of the interesting aspects of the housing unit methods are that they can consider specific local area characteristics and help generate future scenarios and assumptions used in modelling population change by assuming different projections of housing units and the other variables mentioned above. For example, the housing unit method can include factors such as density, morphology and different housing types, amounts of residential construction activity, temporary or holiday home use rates, and other housing market and local factors. Although there are no direct models of population change processes built into these methods, when used in conjunction with cohort component models, housing unit methods are particularly appropriate for local area projections.

While housing unit methods are an excellent input to small area forecasting, one of the major issues is that, while data rich, accessing some key data can be difficult and inconsistent across local government areas, states and territories. One of the most difficult data components to incorporate is dwelling loss. While data on new builds and conversions is available, dwelling demolitions and vacancy rates are very difficult to source consistently.

This method is one that would benefit from the reintroduction of a monitoring group, such as the Indicative Planning Council (IPC) for the Planning Industry which provided many of these datasets in the past. The IPC brought together the public and private sector to share data for short term planning purposes, typically over a moving five-year horizon. Even with these difficulties, this model is a vital input into the forecast process and is used by most state and territory governments and a few private organisations modelling population and housing change.

2.1.6 Land use allocation methods

Land use allocation methods mimic the land development process and employ independent projections of dwelling units for a larger area, distributing these over smaller local areas, based on each small area's probability of development in each projection interval. This probability is affected by factors such as the amount of available land, land zoning regulations, distance from employment nodes, transportation connectivity and availability, access to schools and retail facilities, and adjacency to existing development.

These share a similarity with the housing unit methods with the use of local characteristics, depending on data availability, and thus the resulting projections can be very specific to the local area being forecasted. Land use allocation models mimic the land development process so are not a population projection method per se, but when combined with housing unit and cohort component models they provide conceptually more appropriate projections.

One of the primary limitations for both the land allocation and the housing unit methods (as indicated above) is that they are data hungry and highly dependent on the quality and scale of the available data.

2.1.7 Averaged and integrated projections

The outputs from the various projection methods described in this chapter can be averaged into single, integrated projections. The assumption is that producing a smoothed average from multiple methods could result in a lower error in practice, and therefore reduce the variance introduced from the different projection methods.

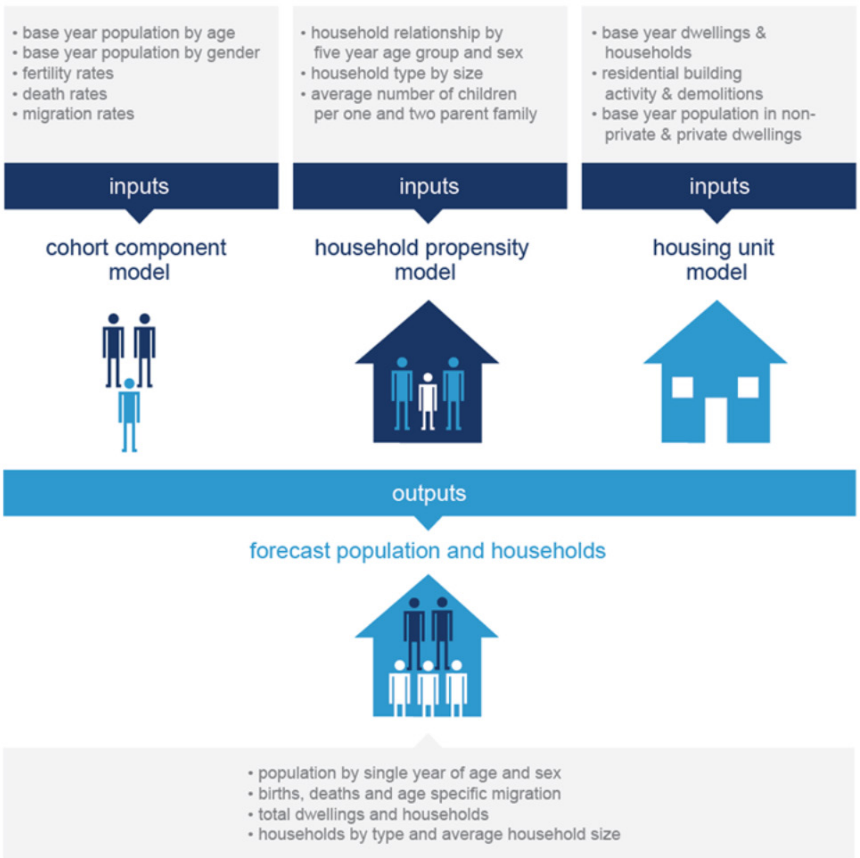
However, in an integrated approach, the projections from the individual input models need to be of high accuracy and reliability as if the errors in individual forecasts were too low or too high, a smoothed average would include this range of errors. Averaged and integrated projections can also be time consuming, as they require multiple models to be run separately to produce a single average.

2.1.8 Small area forecasting models

As indicated above, integrated models are principally used by the private sector organisation. Forecast.id are a key developer of integrated projections for small areas, and currently provide projections to 136 local governments in Australia. While this is a more conceptually robust approach and considers local conditions that might otherwise be missed using a pure demographic model, it does take more time and resources to project.

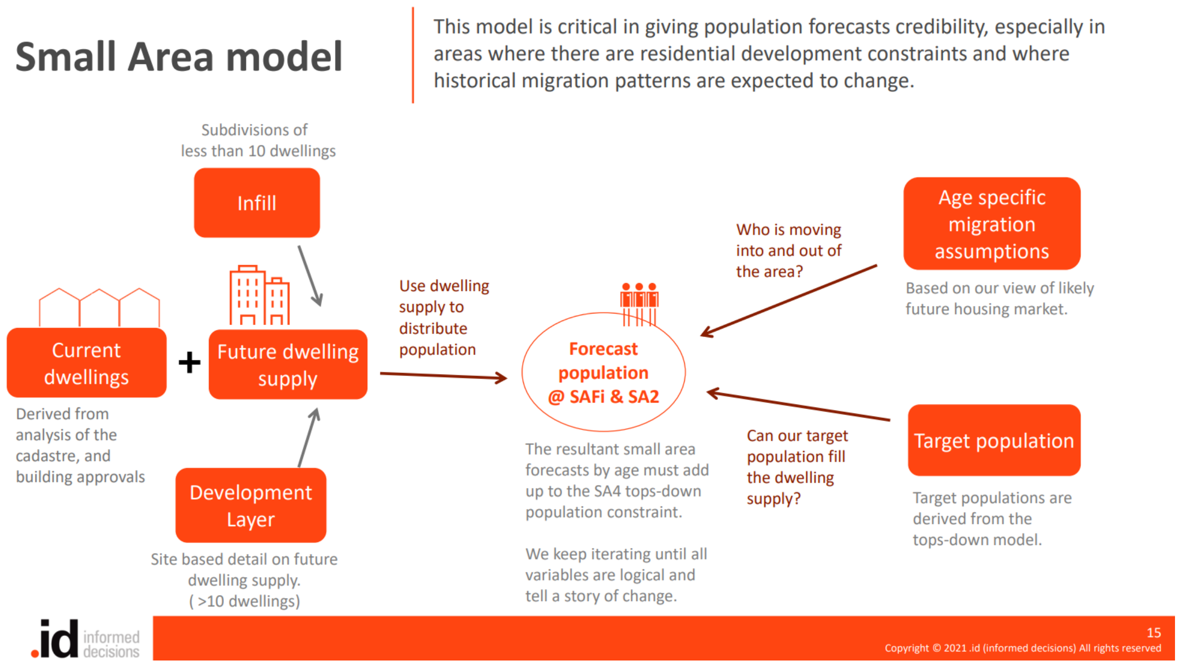
It is perhaps best to describe this approach as a top-down cohort model, informed by a bottom-up land/housing constraint model. Fundamentally, the model is a bottom-up approach with assumptions built from local data sources (correspondingly, a top-down utilises larger, whole of population data). Each assumption is based on local demography or local residential development (Figure 2). It is the combination of these three models (cohort component, household propensity and housing unit) that allow both the demography and local conditions to drive small area forecast results, and inputs on residential development constrain the population to accord with availability of land and housing (Figure 2). In addition to the detailed model inputs, the forecasts are monitored annually and updated if required.

Figure 2: Forecast.id Local government forecasting diagram



Source: https://forecast.id.com.au/adelaide/forecast-modelling-process (accessed 5 October 2022)

Figure 3: Forecast.id small area model components diagram



Source: https://f.hubspotusercontent10.net/hubfs/320463/SAFi/.id%20SAFi%20methodology.pdf (accessed 5 October 2022)

2.2 Recent developments in small area population projection in an international context

The standard approaches outlined above are not specific to Australia; they also apply in an international context (Wilson 2005; Wilson 2022). In comparison to national and state level population projections, the techniques and methods applied in small area population projections are relatively modest (Wilson 2022). Areas of future development in small area projections include more work on model averaging and combining, developing new forecasting methods for situations that current models cannot handle, quantifying uncertainty, exploring methodologies such as machine learning and spatial statistics, creating user-friendly tools for practitioners, and understanding more about how forecasts are used (Wilson 2022).

Of the above mentioned key areas, a development gaining specific attention in academic research is the use of using novel data sources (such as satellite imagery) and novel methods (such as machine learning, specifically deep learning methods) to model population projections, mobility and migration (Robinson, Hohman and Dilkina 2017; Robinson and Dilkina 2018). However, these are still in the development stage for even large area modelling, and there is some evidence for developing population estimates at the regional scale (Hu et al. 2019). Extending and testing machine learning methods for small area population projections is an extremely recent development, and still in its early stages (Grossman et al. 2022).

Within the national bureaus of census, most developed economies (such as the United States, Canada and the United Kingdom) resort to the standard methods and techniques reported in this work. For example, the United Kingdom, England, Scotland, Ireland and Wales currently use the standard demographic methodologies (Office of National Statistics 2020a; 2020b). However, there is some evidence that simulation approaches and advanced statistical and econometric techniques (such as Bayesian and bootstrapping methods, which overlap hugely with modern machine learning methods) are being tested and evaluated (US Census Bureau 2022).

2.3 Assessing accuracy

Projection and forecasting accuracy receive considerable attention in the literature, particularly how best to measure accuracy. The function of projections and forecasts is to provide a view of the total population and age-sex structure that will exist in the future. The models commonly used to project and forecast populations were outlined in the previous chapter. The assumptions used to produce future populations were identified largely to be demographic, land and housing, economic and social inputs. These assumptions form the basis of all population projections, and if well formulated, can result in better matches to actual population outcomes over time. However, circumstances such as the recent COVID-19 pandemic can produce unforeseen results, resulting in significant variations between the projected population and actual outcomes. The COVID-19 pandemic is an excellent example of an unforeseen event that can change both the total count and distribution of the future population. In this research, the population outcomes varied from all the of the projections we analysed, yet the errors were still within a range of what was considered acceptable.

As reported by Bell (1992), prediction accuracy may not be the only purpose for population projections. The concept of using the projection to drive change and generate a desired or target population was proposed by Moen (1984). Isserman (1984) classified projections or forecasts into four groups:

1. baseline projections that extrapolate current trends and illustrate their impact on the size and composition of the population
2. pure forecasts that indicate the most likely future in the absence of unanticipated events
3. contingency forecasts that indicate possible futures under alternative hypothetical (but plausible) assumptions
4. normative forecasts that describe a desired future (Bell 1992).

Whatever the purpose for projections and forecasts, the concept of measuring their accuracy has resulted in a number of papers proposing different approaches. It would be safe to suggest that there is no gold standard for measuring accuracy. However, there are some metrics worth noting. These include the per cent error (PE), standard mean error (SME), mean absolute per cent error (MAPE), median absolute per cent error (median APE), and M estimator (Bell 1992; Wilson and Rowe 2011; Rayer 2007; Chi and Wang 2019; Baker et al. 2020; Tayman et al. 2010). The most often cited are the PE and MAPE.

However, there has been some criticism of the MAPE as it can be biased by outliers and skewed, thus overstating the error (Tayman, Swanson and Barr 1999). Despite this criticism, these two measures are easy to interpret and have been used for the purposes of this review to measure the accuracy of a range of national, state and sub-state projections. In all cases, the per cent error has been reported as the absolute per cent, and the direction of error has not been included. Wilson and Rowe (2011) proposed a classification of within 10 per cent as small error, 10—20 per cent as a moderate error, and greater than 20 per cent as a large error. These classifications were used in this review.

It is a function of projections and forecasts to act not only as a predictive tool, but as a means to consider and alter future outcomes. Results can be judged on the basis that they project future populations within a narrow percentage 'small error' band (+-10%), or alternatively, how they were used as a catalyst for strategic planning and policy change. An example of this is the much publicised notion proposed by the Australian Government to encourage a higher birth rate; "have one for mum, one for dad, and one for the country" (Costello 2002).

This section compares forecasts over a five-year period using 2017 (base) ABS population projections, and recently released 2021 ABS Estimated Resident Population (ERP). The most recent projection timeframe has been chosen as this best represents the time these projections would be used for planning and policy considerations. While earlier (2011) releases also project to 2021, it was considered unfair to incorporate these as the usefulness of projections are known to diminish with time. More distant populations are indicative of what may occur given the assumptions used are held true over the whole period, and as this is very unlikely to occur, projections are typically rerun at least once (sometimes more) each intercensal period. Sensitivity testing or rebasing of the ERP is regularly undertaken by the ABS. Usefully for this project, rebasing of the ERP against newly collected Census data was undertaken recently. It suggests, for example, that ERP estimates for 2021 (pre-Census) align quite well with the Census count. On average, there was a –0.36 per cent difference. This, of course, varied across smaller spatial units such as LGAs. The largest differences between ERP estimate and the subsequent Census were in the smaller LGAs. We do note, however, some sizeable ERP corrections in Melbourne and Sydney. While there are many projections and forecast datasets available in Australia, this review has selected a sample that represents national and state projections calculated by the ABS and state planning agencies, sub-state projections prepared by state planning agencies (SA2), and local government forecasts prepared by private sector organisation Forecast.id.

To provide some context to the accuracy question, the following section details a case study comparison between the ABS 2021 ERP and various projections and forecasts.

2.4 ABS projection case study

The projection series assessed in this review uses the 2016 Census as a base, and projects population from 2017. The ABS traditionally releases three projection series: high, medium and low. The medium series (Series B) is considered the most likely outcome and is therefore used in this review. As stated, the base year was 2017 and the comparison point was 2021. The ABS provide a useful caveat on the use of these projections:

> *These projections are not predictions or forecasts. They are an assessment of what would happen to Australia's population if assumed levels of the components of population change (births, deaths and migration) were to occur between 2018 and 2066… [ABS 2022]*

Between 2017 and 2021, the ABS projection estimated a population increase of 1.7 million people. The 2021 Census population count (ERP) suggests that the actual increase was smaller. Table 2 provides a comparison broken down by state jurisdiction.

Table 2: 2021 ERP and Series B 2021 population, Australia and states

	ABS Series B	ABS ERP	Difference (Prj-ERP)	Absolute Percent Difference (Diff/ ERP*100)
New South Wales	8,410,280	8,093,815	-316,465	3.91
Victoria	6,904,453	6,548,040	-356,413	5.44
Queensland	5,275,645	5,217,653	-57,992	1.11
South Australia	1,773,127	1,803,192	30,065	1.67
Western Australia	2,688,994	2,749,864	60,870	2.21
Tasmania	540,012	567,909	27,897	4.91
Northern Territory	257,110	249,200	-7,910	3.17
Australian Capital Territory	446,983	453,558	6,575	1.45
Australia	26,301,274	25,688,079	-613,195	2.39

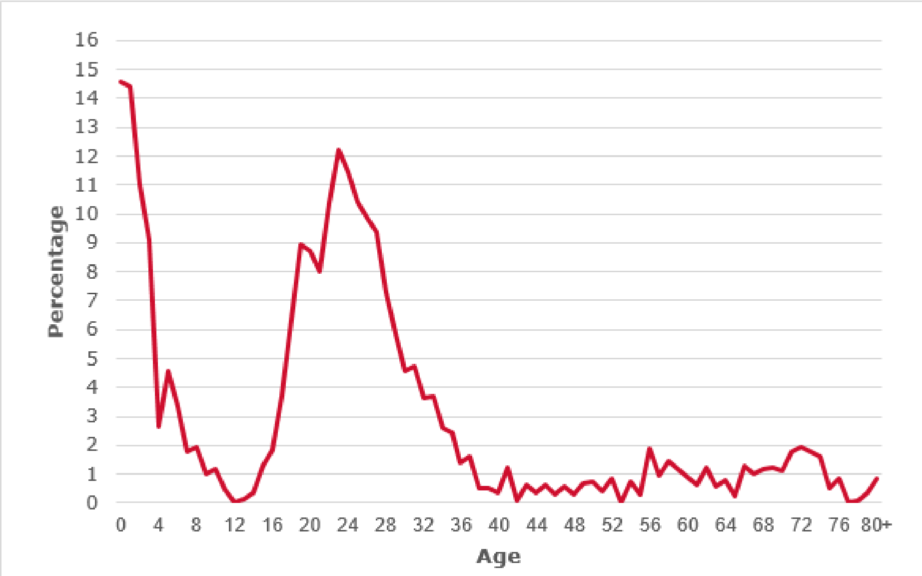
Source: Authors' own calculations using Australian Bureau of Statistics data

In absolute terms, there was an over-projection of just over 600,000 persons for the period, largely driven by New South Wales and Victoria. This could be seen as a function of the COVID-19 pandemic. The COVID-19 pandemic severely limited overseas migration for two of these years, and interstate and intrastate migration was limited. Many overseas residents returned, but this was limited by border closures. This was an unexpected but dramatic influence on the traditionally predictable flows of population into and out of Australia. Because population projections were undertaken before the pandemic, they were less than usually reliable during the period of border and travel restrictions. Interestingly, in some states and territories, COVID-19 restrictions resulted in an under-projection, while in others an over projection was evident. This is no doubt related to a combination of the relative scale of migrant arrivals to states, the porosity of state borders during COVID-19 restrictions, and traditional intrastate population flows.

The largest state difference between the projected and ABS ERP was 5.4 per cent in the Victoria, while the smallest difference was in Queensland with 1.1 per cent. The absolute per cent error across all spatial units was 2.39 per cent, well within a 10 per cent error band. Based on the classification these are all small errors. Acknowledging the uncertainty of the COVID-19 pandemic, the ABS projection can be deemed reliable overall.

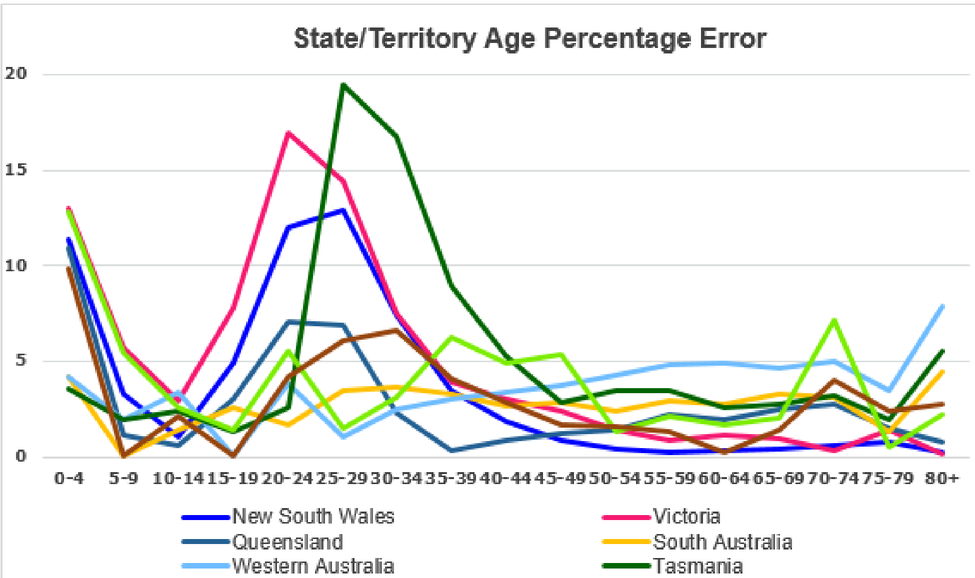
While at the population level these projections can be considered reliable, there were some significant variations in reliability by age cohort. Projections for very young people and the early working age cohort were also notably less reliable (Figure 4). Figure 4 details age cohort variation by state. It shows that New South Wales, Victoria and Tasmania have the least reliable population projections for young and early working age cohorts.

Figure 4: ABS age absolute percent error, Australia Series B, 2021



Source: Authors' own calculations using Australian Bureau of Statistics data

Figure 5: ABS Series B, 2021, absolute percent error by age (five-year cohorts), state and territory



Source: Authors' own calculations using Australian Bureau of Statistics data

Table 3: Mean error across all ages (single-year cohorts) by state

	Mean error across all ages (single-year cohorts)							
	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Mean	3.93	5.28	2.97	2.79	3.67	5.40	4.55	3.24
Min	0.01	0.07	0.03	0.61	0.18	0.29	0.19	0.10
Max	16.28	21.45	17.31	8.09	7.66	22.36	18.12	15.41
St Dev	4.83	5.68	3.26	1.29	1.42	5.55	3.67	3.25

Source: Authors' own calculations using Australian Bureau of Statistics data

This next section extends the analysis to explore how well ABS state projections performed against state agency projections. The next section compares the ABS Series B state projections with state agency projections (Table 4).

Table 4: ABS Series B state projection and state agency state projection comparison, 2021

	ABS ERP	ABS Series B	State Agency Median	Percent Difference	
				ABS Series B	State Agency
New South Wales	8,093,815	8,410,280	8,166,757	3.91	0.90
Victoria	6,548,040	6,904,453	6,861,925	5.44	4.79
Queensland	5,217,653	5,275,645	5,261,567	1.11	0.84
South Australia	1,803,192	1,773,127	1,778,840	-1.67	-1.35
Western Australia	2,749,864	2,688,994	2,720,280	-2.21	-1.08
Northern Territory	249,200	257,110	251,727	3.17	1.01
Mean				1.63	0.85
Min				-2.21	-1.35
Max				5.44	4.79
St Dev				3.10	2.20

Source: Authors' own calculations using Australian Bureau of Statistics data

Overall, the state agency generated projections performed better than the ABS, with the exception of Queensland. The projection error for Victoria was the largest for both the ABS and the state projection. However, in all cases, the projection error is classified as small (within 10%). It is also noteworthy that both the ABS and the South Australia and Western Australian planning agencies under projected the total population, and these were the only under projections; the rest were over projected.

By age, the ABS projected single year of age have been summed to the five-year age cohorts to provide a comparison with the state agency state and territory age projections (Table 5). The per cent difference (error) between the ABS ERP 2021 and the state agency age cohorts are generally all within the small error class. As has been noted before, the young age cohort (0—4) and the young adults (20—24 and 25—29) were the age cohorts with the largest error.

Across the different state agencies, the absolute per cent error was lowest for New South Wales and highest for Victoria. Within the age cohorts Victoria projected the largest errors, especially in the 0—4 through to the 25—29 age cohorts. However, as reported above with a few exceptions (Victoria) both the age and total populations were all small errors.

Table 5: Selected state agency age projections, per cent errors, 2021

Age	NSW	VIC	QLD	SA	WA	NT	Australia
0-4	0.97	8.20	10.00	2.86	6.68	9.93	10.28
5-9	0.98	4.94	1.09	0.24	-2.55	-0.96	2.53
10-14	-0.43	3.02	-0.68	-0.89	-3.92	-2.07	0.41
15-19	0.68	8.26	2.03	1.11	2.03	-2.28	4.37
20-24	2.85	11.93	2.73	-0.32	0.04	-0.40	10.20
25-29	3.91	13.31	3.03	-1.25	-1.72	0.49	8.53
30-34	2.00	7.02	1.28	-1.72	0.75	2.27	3.84
35-39	0.33	3.67	-0.71	-3.19	-0.60	2.27	1.31
40-44	-0.10	3.04	-0.56	-1.40	-2.05	1.50	0.52
45-49	-0.25	2.47	-0.60	-1.32	-0.73	5.45	-0.01
50-54	-0.08	1.65	-0.47	-1.50	-1.11	2.15	-0.57
55-59	-0.37	1.19	-0.76	-2.35	-1.88	1.44	-1.14
60-64	0.52	1.07	-0.26	-2.52	-2.74	-1.29	-0.82
65-69	0.87	0.87	-0.73	-3.26	-3.41	-2.80	-0.97
70-74	-0.13	0.29	-1.37	-3.57	-4.30	-8.05	-1.65
75-79	1.59	1.71	-0.64	-1.62	-2.86	0.56	-0.25
80+	1.74	1.84	-0.57	-1.93	-3.48	-6.37	-0.83
Total	0.90	4.79	0.84	-1.35	-1.08	1.01	2.39
Mean	1.04	4.40	1.58	1.80	2.33	2.85	2.81
Min	-0.43	0.29	-1.37	-3.57	-4.30	-8.05	-1.65
Max	3.91	13.31	10.00	2.86	6.68	9.93	10.28
St Dev	1.18	3.86	2.65	1.58	2.59	4.02	3.88

Source: Authors' own calculations using NSW, VIC, QLD, SA, WA, and NT State Government Projections, and Australian Bureau of Statistics data

It would be fair to conclude that the short-run results prepared by the state agencies performed well, particularly in the wake of the COVID-19 pandemic and changes to migration, which is often the most difficult demographic component to calculate when forming the projection assumptions.

The state agencies produce sub-state projection as well. Historically, the LGA was the main sub-state unit projected by state agencies. However, since the update of the ABS statistical geography, the state agencies calculate age projections for the SA2, SA3 and SA4. They also assess the error in the sub-state spatial units. Table 6 (below) provides the mean per cent error across all age cohorts across all sub-state units (specified in the table) for selected state agency projections. This differs from Table 3 as it is the mean difference calculated for each age cohort for each spatial unit. There are differences between the spatial units (SA2 and SA3) and South Australia used a custom age grouping that did not match the other states used for the comparison. The aim of this comparison is to understand how the per cent error differ from the state age groups in Table 2.

The mean difference in the younger age cohorts is also larger, as has been evident across most of the comparisons presented in this review. As was the case with the state total population, the Northern Territory is the worst performer, especially in the terminal age cohort where the difference between the ABS 2021 URP and the projection was 43 per cent. Overall, all three are in the small error class. However, Queensland and the Northern Territory are on the cusp of moderate. As the Northern Territory has a smaller overall population and the SA3 subunits are small low population units, when projected by age cohort is subject to the relationship highlighted in the literature regarding higher errors for smaller populations.

Table 6: State agency mean difference by age cohort and spatial units, 2021

	Victoria	Queensland	Northern Territory	
	(SA3)	(SA2)	(SA3)	
Age Cohort	% Difference	% Difference	% Difference	Mean
0-4	10.02	15.51	12.22	12.59
5-9	7.45	9.47	5.17	7.36
10-14	4.56	8.54	5.89	6.33
15-20	8.09	9.11	6.52	7.90
20-24	11.95	12.19	7.83	10.65
25-29	12.45	13.38	7.20	11.01
30-34	8.59	10.77	8.11	9.16
35-39	6.56	8.42	7.45	7.48
40-44	4.83	7.82	8.77	7.14
45-49	3.42	6.66	8.42	6.17
50-54	3.35	7.06	6.57	5.66
55-59	3.25	6.68	5.10	5.01
60-64	3.66	7.24	6.49	5.80
65-69	3.93	7.58	5.91	5.80
70-74	4.99	8.17	6.87	6.68
75-79	4.50	10.60	12.25	9.11
80-84	5.42	11.86	16.18	11.15
85+	6.49	20.86	43.12	23.49
Mean	6.31	10.11	10.00	8.81
Min	3.25	6.66	5.10	5.01
Max	12.45	20.86	43.12	23.49
STDEV	2.90	3.65	8.74	4.28

Source: Authors' own calculations using VIC, QLD, and NT State Government Projections, and Australian Bureau of Statistics data

What is evident from this review analysis is that the errors are more likely to be larger in the population that is more mobile (late teenagers and 20s) and the 0—4 cohort. The latter may indicate an issue with the fertility assumptions, while the former is more likely an issue of the way mobility is measured in Australia. Younger people are quite mobile but do not always update their address details or may maintain their address at their parents' house and this will only be identified every five years when the Census is collected. This is more problematic when developing assumptions for intrastate and interstate migration for smaller population spatial units. This is an area that has been challenging for demographers. The Census is the main source of data to measure mobility and alternative measures are not readily available in Australia. This is one area that would benefit from improved measurement.

Forecast.id prepare forecasts for local governments using a mixed methodology (included in an earlier section) and provides the option for updates based on the clients' needs, which may be more regularly than once per Census cycle. The final section compares the 2021 LGA ABS ERP for 2021 against the Forecast.id projection. Reflecting the ABS 2022 definition of forecast being a 'more likely' outcome of the future population, these are provided to the local governments as forecasts. Table 7 provides data for a selected set of LGAs and uses the same measure as per the other comparisons presented in this review.

Table 7: Forecast.id LGAs population by age cohort projections, 2021

Age	Adelaide	Ballarat	Bendigo	Coffs Harbour	Fraser Coast	Perth	Sydney	Wollongong	Mean Percent Diff
0-4	4.03	12.13	9.89	21.12	12.84	23.05	13.22	28.76	6.91
5-9	2.78	8.76	5.21	5.52	1.89	5.28	21.24	11.66	7.83
10-14	1.46	4.48	0.15	1.40	5.83	6.40	6.61	10.24	2.51
15-19	1.91	71.15	12.17	10.47	4.18	8.06	82.09	179.07	12.64
20-24	4.61	13.80	3.66	8.36	12.12	2.28	36.97	67.94	6.72
25-29	4.78	5.35	6.97	0.89	3.44	0.61	19.16	27.25	5.32
30-34	3.15	1.21	3.07	0.26	4.31	2.08	2.12	10.04	1.80
35-39	0.98	9.49	0.73	3.24	7.15	3.28	8.43	4.03	2.19
40-44	0.32	9.25	4.81	5.55	0.49	5.28	3.74	7.84	6.41
45-49	0.21	1.73	0.96	0.54	0.60	1.25	5.07	14.17	2.14
50-54	0.60	16.62	0.52	1.49	1.48	2.66	5.85	13.86	4.51
55-59	0.28	10.34	0.12	1.56	3.60	8.91	6.73	13.38	0.67
60-64	0.49	1.35	3.00	2.39	0.11	8.79	2.34	13.14	1.40
65-69	1.50	2.58	4.45	5.66	2.45	10.25	1.43	17.61	0.02
70-74	2.02	5.82	6.24	7.44	4.72	10.82	3.26	9.47	2.52
75-79	1.21	4.49	4.57	3.60	0.49	8.01	8.77	12.62	1.33
80-84	1.31	17.96	3.49	1.65	0.88	4.39	4.14	10.57	2.00
85+	18.27	3.58	18.27	11.97	1.40	1.57	31.34	15.35	16.78
Total	1.20	6.84	0.21	1.99	0.34	3.13	10.79	24.28	3.03
Mean	1.76	12.22	5.84	6.35	4.39	7.27	22.01	27.87	6.03
Min	0.04	1.40	0.43	0.14	0.66	0.02	1.72	4.98	0.37
Max	4.78	85.11	20.03	23.63	15.39	27.32	98.23	198.54	18.47
St Dev	1.52	19.16	5.11	5.90	4.17	5.83	28.60	45.41	4.53

Source: Authors' own calculations using Forecast.id data

On face value, the Forecast.id results are similar to those reviewed above, with most classed as small errors and similar issues associated with the younger population and mobile younger adults. Also of note are the very large errors in the major cities in the 15—19 age cohort. We note that these cities are also the location of some of the major universities in Australia. As COVID-19 prevented overseas students from travelling to Australia, and domestic students from attending in person, it is unsurprising that this age group is significantly variant to the census data collected in 2021 (at the height of lockdowns across Australia).

Further, Forecast.id undertake detailed reviews of their forecast accuracy and have provided all the LGA forecasts. Across all 176 LGA total population forecasts, the MAPE is 0.81 per cent for the population and 0.42 per cent for dwellings.

This review has assessed a range of projections and forecasts from national to sub-state over the 2016—17 to 2021 period. This was chosen to reflect the timeframe within which these projections and forecasts are revised and updated for the latest census ERP populations. While other researchers have included projections over five, 10, 15 and 20-year time spans, this review was more interested in how the results for the functional time span from a planning perspective performed. This in part reflects the purpose of projections and whether the aim is prediction, a tool for guiding planning, or for actively setting strategy to change the future population to a more desired outcome by intervening and setting in place actions that promote growth or curb growth depending on the circumstance.

What is evident from the review is the projection and forecast errors were mostly small (within 10%) with a few notable variations, particularly in the very young (0—4) and younger adults (20—29). There were also some very large errors in the capital city LGA projections. However, as stated above, this is most likely an impact of the COVID-19 pandemic, lockdowns and national and state border closures that stopped the flow of people, particularly students.

3. How do population projections inform decision-making?

- **Projections are utilised in a broad range of ways, but the scale of decision-making tends to dictate the type and source of projection used.**
- **At the local government level, stakeholders spoke of the importance of population forecasting in understanding place and the development of placed-based stories.**
- **In general, there was an acknowledgement that the state and territory government published projections were influenced not just by population considerations, but also broader (non-population) policy priorities and considerations.**
- **There is a need to more clearly communicate and provide understanding of the uncertainty implicit in population projections.**
- **There are many opportunities for methodological improvement in the way population projections are produced and provided to decision-makers.**

Stakeholders develop and use population projections, including small area projections, in quite different ways. We spoke with eight stakeholders who primarily developed population projections within both private and government contexts. The government stakeholders represented both the Australian Government and state and territory government levels, and were located across at least four states. All stakeholders interviewed had high-level experience. Interviews were conducted via online meetings during which the researchers took notes to inform the later analysis of themes. Overall, the interviews suggested two broad ways in which population projections were utilised.

The first was largely represented in our discussions with national and state and territory government projection developer stakeholders, where population projections were positioned as an official benchmarking tool for the allocation of funding and resources. In general, this meant that projections were at the larger spatial level, had longer timeframes, and were predominantly based on demographic change. Within these contexts, forecasts represent a shared source of truth that is mandated and approved by government.

The second was represented in our discussions with stakeholders from private enterprise, research and consultancy. In this case, population projections were conceived as important reflections of what is likely to happen on-the-ground, and were therefore characterised by shorter projection horizons, larger variety and quantity of input data, smaller spatial areas and frequent updating.

> *Forecasting is not just forecasting … it's a really useful exercise for understanding place. (Stakeholder participant)*

These two distinctions in the use of population projections frame the following four sections, which explore in more depth the types of decision-making supported by population projections, the characteristics of projections, issues around reliability and uncertainty, and opportunities for methodological improvements and innovation. The chapter concludes with a discussion of the implications for policy development.

3.1 Use and application

Population projections and forecasts are used to inform a wide range of decision-making processes across national, state and territory and local governments, as well as private business. For example, stakeholders spoke to their use in:

- the apportionment of GST across states and territories
- the identification of new infrastructure need
- understanding student enrolment dynamics, where new schools should be located, and where resources are required
- the formation of labour force data and creation of business development plans
- the identification of demand for new land release, dwelling requirements and redevelopment opportunities
- the development of electoral boundaries.

In addition to the specific uses above, stakeholders noted that treasury and health departments were major uses of population projections.

At sub-state levels, local governments use population projections in similar ways (such as land use planning and assessing infrastructure needs), as well as in support of requests to state and territory governments, though generally at a finer spatial grain. Several stakeholders noted that local governments tend to engage private developers of population projections as the outputs tend to be more ambitious (higher growth), with smaller, particularly regional, local governments being the main users of the state produced projections.

At the local government level, stakeholders spoke of the importance of population forecasting in understanding place and the development of place-based stories:

> *[as a former state demographer], I know that I need to tell ripping good yarns about place and the future … it's not only delivering data, but also delivering those stories is really important. (Stakeholder participant)*

In the discussions, particularly around the use of population projections by councils in development of local government plans, several stakeholders noted the potential for circularity:

> *Things get very circular, strategies based on projections, and vice versa. A vision and a back cast sometimes more important than a forecast. (Stakeholder participant)*

The use of projections by private clients was less discussed, however one stakeholder noted that they would be used to inform locational decisions, for instance, where a new shop might be best located to match future demand.

3.2 Methodological considerations

Most of the small area projections that stakeholders spoke to were modelled at the SA2 level. Although, many stakeholders noted the difficulty of forecasting at this finer grain. As put by one stakeholder, 'once you get down to a small geography [SA2], they get a bit hairy'.

To deal with the high degree of uncertainty at small area levels, several stakeholders mentioned using clustering (to develop a profile(s) from larger areas that could be applied for smaller populations) or aggregate techniques (which combined multiple, similar geographic areas to draw strength from greater data size).

A few stakeholders mentioned SA1s and transport zones as even smaller units of analysis but commented: 'local area ones are the most difficult'. There was a consensus that there was a very high degree of uncertainty in small area projections, which will be explored further in the following section.

During the discussions, we asked stakeholders to reflect on whether a top-down or bottom-up approach was more appropriate. Two of the stakeholders suggested a combination of the two. For example, starting with a top-down approach and then taking a bottom-up view to allocate the simple top-down projections into a more reliable representation of population spread. On this process, another stakeholder observed that 'the top-down vs. bottom-up approach is an unrealistic view, it's always both an iterative process, or it should be anyway', and that 'top-down and bottom-up will never add up…it is purely an academic exercise'.

A state government-based stakeholder commented:

> *We tend to work top-down. The reasoning behind that is because we're working with numbers that are robust at state level so they're good to work to. Whereas if you're working from small areas, there's a lot of volatility so working up, it's going to be quite messy. (Stakeholder participant)*

The input data for projection models ranged from straight demographic components of change, in some cases coupled with land constraint variables, to models enriched with a range of public and private data. For example, a stakeholder from a department of education spoke of enriching projections with departmental information. Other stakeholders drew on external data sources, many of those mentioned concerning land use or housing requirements. Enriching basic models was particularly important for the stakeholder from private enterprise as better coverage would attract higher fees.

Developers noted other methods to improve projection inputs, including clustering (as mentioned above), synthetic local area models, and inclusion of land use variables. An input component that presented a challenge for several stakeholders was migration, both interstate and overseas (discussed in further detail in the opportunities section below).

Stakeholders commented on the average horizon of small-area projections, which are generally forecast to 15 years, and updated every five years post-Census. At state levels, stakeholders cited projections between 40—50 years. In general, when discussing horizons, stakeholders noted that 'producers and users want projections out far longer than they are suitable for'. Users' understanding of the uncertainty, error and reliability of projections was raised in great depth by almost all the stakeholders (discussed in further detail in the opportunities section below). Most of the forecasts discussed by the stakeholders included high-medium-low growth style ranges. One stakeholder reflected on the utility of graduated projections for users noting that, typically, 'we don't produce a range, most [users] prefer just a number'.

Across many of the interviews, stakeholders touched on the influence of the broader policy considerations of governments. In general, there was an acknowledgement that the state and territory government published projections were influenced not just by population considerations, but also broader policy priorities and considerations. Such considerations are largely not controversial, but can be regarded as reflecting the need for projections to acknowledge and predict the effect of emerging policy. As one stakeholder mentioned, 'the challenge is that our state-based projects are based on science, but also go through a political filter… there's certainly an amount of manual tweaking with forecasts [based on] plausibility and "expert judgement"'. Another stakeholder argued that although their projections are more pragmatic, discussions indicated that even these were open to influence that varied results from actual outcomes, making particular reference to 'small areas that are declining, but are forecast to have hopelessly optimistic projections'.

3.3 Reliability and certainty

We spoke to stakeholders extensively about the performance and reliability of population projections beginning with a discussion about their accuracy during the COVID-19 pandemic. At the larger spatial scales, and for those who produce forecast ranges, most projections performed well. The biggest challenges were unknown (and often rapidly changing) interstate and overseas migration trends.

Following on from the specific example of the COVID-19 pandemic, stakeholders discussed a range of specific types of assumptions and input data that presented challenges in the formulation of reliable projections. Several stakeholders spoke to issues within the demographic data available, saying that quality and sufficiently long time series were a 'significant basic limitation'. Others spoke to the 'shelf-life' of demographic data, giving the example of it being most reliable for older populations and least reliable for young populations (babies and children) with 'huge amounts of noise in the data'. In this instance, data noise was attributed to an under recording of births and delays in recording births, with anecdotal evidence from LGAs that their local maternity wards were far busier than projections might suggest. There was also general agreement that land use inputs present a challenge, and that cross-checking model outputs with known plans to see if 'projections look sensible' was common.

As briefly touched on in the section above, some stakeholders expressed quite strong views on the reliability of population projections at small areas. For instance, one stakeholder commented that SA2 projections were so unreliable 'you may as well buy a dartboard'. Another characterised SA2s as 'unforecastable'. The tension between forecasting capability and the demand for small area projections was represented well in a comment from a national developer:

> *If you're looking at doing local area projections, they can be quite tricky … there's a view that maybe we should just not do them at all … then there's a big fuss when we don't. (Stakeholder participant)*

A theme throughout our discussions was that there will always be a degree of uncertainty inherent to population projection, particularly at the smaller spatial scales. As one stakeholder described 'the key is not if they are right or wrong, but WHY and that we can explain why', and, 'the degree to which you are wrong is what you've got to manage'.

For these stakeholders, being able to communicate the level of reliability of projections to clients and users was of more importance. For example, citing a general lack of understanding of the limits of projections, one stakeholder stated that 'people assume that there's a certain level of truth in forecasts but don't understand all of the risks and how to use them' and '[there is a] total lack of understanding of what projections mean, zero knowledge in those areas'. In some cases, a reticence to have open discussions around uncertainty or error was also raised, with one stakeholder mentioning that '[the] government don't like to talk about error because it is seen as a lack of confidence'.

Overall, discussions in this area revealed a number of opportunities for improvement to input data, debate on the appropriateness of forecasting at small spatial scales, and communication of reliability and error (and, in turn, appropriate use).

3.4 Opportunities for innovation

We explored a range of opportunities for improvement to population projection with stakeholders from the high-level to the specific. At the high-level, stakeholders spoke to aspirational goals such as increased data sharing, automation of forecast models, attaining data at the finest possible spatial scales, integration of technology, and development of user dashboards. When asked about small-area projections, stakeholders spoke extensively of the need to improve data in three key areas:

- Demographic data, with one stakeholder stating that 'the ABS needs to fundamentally rethink demographic stats', and suggesting an 'Australia card'.
- Housing data, with a particular focus upon development completion and occupancy data that pipelines 5+ years into the future to help determine when and where services are required.
- Migration data, including overseas migration ('but that's crystal ball stuff'), as well as interstate, and intrastate migration. Particular mention was also made of environmental migration. As one stakeholder stated, 'we're about to rapidly increase and we're losing land supply through climate change impacts like fire and flooding'.

Suggestions for data improvement also included having the ability to access a richer suite of more detailed measures. An example of this might include examining change of address requests on drivers' licenses to understand internal migration. In addition, the capacity to translate anecdotal observations into usable forms may be valuable. An example might include documentation of knowledge of new employment opportunities (new company to regional town, bringing a specified number of jobs) and how that might translate to population growth. Essentially, suggestions included creating a reliable method for taking local information and turning it into robust assumptions.

When posed with a question about the merit of nationally consistent population projections, stakeholders were generally in favour of a shared approach or set of assumptions to incorporate into models, rather than an enforced set of consistent forecasts.

To advise or govern the development of population projections, stakeholders suggested the formation of an 'indicative planning council', a heads of planning government group, or community of practice. Overall, it was observed that there is no obvious existing body to fulfil this unifying role:

> *There's a vacuum … especially as the uncertainty about the role of the ABS … we are resourced to do the national and greater capital cities but in terms of anything smaller than that, there's little resources. (Stakeholder participant)*

Another key opportunity discussed for projections was education, in particular for users to understand the reliability, uncertainty, and error in population forecasting. As stated by one stakeholder, 'the big challenge is the expectations of users, that we can produce accurate small area projections that are robust', and that 'we need to provide a way of communicating uncertainty, even if it's uncomfortable for the state and others who produce projections'.

3.5 Implications for policy

The findings from this consultation suggest that views of the developers (government) contrast with private sector development. This is fundamentally an issue of a top-down versus a bottom-up approach to projecting and forecasting. Government forecasting agencies are projecting using demography through a cohort component model, with few indicating the use of land or housing constraint models. Additionally, few government agencies are engaged in small area or small population projecting, with SA2 most commonly the smallest geography.

The private sector forecasting developer employs a bottom-up and top-down model that incorporates demography and cohort component, housing unit and land availability models.

One issue that was evident from both the review and the consultation is that there is little methodological development, with the cohort component method still preferred across all government forecasting agencies. This is not to suggest that the cohort component model is not suitable for purpose, but given advances in computing and data, investigation of new methodologies incorporating new data was not mentioned during the consultation phase. The exception was the private projection company that indicated it was investing in developing a more holistic approach for national down to local forecasts. There was a view propagated by both the state agency and the private sector developer of population projections that the outcomes produced by each were superior to the other.

This perhaps represents the user requirements across these two broad groups. National and state projections are required for national and state planning, whereas local governments require projections that specifically inform local councils about how population change might be distributed across their jurisdictions. While national and state planning is informed by national and state projections, the application of national and state policy is manifest at the local government scale. State and national projections form a key input into national and state policy, however small area projections are critical to assist in translating and applying national state policy to local areas.

In reflecting on the central research aim, we conclude from these interviews that current population projections are relatively effective as these two different approaches service different user needs. Against this backdrop, the accuracy of projections is necessarily different between approaches. That is, the top-down approach prioritises accuracy at a larger spatial scale and generally over longer horizons. In comparison, the bottom-up approach places greater importance on regional specificity and short- to mid-term horizons.

In the current context of disparate forecast producers, varied methodological approaches and distinct remits, it is unlikely that the top-down and bottom-up approaches could be unified to one nationally consistent approach that would fulfil users' needs with sufficient accuracy. All interviewees were asked about new data or methodologies they might employ for projecting, but there was no suggestion from any party that some of the newer detailed spatial data sets (such as GNAF and GeoScape) were of interest. Furthermore, there was no discussion around new methodology development.

Access to detailed land availability data was mentioned by several developers, but there was concern about consistency, timeliness, and availability. National and state developers expressed interest in access to these data. However, they were concerned that as these data were supplied from local government it would be too difficult to source. For the private sector developing local government forecasts, land availability can be supplied as required on an LGA-by-LGA basis. For land availability data to be useful for state agencies they would need all the data at one point in time from all local governments. This was viewed as a major impediment to its use by national and state developers. There was also mention of establishing a function similar to the IPC for the housing industry, as this provided access to more detailed and timely data regarding land and housing supply.

4. Implications for future policy

This project was designed to provide an understanding and critical assessment of the population projection resources available to Australian decision-makers and planners, and the way that they are utilised. It was undertaken in a context of active policy reflection, and conscious consideration – by governments and the private sector – of the degree to which our current sources of population projections are fit for future purpose.

In order for future policy to be based on solid and reliable estimates of how many and what people are where in Australia, this project suggests that we prioritise:

- consistent approaches and shared information sources
- good quality, reliable and timely data
- a thorough understanding of land and dwelling supply
- better methods (especially for estimating small area populations)
- a more widespread understanding of error and accuracy.

Overall, this work reinforces the need for consistency, such as agreed methods, definitions, shared datasets, accepted and explicit error boundaries. This is neatly captured in the reflections of two key panel members (shown as Box 1 and Box 2).

Box 1: How could small area population projections be improved?

- Better quality, and more timely, ERPs, births, deaths, and migration data for small areas. Currently, all of these data sources are imperfect, but small area migration data is the least reliable.
- … need much longer time series of small area demographic data on consistent geographies than is currently available. This would facilitate analysis, and hopefully better understanding, of long-run change trajectories at the small area scale. …
- We need a more nuanced understanding than just assuming many areas follow the 'lifecycle of suburbs' model or that recent demographic rates should be held constant.
- Better residential dwelling data [is required], including estimates of dwellings occupied on a usual residence basis.
- Related to the point above, good quality residential dwelling forecasts [are needed]. Realistically, this data would be collected and provided by State/Territory Governments in a nationally consistent way.
- More use of the latest statistical and computational methods to borrow strength to estimate and smooth small area age profiles of fertility, mortality, and especially migration, rates.

- Experimentation with combining methods, borrowing methods from other disciplines, testing machine learning etc. to try to create projection methods which give more accurate forecasts.
- A better understanding of how users interpret small area population projections and what they use them for.
- User-friendly population projections tools/packages for practitioners, preferably open access.
- Quantification of small area forecast uncertainty, and effective communication to non-technical users.

Box 2: How could small area population projections be improved?

[reflecting on 25 years of small area forecasting]

- top-down and bottom-up models function with a high level of efficiency and are very fast to run and review.
- The most significant challenges with small area or micro-geography forecasting is having a handle of the multiple aspects of land and housing supply.
- Monitoring residential development as it occurs is surprisingly tricky from state to state and region to region.
- … monitoring the supply of land, dwelling capacity, likely rates of development, take up and specific patterns of development are a significant challenge.

While the need for consistency is reinforced in this report, we also acknowledge and highlight the diverse uses (and users) of population projections. This means that one package of projections cannot meet the diversity of applications required. Different scales, error tolerances, and foundational data, for example, are necessary to meet the decision-making needs of local governments versus Australian Government agencies. Perhaps a less expected finding of this project, was the value placed on more responsive, detailed bottom-up generated estimates. Looking more broadly to the characterisation of what projections Australia should have in its decision-making support armoury, there is a place for strong top-down projections, and more flexible targeted bottom-up ones.

The data landscape for population projections has almost certainly changed in recent years, and we should be considerate of these changes in our future planning. Traditionally the data components of projections were tied to national Censuses and large-scale agency collections. Recent (and potential) developments in technology have expanded the depth and diversity of data that can form the basis of reliable population projections. For example, many of our expert panel participants referred to the usefulness of a diversity of residential dwelling data, such as from sales, land development applications or the planning system.

Finally, projections should be seen as well-informed estimates of what our population may look like in future, so it is no surprise that considerations of error are an important finding of this work. In terms of future policy, a certain amount of error tolerance in projections is implicit. Better decision-making comes from an understanding that error is inherent in population projections. Making that error and the surrounding assumptions more understandable to users will result in better applications and use of projections.

4.1 Conclusion

Looking back critically on this project, from the question originally posed by the policy community, to the assumptions of our project design, and the findings of the review and consultation, we have found both the expected and the unexpected. The suggestion that projections need good quality data will be no surprise, nor that consistency and transparency of the assumptions and methods will improve the quality of future projections. Our finding that error needs to be made an explicit feature of projections is uncontroversial, but important.

However, this project has also revealed a population projection landscape in Australia that is slightly different to the one expected. Firstly, it is a more conservative landscape than anticipated, with very limited uptake of novel datasets (such as GNAF, Geoscape and the Survey of Tourist Accommodation). In fact, what was clear was not the desire for new data, but for better national, sub-state and small area collections of existing data.

Secondly, this research responded to an assumption posed by the policy community that there was the potential for a one-size-fits-all solution to doing projections better in Australia. Our assumptions as researchers also anticipated the possibility of a one-size-fits-all solution in the design of the project. However, what was clearly revealed was the need, not for a single solution, but for many solutions to meet the very different requirements of a diversity of users who are using projections for a very wide set of decision-making applications.

Importantly, our consultations with experts indicate a widespread concern that our ability to provide high quality and reliable projections was affected (and likely caused in part) by a national 'demography brain drain'. Anecdotal evidence suggests that the offering of demographic training has declined in Australian universities, and that there are relatively few graduates with high level skills. This problem has been reinforced by a parallel shift in government demographic units toward outsourcing. Together there are fewer opportunities for training in high level demographic skills. This is an area that requires action to ensure there is a qualified workforce in this field.

Finally, the timing of this research allows us to reflect on ability of population projections to respond to unforeseen events, such as the COVID-19 pandemic. It suggests the need for some flexibility in the formal creation of projections, and the possibility to consider a process for timely, and perhaps temporary, revisions.

We end this report with a call to action. This research has highlighted a shared and generous concern – across government, policy, and industry stakeholders – to work together on improving the projection landscape in Australia. What is needed is a body to take the lead and drive the discussion. An initial step might be to bring the main players together to review the present situation and start to develop an agenda for future action.

This project's findings suggest the need for an Australian roadmap towards a nationally consistent program of quality local area population projections that will:

- be accessible and interpretable to both technical and non-technical users
- aim to utilise (sometimes opportunistically) new (administrative, commercial, intentional) data, at small and large scale
- use new methods, individually, and in combination
- provide rapid and regularly updated guidance to stakeholders
- be accurate and reliable at the small scale, and provide an interpretable estimate of uncertainty
- better monitor small area migration patterns, as well as housing supply
- enable a solid pipeline of training in demographic skills – to address the continuing brain drain in the sector.

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