



FINAL REPORT NO. 356

New housing supply, population growth, and access to social infrastructure

Authored by

Somwrita Sarkar, The University of Sydney

Emily Moylan, The University of Sydney

Hao Wu, The University of Sydney

Rashi Shrivastava, The University of Sydney

Nicole Gurrán, The University of Sydney

David Levinson, The University of Sydney

Publication Date June 2021

DOI 10.18408/ahuri73233

Title

New housing supply, population growth, and access to social infrastructure

Authors

Somwrita Sarkar, The University of Sydney
Emily Moylan, The University of Sydney
Hao Wu, The University of Sydney
Rashi Shrivastava, The University of Sydney
Nicole Gurran, The University of Sydney
David Levinson, The University of Sydney

ISBN

978-1-922498-23-6

Key words

Accessibility, social Infrastructure, Population Projection
Methods, urban growth, spatial equity, quantitative urbanism,
evidence-based policy and planning.

Series

AHURI Final Report

Number

356

ISSN

1834-7223

Publisher

Australian Housing and Urban Research Institute Limited
Melbourne, Australia

DOI

10.18408/ahuri73233

Format

PDF, online only

URL

<https://www.ahuri.edu.au/research/final-reports/356>

Recommended citation

Sarkar, S., Moylan, E., Wu, H., Shrivastava, R., Gurran, N.
and Levinson, D. (2021) *New housing supply, population
growth, and access to social infrastructure*, AHURI Final
Report No. 356, Australian Housing and Urban Research
Institute Limited, Melbourne, [https://www.ahuri.edu.au/
research/final-reports/356](https://www.ahuri.edu.au/research/final-reports/356), doi: 10.18408/ahuri73233.

AHURI

AHURI is a national independent research network with an expert not-for-profit research management company, AHURI Limited, at its centre.

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.

Using high quality, independent evidence and through active, managed engagement, AHURI works to inform the policies and practices of governments and the housing and urban development industries and stimulate debate in the broader Australian community.

AHURI undertakes evidence-based policy development on a range of priority policy topics that are of interest to our audience groups, including housing and labour markets, urban growth and renewal, planning and infrastructure development, housing supply and affordability, homelessness, economic productivity, and social cohesion and wellbeing.

Acknowledgements

This material was produced with funding from the Australian Government and state and territory governments. AHURI Limited gratefully acknowledges the financial and other support it has received from these governments, without which this work would not have been possible.

AHURI Limited also gratefully acknowledges the contributions, both financial and in-kind, of its university research partners who have helped make the completion of this material possible.

Disclaimer

The opinions in this report reflect the views of the authors and do not necessarily reflect those of AHURI Limited, its Board, its funding organisations or Inquiry Panel members. No responsibility is accepted by AHURI Limited, its Board or funders for the accuracy or omission of any statement, opinion, advice or information in this publication.

AHURI journal

AHURI Final Report journal series is a refereed series presenting the results of original research to a diverse readership of policy-makers, researchers and practitioners.

Peer review statement

An objective assessment of reports published in the AHURI journal series by carefully selected experts in the field ensures that material published is of the highest quality. The AHURI journal series employs a double-blind peer review of the full report, where anonymity is strictly observed between authors and referees.

Copyright

© Australian Housing and Urban Research Institute Limited
2021

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, see <http://creativecommons.org/licenses/by-nc/4.0/>.



Contents

List of figures	iii	3. Access to social infrastructure	44
List of tables	iv	3.1 Understanding measures of infrastructure provision	45
Acronyms and abbreviations used in this report	iv	3.2 Accessibility analysis	46
Executive summary	1	3.2.1 Person-weighted access to social infrastructures	46
Key findings	2	4. Panel discussion and interview results	54
Policy development options	3	4.1 Better methods for understanding future population growth and mobility	55
The study	3	4.2 Identifying lag hotspots at fine spatio-temporal scales	55
1. Introduction	5	4.3 Use for future planning of social infrastructure	56
1.1 Policy context	6	4.4 Evaluating performance of plans	56
1.1.1 Planning for social infrastructure	6	4.5 Aiding development of novel data indicators for planning	56
1.1.2 Prioritising and delivering social infrastructure	6	4.6 Additional uses of the tools and methods developed in this project	57
1.2 Applications of big data and urban science to spatial planning and infrastructure delivery	7	5. Policy development options	58
1.2.1 Tracking building activity and urban form at fine spatio-temporal scales	7	5.1 The importance of novel data and spatial accessibility tools	59
1.2.2 Population estimation	8	5.2 Limitations and priorities for further research	60
1.2.3 Accessibility measurement	8	5.3 Final remarks	60
1.3 Research methods	9	References	61
1.3.1 Data inventory	9	Appendix: Full set of spatial accessibility profile maps for schools and hospitals	62
1.3.2 Tracking residential supply and population growth	10		
1.3.3 Accessibility analysis	15		
1.3.4 Panel discussion	16		
2. Dwellings, residential built form, and change and population estimation	17		
2.1 Understanding spatial population and dwelling growth profiles for Sydney, Brisbane, and Perth, 2011–2016	18		
2.1.1 Population growth profiles	18		
2.1.2 Dwelling growth profiles	21		
2.2 Tracking growth from built-environment data	27		
2.2.1 Change in built-form density	31		
2.3 Population estimation	40		
2.3.1 Method	40		
2.3.2 Validation	40		
2.3.3 Caveats	43		

List of figures

Figure 1: Snapshot of PSMA Geoscape buildings data, August 2018	12	Figure 27: A close-up of the Marsden Park area, NWPGA, Sydney	32
Figure 2: Sydney PSMA Geoscape data	12	Figure 28: Tracking longitudinal built-form density and estimated population growth over time, NWPGA, Sydney	33
Figure 3: Brisbane PSMA Geoscape data	13	Figure 29: Tracking absolute growth in residential buildings and areas and identifying top local growth areas, NWPGA, Sydney	34
Figure 4: Perth PSMA Geoscape data	13	Figure 30: Map of Ripley Valley PDA, Brisbane, showing clear boundaries around planned developments	35
Figure 5: Population growth profile for Sydney at SA2 level	18	Figure 31: New buildings built May 2017–July 2019 in the Yarrabilba PDA, Brisbane	35
Figure 6: Population difference for Sydney, 2016–2011	19	Figure 32: Growth in the number and area of buildings compared to the change in the residential population estimated by the ABS in the Brisbane growth areas	36
Figure 7: Population growth profile for Brisbane at SA2 level	19	Figure 33: Growth in the number and area of buildings, May 2017–July 2019, Brisbane growth areas	37
Figure 8: Population difference for Brisbane, 2016–2011	20	Figure 34: Map of mesh blocks in the north-west corridor showing Yanchep and Alkimos, Perth	38
Figure 9: Population growth profile for Perth at SA2 level	20	Figure 35: Comparison of estimated resident population growth to growth in the built environment, Joondalup and Wanneroo SA2s	39
Figure 10: Population difference for Perth, 2016–2011	21	Figure 36: Growth in number (top) and area (bottom) of buildings in Joondalup and Wanneroo SA3s	40
Figure 11: Dwelling densities by area for Sydney, 2016	21	Figure 37: Verification of the 2016 baseline population showing inconsistencies between LGA and SA2 boundaries	41
Figure 12: Dwelling densities by population for Sydney, 2016	22	Figure 38: Comparison of the ABS ERP with the population estimated from growth in the built environment	42
Figure 13: Dwelling difference for Sydney, 2016–2011	22	Figure 39: Sydney: person-weighted accessibility, transit, 30-minute threshold	47
Figure 14: Dwelling densities by area for Brisbane, 2016	23	Figure 40: Sydney, person-weighted accessibility, car, 30-minute threshold	47
Figure 15: Dwelling densities by population for Brisbane, 2016	23	Figure 41: Brisbane: person-weighted accessibility, transit, 30-minute threshold	48
Figure 16: Dwelling difference for Brisbane, 2016–2011	24	Figure 42: Brisbane: person-weighted accessibility, car, 30-minute threshold	49
Figure 17: Dwelling densities by area for Perth, 2016	24	Figure 43: Perth: person-weighted accessibility, transit, 30-minute threshold	50
Figure 18: Dwelling densities by population for Perth, 2016	25	Figure 44: Perth: person-weighted accessibility, car, 30-minute threshold	50
Figure 19: Dwelling difference for Perth, 2016–2011	25	Figure 45: Sydney: total accessibility, transit, 30-minute threshold	51
Figure 20: Correlation between population growth and dwellings growth, Sydney	26	Figure 46: Sydney: total accessibility, car, 30-minute threshold	52
Figure 21: Correlation between dwelling density and population density at the mesh-block level, Sydney	27		
Figure 22: Correlation between number of buildings per km ² and the area of buildings per km ² , Sydney	28		
Figure 23: Relationship between density of buildings in each NWPGA mesh block (ABS) and the number of usual residents (PSMA)	28		
Figure 24: Relationship between population and residential buildings, Brisbane	29		
Figure 25: Relationship between population and residential buildings showing patterns of homogeneity in household size and heterogeneity in housing type, Perth	30		
Figure 26: NWPGA: building growth (top), in mesh blocks and principal LGAs (bottom left), and location within Sydney GMR (bottom right)	31		

List of tables

Table 1: Case study greenfield sites	10
Table 2: Sydney: person-weighted access to social infrastructure	46
Table 3: Brisbane: person-weighted access to social infrastructure	48
Table 4: Perth: person-weighted access to social infrastructure	49
Table 5: Sydney: people reaching social infrastructure	51
Table 6: Brisbane: people reaching social infrastructure	52
Table 7: Perth: people reaching social infrastructure	53

Acronyms and abbreviations used in this report

ABS	Australian Bureau of Statistics
AHURI	Australian Housing and Urban Research Institute Limited
ERP	estimated residential population
GMR	greater metropolitan region
GTFS	General Transit Feed Specification
LGA	local government area
MB	mesh block
NWPGA	North West Priority Growth Area
PDA	priority development area
PSMA	Public Sector Mapping Agency (now Geoscape)
SA2	Statistical Areas Level 2

Executive summary

Key points

- This research develops a quantitative geographic methodology to assess and inform the forward planning of social and community infrastructure in rapidly growing areas of Australian cities. It focusses on greenfield areas of Sydney, Brisbane, and Perth greater metropolitan regions (GMR) to demonstrate data sources and methods that are able to be replicated in other contexts.
- Social and community infrastructure is critical to the effective functioning of rapidly growing urban regions, but lag times between population growth and new infrastructure delivery are pervasive in new greenfield development areas.
- Timely fine-grained spatial data is critical to informing and measuring performance in spatial planning and infrastructure delivery processes, but existing datasets are limited.
- This project tests and demonstrates the utility of new datasets—particularly high-capacity data such as Geoscape, median speed on individual road links, and Open Street Map — which are updated with greater frequency than traditional data sources, such as the census. The new datasets are available for very fine-scale geospatial analysis.
- A general quantitative analytical framework for measuring social infrastructure provision is developed for the three greenfield areas. It is able to be adapted to other rapid-growth settings in metropolitan Australia.

Key findings

Access to social infrastructure such as schools, health services, leisure and recreation facilities is critical to community wellbeing in newly developing areas—especially if we hope to realise Australia's urban policy aspiration of '30-minute cities'. However, coordinating the delivery of new social infrastructure and services is complicated by:

- the fragmentation of delivery agencies
- the lack of coordinated and timely data sharing.

New data sources and tools offer an opportunity to address this problem by providing more timely insights to inform the planning and provision of social infrastructure in rapidly growing areas.

In this context, this project achieves two aims:

- It develops and tests an enhanced method for projecting population growth by using fine-grained spatio-temporal scale buildings and dwellings growth as a leading indicator and explanatory variable for future population projections. The analysis demonstrates that including urban development as an explanatory variable in population projection methods can result in more accurate and reliable projections.
- It develops 'spatial accessibility profiles' that provide a measure of existing and potential proximity to social infrastructure and services, which—when combined with fine-grained and time-sensitive population data—can be used by diverse organisations to prioritise funding and delivery decisions. In this project, the utility of this measure is demonstrated by creating 'spatial accessibility profiles' for greenfield case study areas, based upon access to education and health services.

Overall, the project finds that novel data sources, which are widely available, can enrich spatial and infrastructure planning in high-growth areas of Australia. These data sources include:

- Geoscape buildings growth data—used to add urban development information to population data
- OpenStreetMap (OSM) – open-source map data
- median speed data for every road link across Australia used to measure travel time by car (2019 data by Compass IoT)
- General Transit Feed Specification (GTFS) data—used to measure travel times on transit in the cities of Sydney, Brisbane, and Perth.

Data methods and measures demonstrated in this study were tested with planners and industry experts familiar with the three capital cities of Sydney, Brisbane, and Perth. These experts saw value in publicly available 'real-time' data to inform and measure social infrastructure accessibility in new growth areas of metropolitan Australia, and more widely in regional Australia. Big-data approaches and modelling are increasingly being used to inform the spatial planning exercises.

However, there are difficulties in data and information sharing across agencies, and in translating data insights into funding and delivery priorities. There are also difficulties around accessing valuable data maintained by individual government agencies, despite increasing commitment to open data platforms. Further efforts to develop innovative measures for understanding and informing social infrastructure requirements and provision in Australia should address these implementation challenges.

Policy development options

The findings of the study have four implications for policy development and practice.

1. There is an opportunity to improve planning and coordination of new development areas in metropolitan and regional Australia through the use of new analytical tools and methods, such as those demonstrated in this project. In particular, novel 'big data' sources should be incorporated to inform evidence-based planning, after ensuring that they are accurate and reliable.
2. Open data platforms, including data on existing and planned social and physical infrastructure, should be shared across government agencies, researchers, and members of the public. This would ensure that common datasets are used to inform planning and decision-making processes. This has begun to occur—but progress to date is slow.
3. Fine spatio-temporal scale building and construction data should be used as a leading indicator for small area population projection models, in the short term.
4. 'Spatial accessibility profiles' provide a powerful basis for community engagement around priority development and infrastructure decisions. They can be extended to many thematic applications—from schools and health facilities, as demonstrated in this project, to parks, recreation, or retail services. As well as informing planning and funding decisions, the accessibility profiles provide a powerful measure of urban performance and spatial equity.
5. The accessibility profiles can be used to inform and measure progress towards sustainable transportation and a reduction in car dependency. Accessibility profiles can be measured for different modes, such as walking, cycling, car-driving and transit, as well as for chosen infrastructure dimensions. Planning process can prioritise accessibility through transit and active modes of transport.

The study

This research reports findings from an AHURI standalone data project: *New housing supply, population growth, and access to social infrastructure*. It focusses on the potential to better inform the planning, scheduling, delivery, maintenance, and coordination of social infrastructure in the rapidly growing greenfield areas of major Australian cities through the use of big data sources and techniques.

Several novel data sources were used in this project, and new methods were adapted and developed. New data sources included:

- Geoscape dataset—a longitudinal dataset comprising the footprints and attributes of over 15 million buildings across Australia.
- median speed data for every road link across Australia (2019 data)
- Open Street Maps (OSM)—open-source map data
- General Transit Feed Specification (GTFS)—developed by Google, that defines common format for public transportation schedules and associated geographic information.

While the Geoscape data is used to track the growth of buildings at the finest possible spatial scale, the other datasets are used to accurately compute travel times on various modes (walking, transit, cars) — which form a critical component of the accessibility computations.

This project aimed to develop a monitoring and coordination tool that enables computation, mapping, and visualisation of fine spatial scale accessibility for various social infrastructure dimensions. In this report, the tool is used to demonstrate accessibility to schools and hospitals, including their hierarchical distributions—for example, primary and secondary schools, primary healthcare centres, and large hospitals.

The project uses three cities for case studies: Sydney, Brisbane, and Perth. Accessibility is mapped for entire metropolitan regions, with special focus on three greenfield development areas in each city.

Finally, a ground-truthing exercise was performed. The authors conducted a panel discussion and workshop with several local and state government officers, along with private industry consultants and practitioners, to reveal how the tool could be beneficial in different policy and planning contexts.

As well as developing a tool to inform policy and planning practice, the project extends previous research on urban accessibility by computing it for the first time at the mesh-block level. (A mesh block is the finest geographical area defined by the Australian Bureau of Statistics (ABS) at which census information is collected).

Most accessibility mapping studies focus primarily on the number of jobs and workers accessible to and from different parts of the city. In other words, they make work-home relationships and employment catchment analysis the focus of their accessibility studies and urban performance. This study breaks new ground, as it extends the idea of accessibility to social infrastructure as a critical facility to support daily life.

1. Introduction

- **This project sought to develop new methods and measures to inform planning processes for social infrastructure delivery in rapidly growing communities—particularly new ‘greenfield’ release areas.**
- **This introductory section provides the policy context for the project and situates the research in relation to existing advances in big data and urban science. Data sources and methods used in this project are also explained.**

Efficient access to social infrastructure is critical to sustainable residential development (NHS 1992). However, planning, scheduling, and delivery of social infrastructure in greenfield growth areas remains a perennial policy challenge in Australia. Greenfield growth areas are plagued by infrastructure lags and deficits, which disadvantage new communities and undermine programs of new housing supply (Infrastructure Australia 2019).

These lags and deficits reflect disjointed planning efforts, as well as key data gaps in relation to the following:

- Correlations between spatial patterns of population growth, new residential supply, and provision of social infrastructure within new and renewing areas of metropolitan Australia.
- Impacts of renewal and greenfield development projects for local and regional transport networks and patterns of accessibility for existing and planned social infrastructure.
- Multi-agency programs for planning, funding, scheduling and delivery of key facilities, services, and infrastructure—particularly in new growth areas.

This project aims to address these data gaps, to develop and demonstrate a monitoring framework and a policy coordination tool focussed on social infrastructure. The tool provides a basis for monitoring population growth, the rate of new housing supply, and accessibility to social and community infrastructure at a fine-grained spatial scale.

The project was guided by three research questions:

- **RQ1:** What is the evolving state of growth in potential population, dwellings/residential supply, and social infrastructure in these priority greenfield areas?
- **RQ2:** How does accessibility to different types of social and community infrastructure facilities and services vary across diverse geographic, planning and policy contexts?
- **RQ3:** What drivers, relationships, and barriers, identified through engagement with local and state government representatives and private players, could explain the observed variations of accessibility and associated infrastructure provision? What is the potential utility of the data tool and methods for policy development and planning practice, and how could the approach be extended or enhanced?

This introductory section sets out the policy context for the study, summarises key literature relevant to the development of the data sources and analytical techniques, and explains the research methods used.

1.1 Policy context

'Social infrastructure' refers to services and facilities that address health, education, cultural and recreational needs. These facilities are accessed at a fixed location, so decisions about social infrastructure needs and provision depend on understanding both:

- the likely scale and dimensions of demand—population size, demographic structure, etc.
- the patterns of accessibility to these critical services (Briggs et al. 2007; City of Parramatta 2017; Infrastructure Australia 2018; Infrastructure NSW 2016).

Fixed-at-point services are delivered in a hierarchical way, from local to metropolitan to regional—for example, local parks or recreational centres through to major hospitals. Primary schools, health and community centres, and local libraries are usually provided at a local scale and ideally are accessible to residents by walking, cycling and other active modes of transport. Regional or metropolitan infrastructure such as universities, TAFEs and hospitals serve a wider catchment and so depend on access through private and public transit modes.

1.1.1 Planning for social infrastructure

Social infrastructure planning has long been a core focus for state and local government in Australia (Briggs et al. 2007; City of Parramatta 2017; Infrastructure Australia 2018; Infrastructure Australia 2019; Newman et al. 1992; NHS 1992; NSW Department of Planning and Environment 2017). However, the complex process of urban and residential development, which involves multiple actors and agencies across state and local government, plus the private sector, makes it difficult to align housing development processes with the funding and delivery of key services and facilities.

Australia's national Smart Cities Plan emphasises containment and proximity to services, as do the state and territorial metropolitan strategies. For instance, the Smart Cities Plan aims to have people reaching employment and services within a 20–30 minute radius of their home (Department of the Prime Minister and Cabinet 2016). This implies that new-release areas must be closely connected to existing facilities, or that new infrastructure is carefully timed to coincide with growth.

However, recent studies have highlighted the spatially isolated residential estates emerging in high-growth areas of Sydney where infrastructure provision is lagging new housing development, which compounds locational disadvantages associated with long journeys to work (Moylan and Sarkar 2019; Sarkar et al. 2019). Further, new infrastructure delivery requires long lead times, but new residents must make locational decisions—as well as select schools and invest in private vehicles—based on existing conditions. Thus, mismatches between population growth, supply of new housing and provision of social infrastructure are particularly an issue of timeliness, where late provision leads to urban inefficiency (Infrastructure Australia 2018; Infrastructure Australia 2019; Newman et al. 1992).

1.1.2 Prioritising and delivering social infrastructure

Australia's national infrastructure audit (Infrastructure Australia 2019) identified priorities across health and aged care, education, recreation, arts and culture, social housing, and justice and emergency services. The audit noted that timely delivery of social infrastructure was a key planning and policy issue for housing supply in fast-growing and densifying cities.

However, the planning, delivery, funding, scheduling, and maintenance of such infrastructure involves a host of organisations, ranging from local, state, and national governments to private developers and not-for-profit organisations. This makes the phased delivery of social infrastructure an extremely complex task, with high inter-organisational coordination loads.

Infrastructure Australia has called for standardised and time-sensitive data to inform the different players involved in delivering social infrastructure to new growth areas (Infrastructure Australia 2018). Further, given the spatial-equity implications of different infrastructure investment scenarios, gains and losses should be identified for target evaluation—as a what-if scenario analysis—as post-implementation scenario analysis (Cui and Levinson 2018; Deboosere et al. 2018; Iacono and Levinson 2017; Levinson et al. 2017; Sarkar et al. 2019).

At the state level, infrastructure planning, delivery and coordination take place at different stages of development. Most jurisdictions have infrastructure strategies, or are in the process of developing them, although these strategies have varying levels of integration across different government portfolios—such as education, health, transport, and planning—as well as different budgetary and delivery cycles. This is a particular issue in relation to greenfield areas, because social infrastructure often requires a critical population mass to justify the expenditure on delivery, operations and maintenance. The challenge is to supply adequate social infrastructure when the critical population mass needed to justify the presence of the infrastructure may not yet be in place, or to phase such delivery just-right in terms of going hand in hand with population growth in these new areas.

Local governments have differing approaches to physical and social infrastructure planning and delivery. ‘Hard’ infrastructure needed to support urban development—such as local roads and stormwater facilities—are often costed within capital works plans or embedded within the master planning and assessment process for major development projects. Local level community facilities—such as libraries, recreational facilities, and local parks—are funded and planned according to different arrangements, typically using a combination of development contributions and rate revenue. Ensuring sufficient and timely access to these services is a key challenge in new-release areas, where funding is limited, population growth is often staggered and unpredictable, and where projects may be spatially discontinuous. Over time, local jurisdictions have developed their own information systems to inform these decisions, but they would benefit from more consistent, time-sensitive, and spatially fine-grained data sources.

1.2 Applications of big data and urban science to spatial planning and infrastructure delivery

Existing research on this topic can be split into three major sections, and the existing research is now outlined.

1.2.1 Tracking building activity and urban form at fine spatio-temporal scales

A primary problem in urban science is to track the growth of cities and changes of urban form at fine spatio-temporal scales. A related problem is the problem of defining city boundaries:

- How can we reliably say where the boundaries of a city are?
- Where does a city end?

Both are primarily academic problems. However, they have policy relevance and are of interest to the topic of the current research, as the development of greenfield areas at the fringes of cities primarily implies expansion of city boundaries. Moreover, tracking this expansion at the level of the individual building footprint at the finest possible temporal and spatial scale is of considerable interest.

Several methods are used in the literature to define cities and track the development of urban form. Satellite imagery and aerial photography are used to track urban land cover, and they have been successfully used internationally to track urban growth and form change for several cities around the world (Angel 2012).

This approach takes into consideration physical growth parameters—the actual changes of land from rural to urban. Parallel approaches of defining cities rest on both physical criteria and functional criteria. Functional criteria include economic and demographic data, for example, tracking the density of built form, such as the number of dwellings or buildings per unit area, along with movements and behaviours of people—primarily their

daily commute behaviours to work—to define physical–functional city boundaries. For example, a particular small area at the fringe of a city can be considered part of that city if it shows a certain density of built form, or if more than a certain percentage of residents go to work in the inner-city employment zones (Arcaute et al. 2015).

For all these approaches, longitudinal continuity of data is extremely critical and important, since identifying and tracking physical and functional urban growth at repeated points in time will reveal the extent of change that is occurring. Further, the finer the spatial and temporal resolution of the data, the better the quality of the tracking.

The Australian Bureau of Statistics (ABS) defines areas based on similar physical–functional definitions, with a view to defining urban areas within Australia. These areas are:

- significant urban areas (SUAs)
- greater capital city statistical areas (GCCSAs)
- greater metropolitan regions (GMRs).

Further, other ABS longitudinal data, such as building approvals and completions, provide avenues to track urban growth on a regular basis. However, all the data available through the census that are relevant to the problem at hand—such as housing/built form, employment patterns, journey to work, internal migration—are only available at five-yearly intervals.

Thus, a primary data challenge for this research was to identify reliable sources of data from which urban growth and change and building-activity tracking could be made feasible at the finest possible spatial and temporal scales.

1.2.2 Population estimation

The standard demographic models include variables such as births, deaths, and migration rates as explanatory variables for predicting the changes in population for a certain area (Australian Bureau of Statistics 2020). However, it is well acknowledged that the development of urban areas acts as attractors of population, in the sense that when new residential supply is produced, it will attract more people into the newly developing region.

However, in the standard population projection models, built-form activity at fine spatio-temporal scales is not usually used as an explanatory variable to compute population estimates. Moreover, population estimation or projection models are usually performed over large areas rather than small areas—in other words, entire states rather than parts of states, cities, or smaller areas within cities.

Thus, a critical open-research challenge is to use the building-activity information at a fine spatio-temporal scale as an additional explanatory variable, and to investigate its reliability as a population estimation variable. If the results of doing so are positive, then demographic change could be computed at a much finer spatial and temporal resolution than allowed by current data sources from the ABS.

1.2.3 Accessibility measurement

Accessibility is defined as the ‘ease of reaching desired destinations’ (Hansen 1959). It is a measure that joins the two aspects of land use and transportation, because it incorporates:

- where people are located
- which specific land-use destinations they wish to travel to
- how the mode of transport, the time of day, and the characteristics of a connecting route affect the travel time and cost of connecting an origin to a destination (Levinson 1998).

The larger part of the body of work in accessibility studies focusses on accessibility to jobs, employment, and labour markets, and is thereby focussed on measuring the efficiencies or inefficiencies connecting the residential and employment zones in a city, or the home–work relation (Cui and Levinson 2018; Deboosere et al. 2018; Iacono and Levinson 2017; Levinson 1998; Levinson et al. 2017; Sarkar et al. 2019; Wu et al. 2019).

The Accessibility Observatory at the University of Minnesota (<http://access.umn.edu/>) publishes a regular series called *Access across America*, where accessibility is measured for the approximately 11 million census blocks across the US. The results are published for all the major cities, and for the major modes of transport: walking, biking, transit, driving. The work has been used as an evidence-base by US state departments of transport and planning to study various aspects of:

- planning better land use
- planning better transport access
- studying and mitigating congestion.

In this work, we use the idea of accessibility measures to develop accessibility measures for social infrastructure as 'desired destinations', extending the ideas of accessibility to jobs and labour.

1.3 Research methods

The research was conducted by bringing together multiple datasets within a novel methodological framework. The data inventory is first described, followed by the main analytical methods.

1.3.1 Data inventory

The following datasets were used in the research:

- *Census of Population and Housing 2016* (ABS).
- *Census of Population and Housing 2011* (ABS).
- *PSMA Geoscape dataset*. The PSMA Geoscape dataset uses satellite imagery to track quarterly change in the built environment at the level of individual buildings. Every building with a roof area of more than 9m² is spatially mapped. At present, the database contains more than 15 million buildings across Australia. Each building is also mapped to a set of non-spatial features, including a land-use label—that is, whether the primary use of a building is residential, commercial, institutional, etc. For the purposes of this research, the built footprints of the priority growth areas chosen as case studies in Sydney, Brisbane and Perth were used for the analysis. The four timepoints at which this data was available are: August 2018, March 2019, July 2019, and October 2019. The study was able to track changes in built form occurring in a single year by spanning across these four time points.
- *School location data for the greater metropolitan regions of Sydney, Brisbane, and Perth*. These datasets provide the latitude, longitude, and address information for all the primary and secondary public schools across the states of NSW, Queensland and WA. The schools location data for the GMRs of Sydney, Brisbane and Perth were extracted.
- *Hospital location data for the greater metropolitan regions of Sydney, Brisbane, and Perth*. This dataset provides the latitude, longitude, and address information for all the Commonwealth-declared hospitals and health care centres across Australia. The location data for all hospitals and health care centres for the GMRs of Sydney, Brisbane and Perth were extracted.
- *Mesh-block-level travel-time data for the greater metropolitan regions of Sydney, Brisbane, and Perth*. This dataset covers the reachable areas from the centroid of each mesh block, from 5 minutes to 60 minutes, in 5-minute increments. The travel-time data includes walking, transit and driving modes. This was developed and computed using the median speed on road links data (Compass IoT), Open Street Map data, and GTFS data, for cars, walking, and transit modes.

1.3.2 Tracking residential supply and population growth

The research tracks changes in population growth and dwelling growth between the 2011 and 2016 census dates at the Statistical Area Level 2 (SA2), and then investigates the spatial signatures of *where* growth has occurred most prominently throughout the three metropolitan regions of Sydney, Brisbane, and Perth. It then employs the Geoscape data to track residential growth in the priority growth areas that are case studies, as outlined Table 1: Case study greenfield sites.

Table 1: Case study greenfield sites

City	Greenfield area of analysis	Rationale for inclusion as a case study site
Sydney	North-West Priority Growth Area	Fastest growing, largest, with dedicated priority growth areas
Brisbane	Yarrabilba, Ripley	Specific policy focus on accessibility and social infrastructure planning
Perth	North-West Corridor	Strong history of coordinating infrastructure growth and residential development

The research uses residential supply growth as an explanatory variable in a simple population growth model and shows that including the residential supply at a fine spatio-temporal scale in population forecasting is extremely relevant. Therefore, population-forecasting models should use fine-scale spatio-temporal information on completions to estimate population growth.

The independent variables that need to be tracked are:

- growth in population
- growth in density of dwellings
- changes in accessibility patterns
- correlations between the above points.

Following an understanding of the issues outlined in the literature review, the primary aim in the first phase of this research was to develop a fine-scale geographic tracking of the local hotspots of growth, in terms of both population and dwellings. At first, the research tracked these three independently, to take stock of the spatial distributions of population and dwelling distribution patterns at fine geographic scales.

a) Population growth profiles

The research tracked population growth by Statistical Areas Level 2 (SA2) by computing the gains or losses in population that have occurred between 2011 and 2016. The following approach is used, where D , the difference (gains or losses of population as a proportion of the base year), is calculated for each SA2:

$$D = (P_{2016} - P_{2011}) / P_{2011},$$

where P_{2016} and P_{2011} represent the respective populations of the years 2016 and 2011.

A methodological complication arose, as the geography definitions of SA2 areas in the two census periods were different, and the 2016 definitions were different to the 2011 definitions, as different areas were merged, split or new areas were created. Also, some existing areas had name changes.

The ABS provides correspondence files that define how 2011 data can be projected onto 2016 geography definitions. The research has employed the use of these correspondence files to recompute the 2011 populations for each SA2 by the 2016 geography.

In other words, all the area definitions were standardised to the 2016 definitions, and the correspondences provided by the ABS were used to recompute the 2011 populations—or later dwelling distributions (see below)—in accordance with the 2016 geography definitions, so that the above computation could be performed. Results in Section 2 show the 2011 and 2016 population density maps for Sydney, Brisbane and Perth, as well as the corresponding difference maps, where the quantity D has been visualised.

b) Dwelling growth profiles

Similarly, the research has tracked dwelling density growths by SA2, by computing the gains or losses in dwellings that have occurred between 2011 and 2016. The following approach is used, where D , the difference (gains or losses of population as a proportion of the base year) is calculated for each SA2:

$$D = (d_{2016} - d_{2011}) / d_{2011},$$

where d_{2016} and d_{2011} represent the respective total number of dwellings in each SA2 for the years 2016 and 2011. Dwelling densities for 2011 and 2016 were also computed by:

- dividing the total numbers of dwellings per SA2 by the area of the SA2, and
- dividing the total number of dwellings by the population of the SA2.

The same pattern of computing correspondence was followed as described earlier, and all 2011 geographies and data were recomputed to equivalent 2016 geographies. Results in Section 2 show the 2011 and 2016 dwelling density maps for Sydney, Brisbane and Perth, (by area and by population) as well as the corresponding difference maps, where the quantity D has been visualised.

c) Tracking growth from the built environment

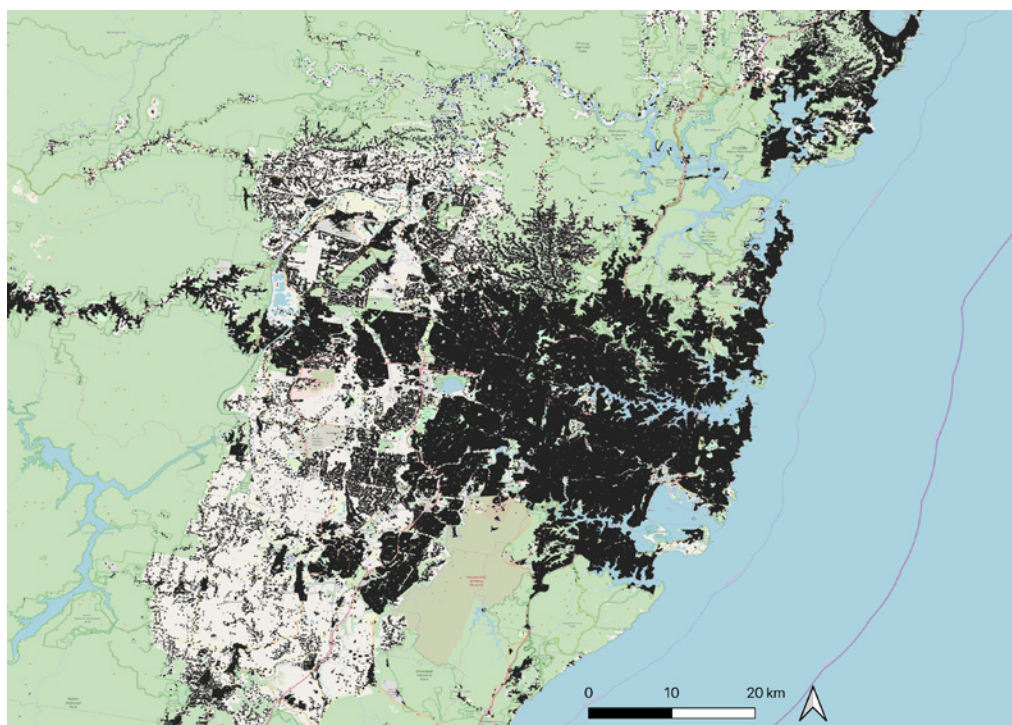
The coarse timescale of the ABS census data masks the rapid population and residential infrastructure growth that occurs in some areas in near-real time. This growth is better captured by the PSMA Geoscape dataset, which uses satellite imagery to track change in the built environment at the level of individual buildings. Every building with a roof area larger than 9m² is spatially mapped, and at present the database contains more than 15 million buildings across Australia. Each building is also mapped to a set of non-spatial features including a land-use label: residential, commercial, institutional, etc.

Figure 1: Snapshot of PSMA Geoscape buildings data, August 2018



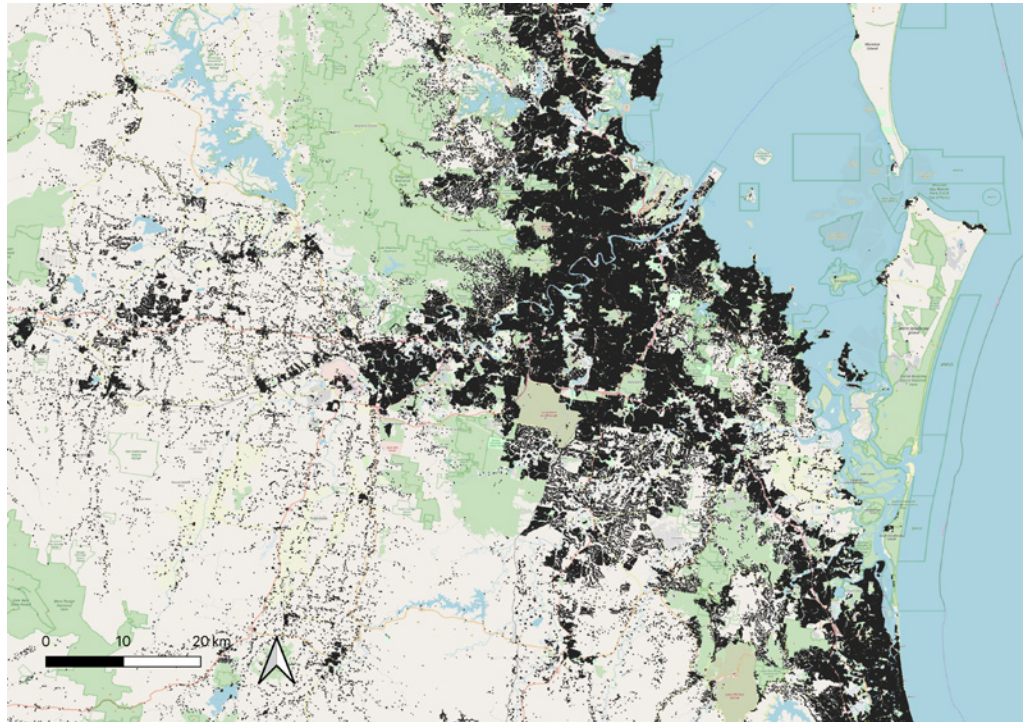
Source: Author generated using data from PSMA Geoscape data, 2018-2019.

Figure 2: Sydney PSMA Geoscape data



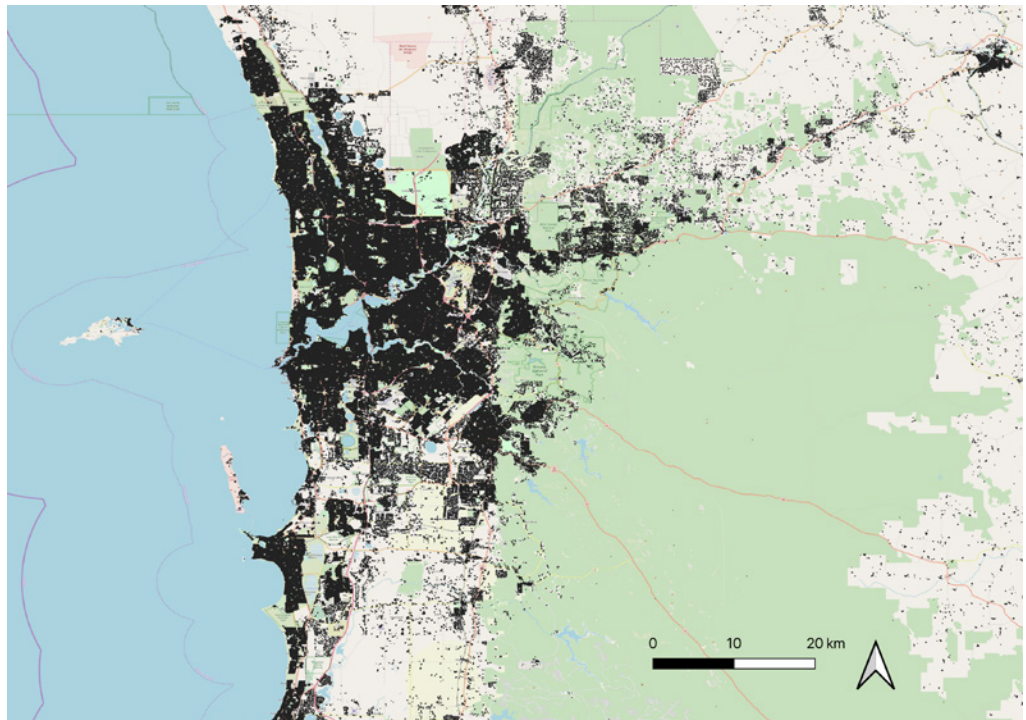
Source: Author generated using data from PSMA Geoscape data, 2018-2019.

Figure 3: Brisbane PSMA Geoscape data



Source: Author generated using data from PSMA Geoscape data, 2018-2019.

Figure 4: Perth PSMA Geoscape data



Source: Author generated using data from PSMA Geoscape data, 2018-2019.

Figure 1 shows a visual snapshot of the PSMA Geoscape buildings dataset, and the individual snapshots for the three cities are also shown: Sydney (Figure 2), Brisbane (Figure 3), and Perth (Figure 4). All the buildings were extracted, and aggregated counts of these were done at the mesh-block level. By aggregating these to the mesh-block level, we can establish the correspondence between the estimated ABS populations at the mesh-block level and the building count at the mesh-block level for 2018-2019. This enables us to make inferences about population growth from the growth in the number of structures.

1.3.2.1 Population estimation method

Satellite imagery is an opportunity to track spatial changes in population at a much finer timescale than the five-yearly census. Measured at the building level, this growth can better capture the highly localised and 'bursty' nature of urban residential development.

This section details a simple procedure for estimating population based on growth in the built environment.

Since building growth is a *leading indicator* of population growth rather than a direct measure, it is necessary to make assumptions about the relationship between the two. In this process, the most recent census data, $P_{2016,i}$ is taken as the baseline population for each mesh block, i . The household size for that mesh block is taken to be the person count divided by the dwelling count from the most recent census:

$$H_{2016,i} = P_{2016,i} / D_{2016,i}$$

Mesh-block household size is assumed to be time invariant in this method, if in the short term, demographic characteristics remain more or less stationary. The method is primarily intended to be applied to residential mesh blocks, but the ratio of census dwellings, $D_{2016,i}$ to buildings, $B_{2016,i}$ (measured from the PSMA Geoscape data taken closest to the census year) represents the ratio of buildings that are residential,

$$R_{2016,i} = D_{2016,i} / B_{2016,i}$$

The growth in buildings is the key input: it is the difference in the number of buildings between the year of interest, t , and the PSMA Geoscape data taken closest to the census year:

$$\Delta B_i = B_{t,i} - B_{2016,i}$$

Combining these terms, the estimated population of each mesh block, i , in year t is given by

$$P_{t,i} = P_{2016,i} + \Delta B_i * R_{2016,i} * H_{2016,i}$$

which simplifies to

$$P_{t,i} = P_{2016,i} * \frac{B_{t,i}}{B_{2016,i}}$$

We present this model as proof of concept to show that buildings growth is a variable that should be incorporated in more formal demographic population estimation models, along with births, deaths, and migrations. Our results are compared against the ABS estimated resident population (ERP) figures for validation, and the results of applying even the preliminary model presented here (without incorporating births, deaths, or migration) show that buildings growth and dwellings growth is a critical lead indicator for population estimates.

1.3.3 Accessibility analysis

The research in this phase takes the population estimate values from the previous step, and then computes accessibility to various social infrastructure types—schools and hospitals—for various time thresholds and modes at the mesh-block level, which is the finest geography region defined by the ABS, and measures:

- 10-minute and 20-minute walking accessibility
- 30 minutes transit accessibility
- 30 minutes car accessibility.

Schools and hospitals were selected for focussed accessibility analysis measurement for two reasons:

1. Education and health facilities are critical items of social infrastructure.
2. Schools and hospitals are significant items of infrastructure. They need large sites and investment, and supporting infrastructure of transport, childcare and health services is often organised around them.

Detailed spatial profiles for accessibility are computed for the entire metropolitan regions of Sydney, Brisbane, and Perth.

Finally, accessibility profiles of the focus priority growth areas are compared with both the metropolitan-wide average profile and the maximum metropolitan-wide profile to determine lag hotspots—that is, to determine whether a particular growth area is performing at, above or below the metropolitan-wide standard.

Although the methodology is demonstrated only for schools and hospitals, the methods developed are more standard and general. The same pipeline of computation can potentially be used for any other social infrastructure type if their locational data is made available. This has potential policy implications, as the same computations can be employed in different ways and for different aims at the local or state levels.

This study computes accessibility to social infrastructures at the mesh block (MB) level, which is the finest granularity spatial unit defined within the existing Australian Statistical Geography Standard (ASGS). The accessibility computations are based on realistic travel time between the mesh blocks in which the social infrastructures are located. Accessibility is defined as follows:

$$A_{i,m} = \sum_{j=1}^J O_j f(C_{ij,m}),$$

$$f(C_{ij,m}) = \begin{cases} 1, & \text{if } C_{ij,m} \leq t \\ 0, & \text{if } C_{ij,m} > t \end{cases}$$

where, $A_{i,m}$ is the accessibility to opportunities at location i using travel mode m , which is a function of the number of opportunities available at all other locations j , multiplied by a function of the time cost of travel between i and j , denoted as $f(C_{ij,m})$, using travel mode m . This function is defined as a threshold function, where the value of $f(C_{ij,m})$ is 1 if the travel time between locations i and j is within a defined threshold (say 20 minutes by walking) and 0 otherwise. This is computed for each pair of locations by fixing i , and then summing the values for all other locations j , which finally provides the accessibility measure for each i .

Two types of accessibility are computed.

First, taking the centroid of a mesh block as the origin, we compute how many schools or hospitals can be reached within a particular travel-time threshold by a particular mode. Thus, a mesh block in a choropleth map is marked by a colour, where the colour denotes the number of schools and hospitals that can be reached within the travel-time threshold on a particular mode.

Second, taking the school or hospital as destination, we compute the population that can access this destination within a particular travel-time threshold using a particular mode. Thus, a school or hospital as a point is marked by a colour where the colour denotes the number of people who can reach this school or hospital within a particular time threshold using a particular mode.

Car accessibility is calculated from a mesh-block level travel-time matrix. Car travel times between locations are calculated based on the road network from OpenStreetMap, and the link speed data from Compass IoT for November 2019. For the walking and transit modes, accessibility is measured using the isochrone coverage area of each mesh block under different travel-time thresholds. Travel time for transit covers all stages of a transit trip, including:

- on-board travel time
- waiting time
- walking phases during the station access
- exiting (or egress)
- necessary transfers.

OpenStreetMap provides the pedestrian network for both walking and transit. The isochrone coverage area originating from the centroid of each mesh block is drawn by OpenTripPlanner (OTP). These coverage areas are then overlaid with the point layer of all destination mesh-block centroids; those destination mesh-block centroids covered within the isochrone are marked as 'reachable' from the origin mesh block.

The travel-time matrix for car and the isochrone coverage areas for walking and transit are stored for later use. The accessibility methodology used for this study is versatile and can be easily adopted for measuring accessibility to any other types of social infrastructure.

1.3.4 Panel discussion

To determine the range of potential ways in which the methods and tools could be employed by the local and state governments, a panel discussion was conducted with three to five representatives from each of the three cities. It was attended by 15 participants. It included representatives from departments of transport and infrastructure planning, as well as private practitioners operating in the social infrastructure space. Interviews were also conducted with two other experts who were unable to attend on the day.

The panel discussion and interviews were then analysed and qualitatively coded into a set of themes that provide future insights into how the set of methods and tool may be employed for policy coordination and for informing planning of social infrastructure.

2. Dwellings, residential built form, and change and population estimation

- This section analyses the population and dwellings growth profiles across Sydney, Brisbane and Perth, performs fine spatial and temporal scale analysis of building growth in greenfield development areas in these three cities and, finally, presents a population estimation model in which building and development activity is included as an explanatory variable.
- First, population growth and dwellings growth profiles are computed by comparing the 2011 census data with the 2016 census data at the SA2-level geography for the greater metropolitan regions (GMRs) of Sydney, Brisbane, and Perth.
- Second, three greenfield development areas are identified in each of the three cities as case studies, and detailed analyses of buildings growth profiles are performed using the Geoscape data. Building point data is aggregated to the mesh-block level, and quarterly longitudinal analysis of buildings growth is performed for residential and other mesh-block types for a period of one year: 2018–2019.
- Finally, using the buildings growth as an explanatory variable, an illustrative model of population estimation is proposed. It is shown that the projections estimated using this model match well with the ERP data from the ABS. Further, the growth patterns are shown to be heterogeneous and non-contiguous—even in priority planned areas.
- In conclusion, it is proposed that tracking residential and building growth at the finest possible spatial scale is critical for policy and planning, and that population and demographic models can be enriched and made more accurate and reliable by including buildings and residential growth as explanatory variables in models.

This section addresses RQ1:

How is the spatial density and distribution of social infrastructure correlated with population density and growth, new residential supply, and accessibility?

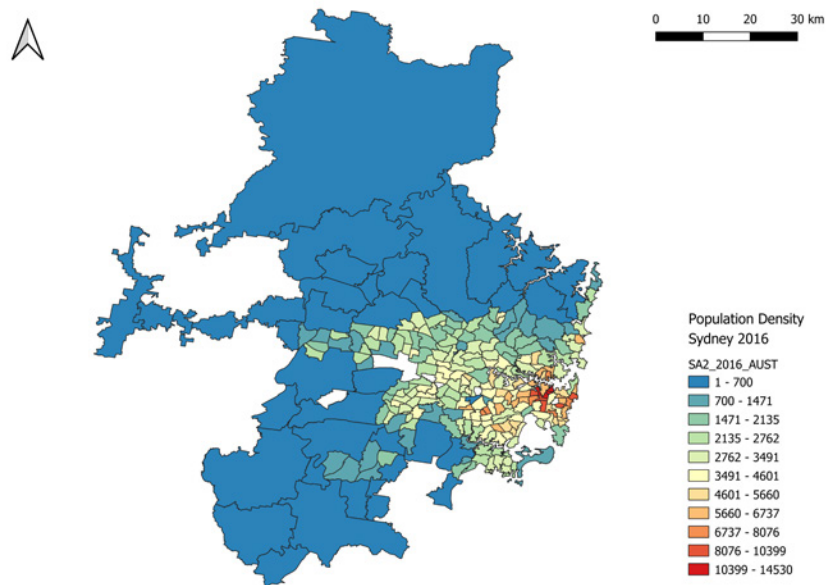
2.1 Understanding spatial population and dwelling growth profiles for Sydney, Brisbane, and Perth, 2011–2016

This section presents findings on tracking population and dwelling growth profiles using 2011 and 2016 census data for the GMRs of Sydney, Brisbane, and Perth, using the methodology described in Section 1.3.2. A series of maps are presented, showing the longitudinal pictures of growth profiles. The results are then discussed.

2.1.1 Population growth profiles

Sydney: population growth profile

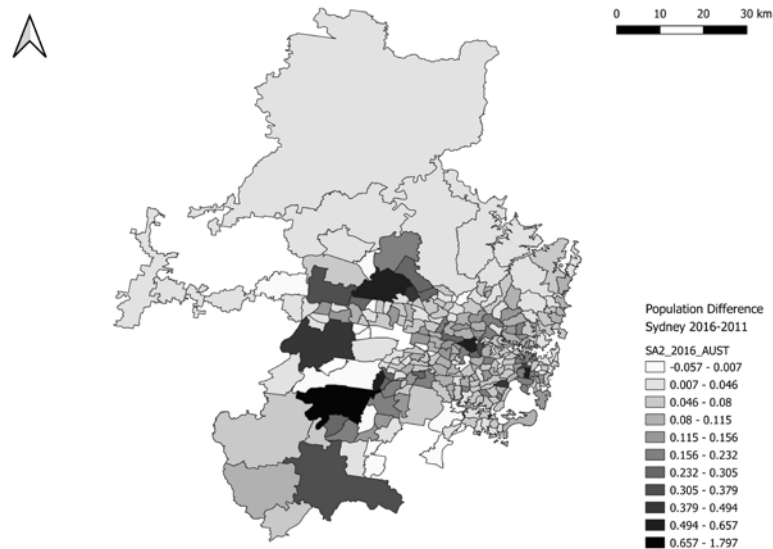
Figure 5: Population growth profile for Sydney at SA2 level



Note: Population density 2016. Numbers are in persons per square kilometre.

Source: Author generated using data from ABS 2016 census data.

Figure 6: Population difference for Sydney, 2016–2011



Note: The difference between the 2016 and 2011 populations is expressed as a proportion of the 2011 populations in each SA2.

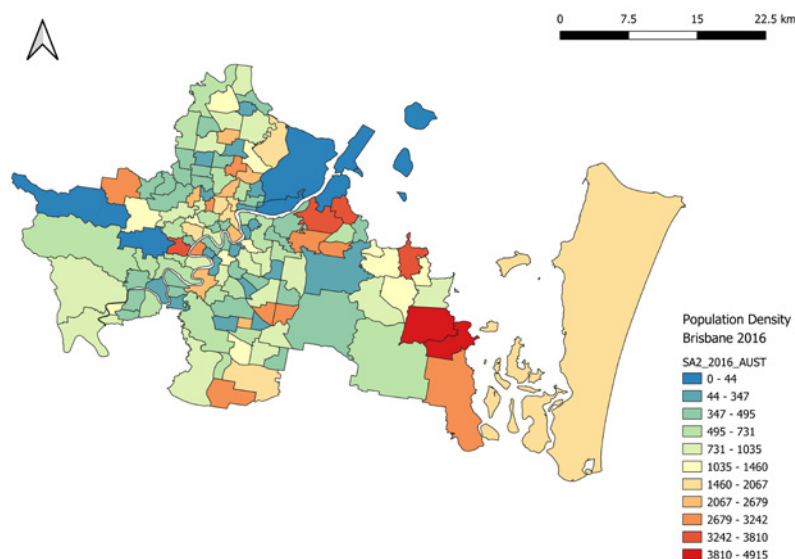
Source: Author generated using data from ABS 2011 and 2016 census data.

For Sydney, a clear spatial signature shows that population growth (Figure 5 and Figure 6) is mainly occurring in the western and southern parts of the metropolitan region, especially correlating with growth priority areas, precincts and corridors.

The northern and eastern parts of the metropolitan region register almost no noticeable growth (except for hotspots of densification in existing brownfield areas), even though the existing population densities in the north and east are comparable to the south and west, and population density is roughly aligned along the traces of transit infrastructure.

Brisbane: population growth profile

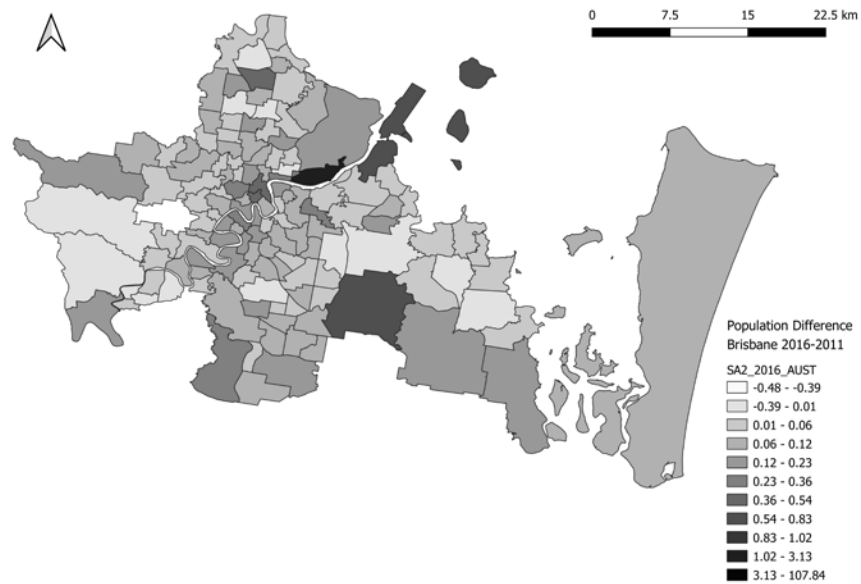
Figure 7: Population growth profile for Brisbane at SA2 level



Note: Population density 2016. Numbers are in persons per square kilometre.

Source: Author generated using data from ABS 2016 census data.

Figure 8: Population difference for Brisbane, 2016–2011



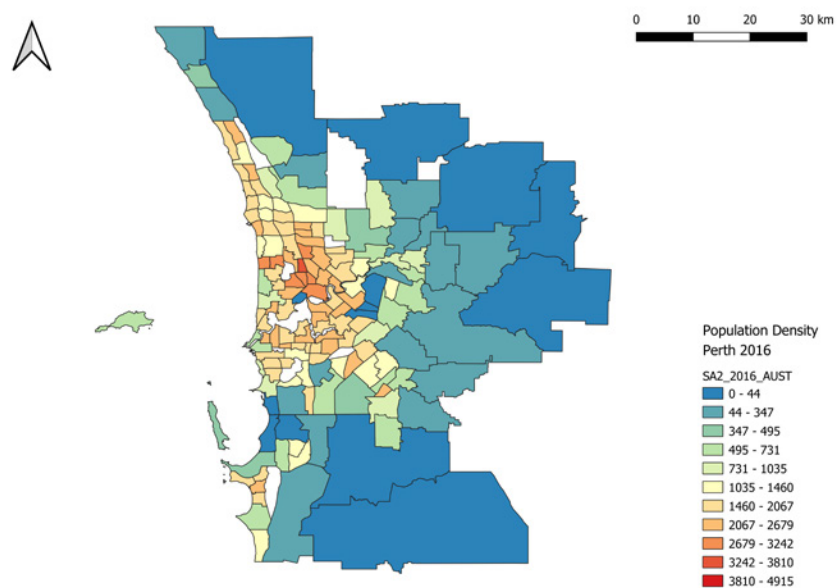
Note: The difference between the 2016 and 2011 populations is expressed as a proportion of the 2011 populations in each SA2.

Source: Author generated using data from ABS 2011 and 2016 census data.

For Brisbane (Figure 7 and Figure 8), a clear spatial signature shows that most pronounced population growth has occurred in a scattered and bursty or clustered manner across the metropolitan region. A few regions in the west, centre and north of the metropolitan region registered a negative change. However, there is visible change in the growth priority areas.

Perth: population growth profile

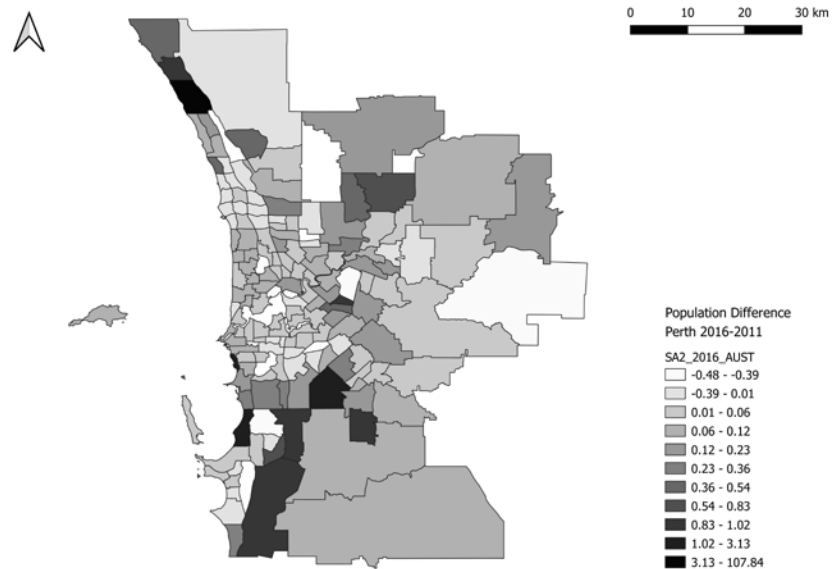
Figure 9: Population growth profile for Perth at SA2 level



Note: Population density 2016. Numbers are in persons per square kilometre.

Source: Author generated using data from ABS 2016 census data.

Figure 10: Population difference for Perth, 2016–2011



Note: The difference between the 2016 and 2011 populations is expressed as a proportion of the 2011 populations in each SA2.

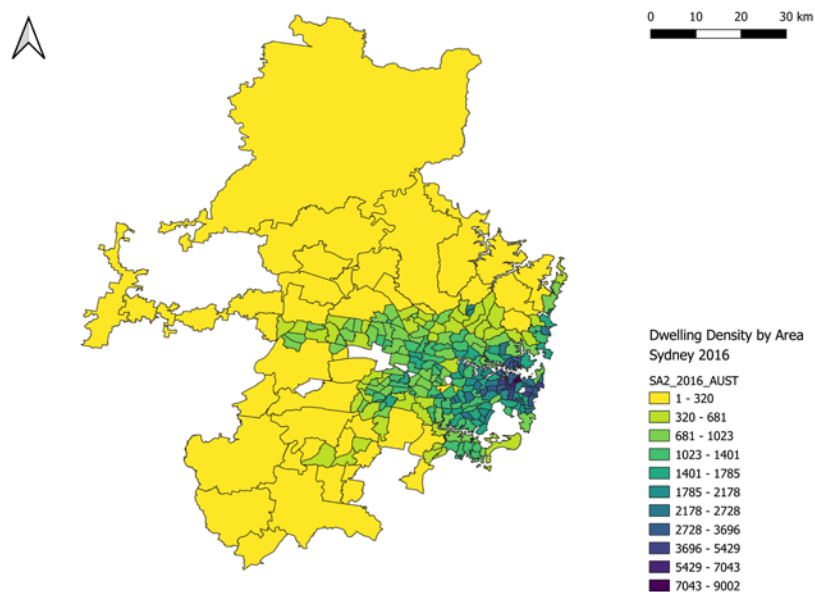
Source: ABS 2011 and 2016 census data.

A clear spatial signature in Figure 9 and Figure 10 shows that most pronounced population growth has occurred north-west and south-west of the metropolitan region of Perth. Regions in the east register a considerably negative change in population.

2.1.2 Dwelling growth profiles

Sydney: dwellings growth profile

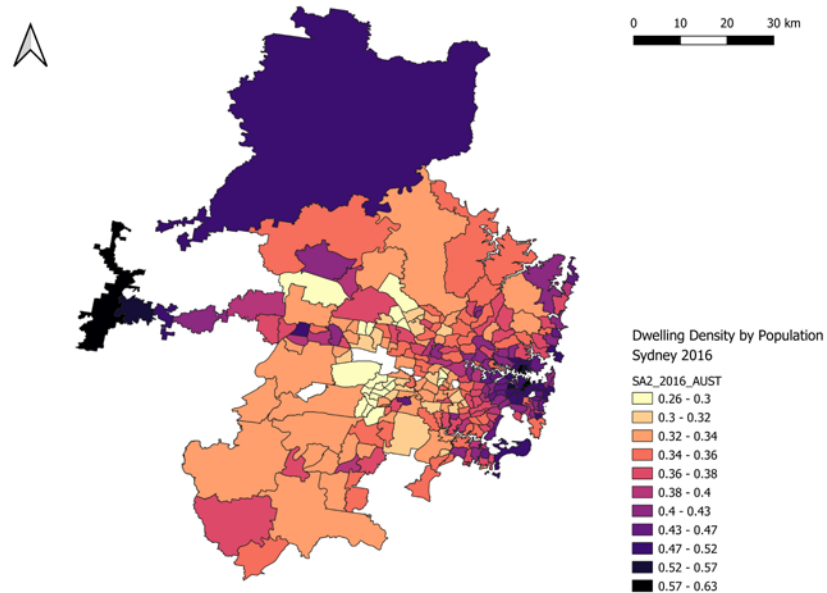
Figure 11: Dwelling densities by area for Sydney, 2016



Note: Dwelling density 2016. The numbers are dwellings per square kilometre.

Source: ABS 2016 census data.

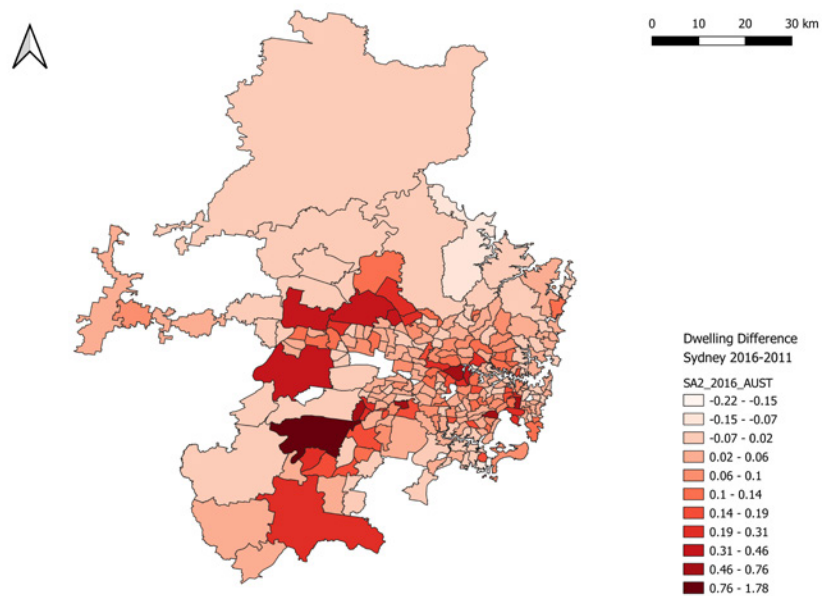
Figure 12: Dwelling densities by population for Sydney, 2016



Note: The numbers are total number of dwellings divided by total SA2 population, giving a dwelling density per capita.

Source: Author generated using data from ABS 2016 census data.

Figure 13: Dwelling difference for Sydney, 2016–2011

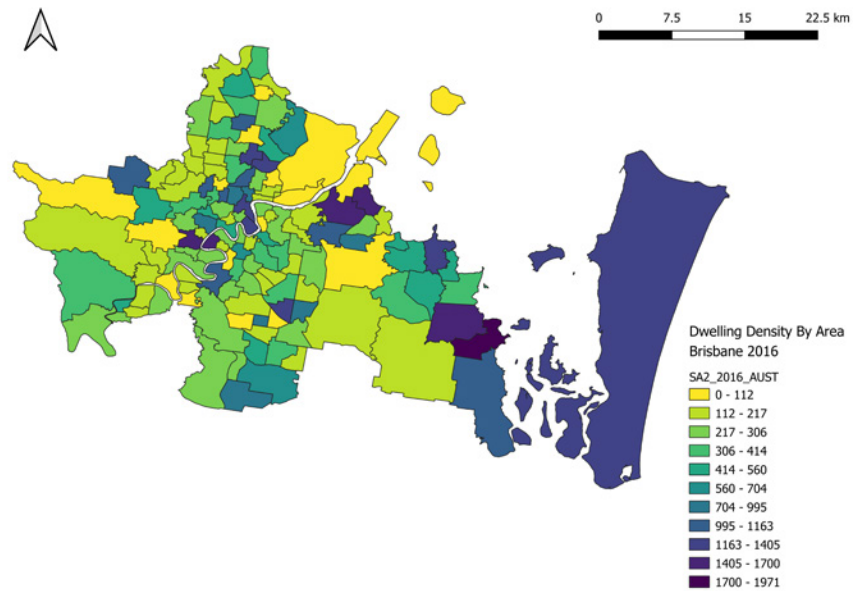


Note: The difference between the 2016 and 2011 dwellings is expressed as a proportion of the 2011 dwellings in each SA2.

Source: Author generated using data from ABS 2011 and 2016 census data.

Brisbane: dwellings growth profile

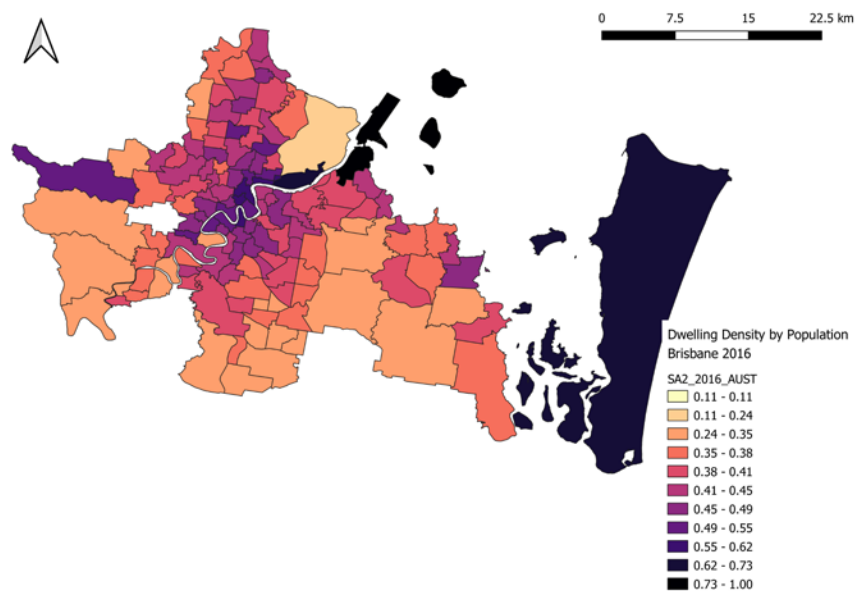
Figure 14: Dwelling densities by area for Brisbane, 2016



Note: Dwelling density 2016. The numbers are dwellings per square kilometre.

Source: Author generated using data from ABS 2016 census data.

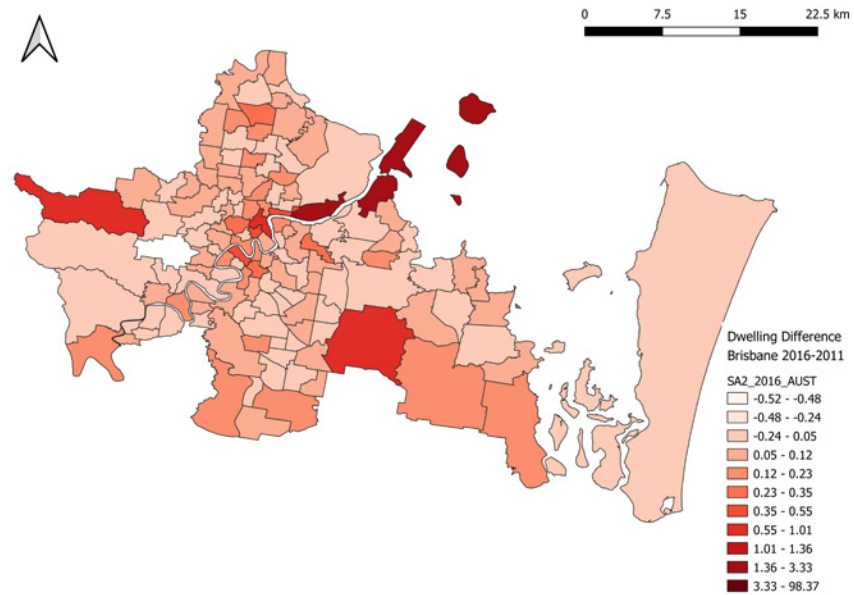
Figure 15: Dwelling densities by population for Brisbane, 2016



Note: The numbers are total number of dwellings divided by total SA2 population, giving a dwelling density per capita.

Source: Author generated using data from ABS 2016 census data.

Figure 16: Dwelling difference for Brisbane, 2016–2011

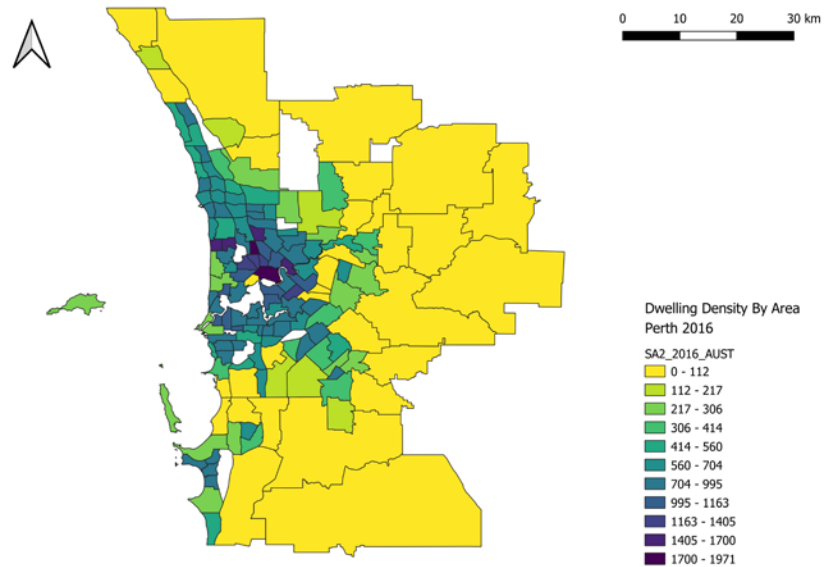


Note: The difference between the 2016 and 2011 dwellings is expressed as a proportion of the 2011 dwellings in each SA2.

Source: Author generated using data from ABS 2011 and 2016 census data.

Perth: dwellings growth profile

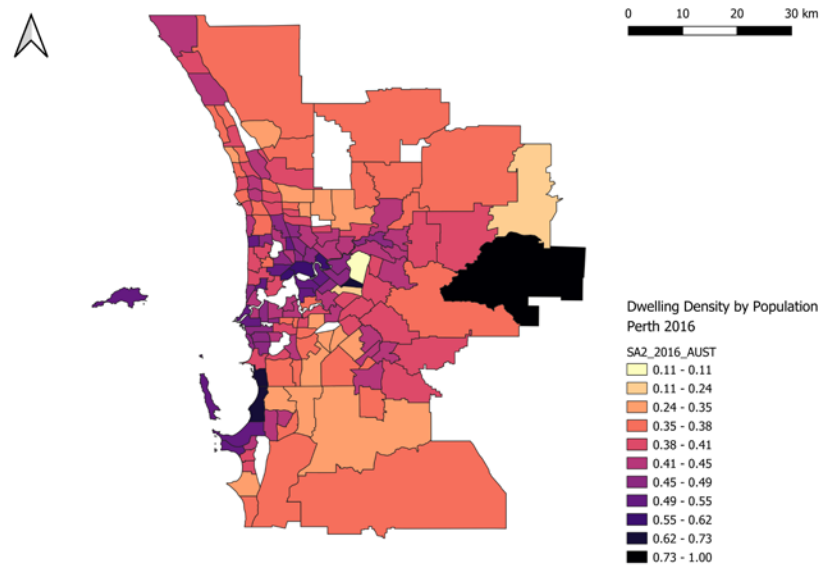
Figure 17: Dwelling densities by area for Perth, 2016



Note: Dwelling density 2016. The numbers are dwellings per square kilometre.

Source: Author generated using data from ABS 2016 census data.

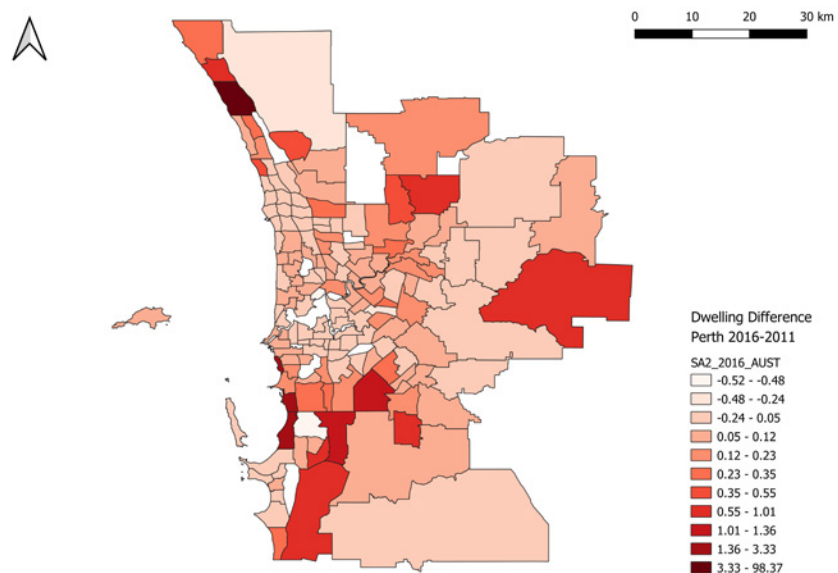
Figure 18: Dwelling densities by population for Perth, 2016



Note: The numbers are total number of dwellings divided by total SA2 population, giving a dwelling density per capita.

Source: Author generated using data from ABS 2016 census data.

Figure 19: Dwelling difference for Perth, 2016–2011



Note: The difference between the 2016 and 2011 dwellings is expressed as a proportion of the 2011 dwellings in each SA2.

Source: Author generated using data from ABS 2011 and 2016 census data.

The dwelling densities by area for all three cities (Figure 11, Figure 14 and Figure 17) show that there is a steady gradient drop-off in dwelling densities with distance from the city centre. There are also hotspots of development in inner-city areas.

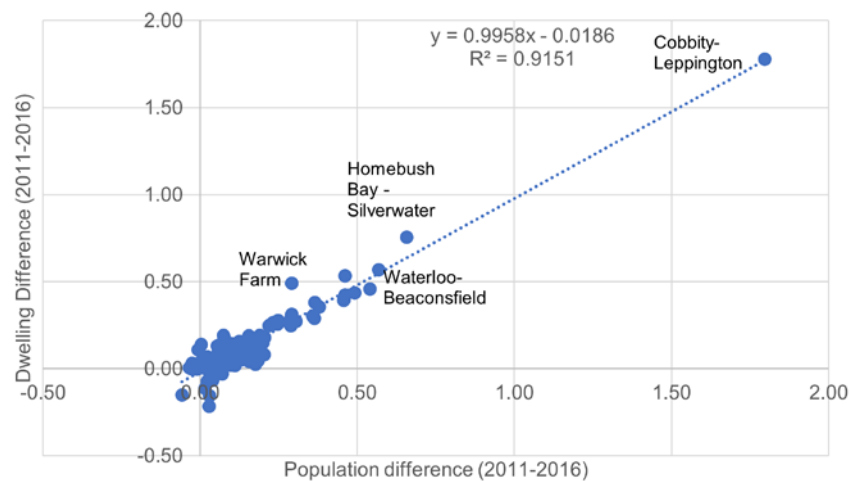
The dwelling densities by population (Figure 12, Figure 15 and Figure 18) clearly show that higher densities are correlated with the inner-city areas and the main transport and transit corridors, but in general low densities are correlated with the newly expanding outer fringes. This is a critical observation for the delivery of social infrastructure. As discussed in Section 1.1, some social infrastructure sectors might need a critical mass of population and dwelling densities; inefficiencies, delays or lags may arise if this critical mass is not reached. Some of the outer areas of the maps are dark because the number of dwellings there is higher when compared to a much sparser population; this indicates lower populations in these areas rather than a high number of dwellings.

Figure 13, Figure 16, and Figure 19 show the dwelling difference maps for Sydney, Brisbane, and Perth over the period 2016–2011, showing a proportional change by SA2 areas. The inner-city hotspots of development are clearly visible. Also visible very clearly is the growth in the respective priority growth areas in all the cities.

Correlations: population growth and dwellings growth

As is clearly visible in the maps, but what can be further confirmed statistically, is that buildings or dwellings growth can therefore be used as a leading indicator for population growth. There is a clear strong and positive correlation observed, for all three cities, between population and dwellings growth. Figure 20 below exemplifies this observation for Sydney, but the results are identical across the three cities. Note that the slope of the graph is nearly 1, with a very high R^2 value, confirming the finding.

Figure 20: Correlation between population growth and dwellings growth, Sydney



Source: Author generated using data from ABS 2016.

Figure 20 shows a clear positive correlation between the population difference and dwellings difference in Sydney. The case of Sydney is particularly interesting, because some specific areas emerge as hotspots of high growth. The SA2 Cobbitty–Leppington, in the South West Growth Area, leads the growth by an extremely large margin. Warwick Farm is in the North West Priority Growth Area. However, not all of the other high-growth areas are in the North West or South West Priority Growth areas. Despite this, the overall analysis shows the clear spatial signature that the outer fringe of Sydney is recording both large-scale population growth and large-scale dwellings growth in spatially discontinuous locations.

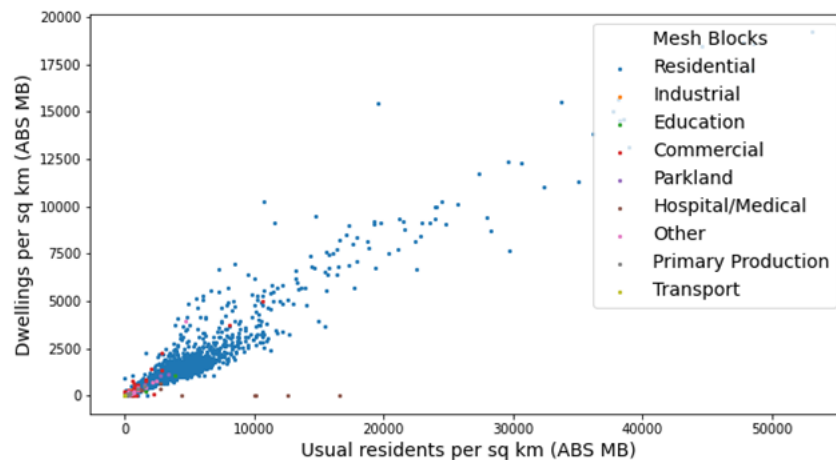
The analysis highlights the intermittent and localised nature of private development, even in priority growth areas. A clear fine-scale geographic understanding of occurring patterns of growth provides important empirical evidence for scheduling and delivery of various social infrastructure sectors, as well as for wider spatial planning.

2.2 Tracking growth from built-environment data

This section presents results from the analysis of the Geoscape dataset used to track near-real time (quarterly) fine-scale spatial and temporal scale growth in the built environment, focussing especially on the case study priority growth areas in Sydney, Brisbane and Perth.

Sydney

Figure 21: Correlation between dwelling density and population density at the mesh-block level, Sydney



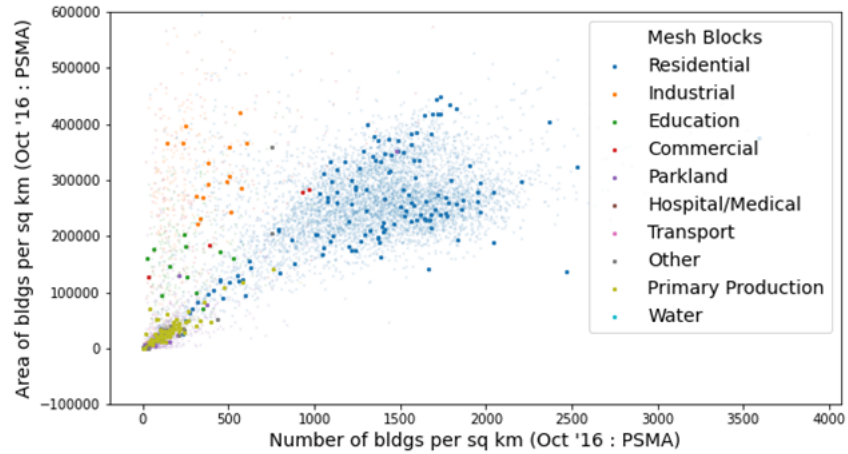
Note: The density of dwellings scales with population density over a range of densities, indicating that building growth can be used as proxy for population growth. MB = mesh block.

Source: Author generated using data from ABS, 2016.

Figure 21 shows the correlation between ABS dwelling density and population density at the mesh-block level, showing that as population densities increase, so does building density. Each dot is a mesh block, with a different colour for each 2016 ABS mesh-block category. Interestingly, the number of residential mesh blocks far exceeds all other land-use categories. The spread of the dots also shows that for the same population served, the density of residential buildings counted per mesh block could show large variations.

The relationship between building and population densities highlights the transformative change that can occur during rapid growth, where not only the number of residents increases but also the way in which they live changes. Considering the area of the residential buildings—which is another data attribute provided per building in the PSMA dataset—as well as the number of dwellings, can capture the transformation of greenfields into single-family homes or higher-density housing. Even within the North-West Priority Growth Area, there is scatter in the relationship between built-form density (square metres per square kilometre) and dwelling density (buildings per square kilometre), as shown in Figure 22.

Figure 22: Correlation between number of buildings per km² and the area of buildings per km², Sydney



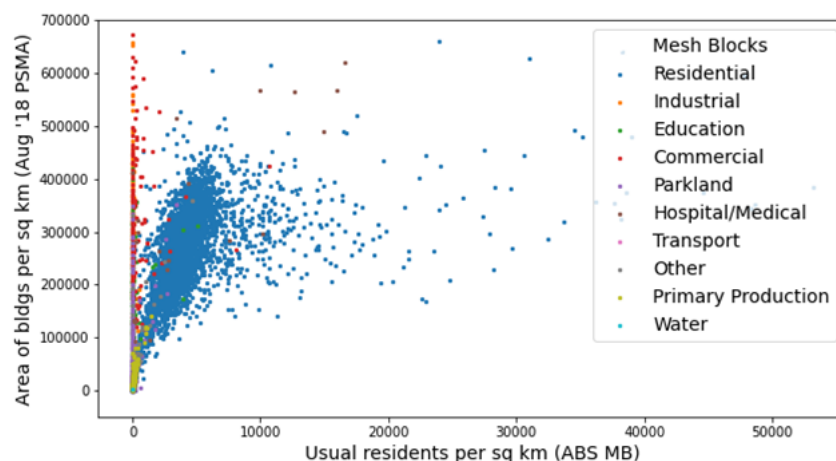
Source: Author generated using data from Geoscape.

In Figure 22 the scatter in the relationship of blue dots encompasses the range of residential built forms, including apartments, terraces, and detached housing. Given the same number of buildings, the building footprints (in square metres) could have large variation.

As the built form changes, the relationship between population density and built-form density also shifts. This represents an important transformation, as the various density measures are strongly tied to accessibility to jobs and infrastructure. Mesh blocks with very high population densities still have moderate building footprints because those mesh blocks are dominated by apartment buildings.

Even within residential neighbourhoods, there is some scatter in the relationship between built-form density and population density, as shown in Figure 23.

Figure 23: Relationship between density of buildings in each NWPGA mesh block (ABS) and the number of usual residents (PSMA)



Note: MB = mesh block; NWPGA = North-West Priority Growth Area.

Source: Author generated using data from ABS 2016 and Geoscape.

Figure 23 shows the results of each mesh block in the North-West Priority Growth Area. The scatter in the blue dots indicates that there is some variety in the residential form even within this limited geography. This includes variation in household size, dwelling density and dwelling size.

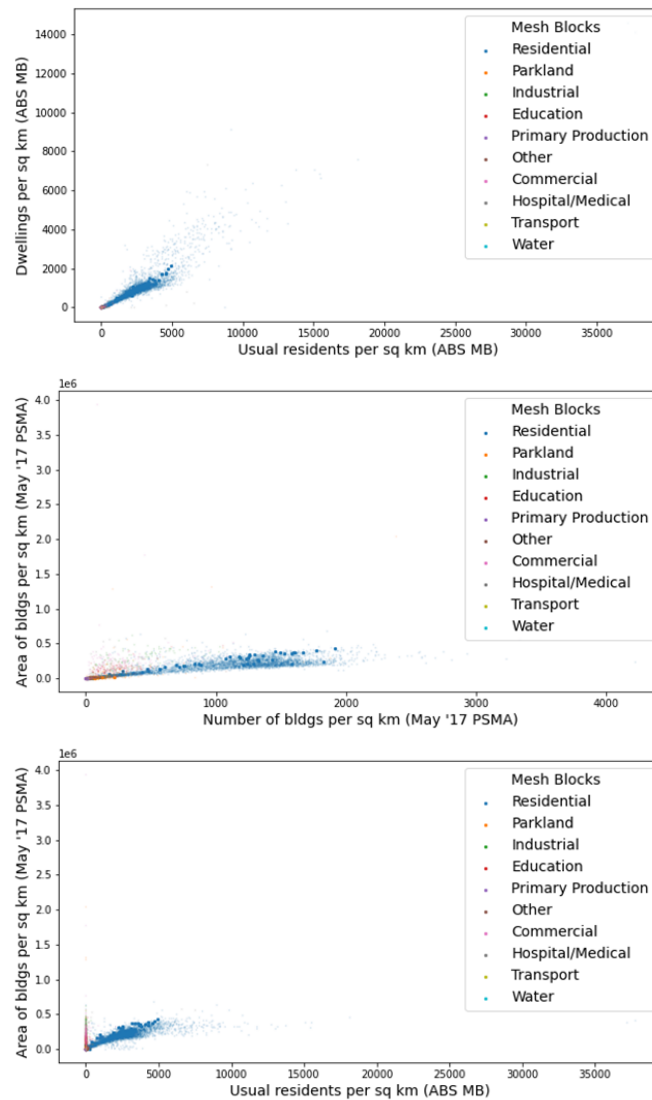
Brisbane

The relationship between built environment and population density is shown for the local government areas (LGAs) surrounding the priority development areas in Brisbane.

In Figure 24, the tight correlation shows the homogeneity of the region, as the mixture of housing stock is consistent across the residential mesh blocks. The bold dots show mesh blocks that land within the Ripley Valley and Yarrabilba priority development areas (PDAs). The ABS data show that rapid population growth had already occurred in some mesh blocks, as the PDA mesh blocks include those with the highest number of residents.

A tight relationship (Figure 24 top) between built form and population implies a homogeneous housing stock for this area. The size of the housing stock (Figure 24 middle) is consistent across the mesh blocks. The distinction between residential and other buildings (Figure 24 bottom) shows that proportionality between population and built form area is only valid for residential mesh blocks.

Figure 24: Relationship between population and residential buildings, Brisbane



Note: MB = mesh block.

Source: Author generated using data from ABS and Geoscape.

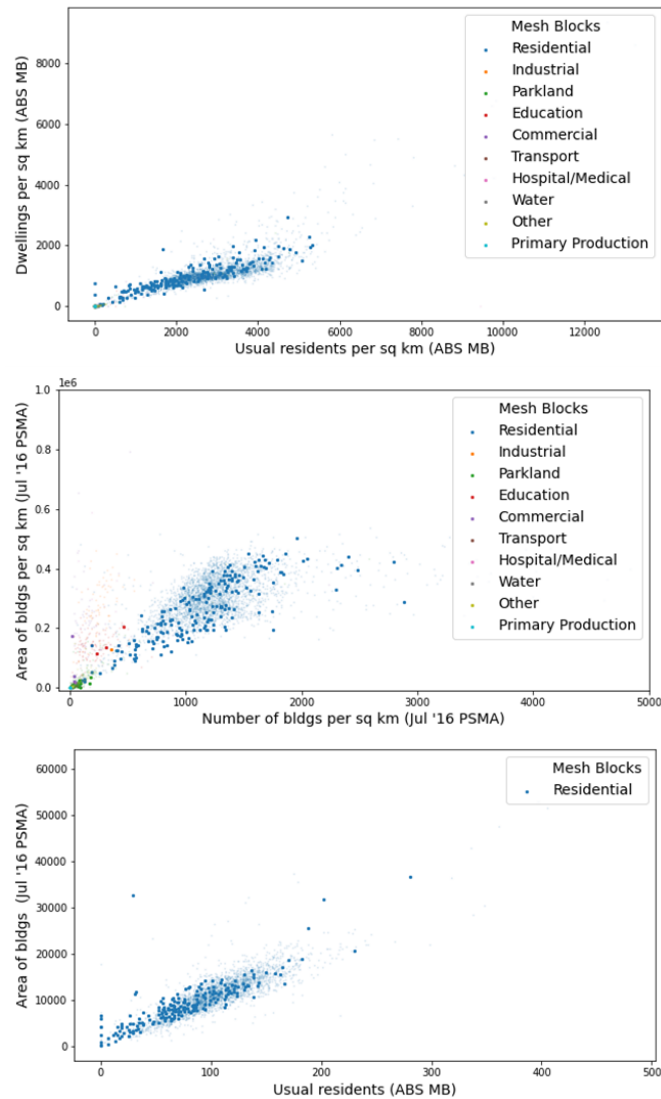
Perth

The relationship between population and buildings for each mesh block in Perth shows the homogeneity of built form. The tight relationship between dwellings and residents (Figure 25, top) shows that household size is consistent across the region.

The larger scatter and hint of bifurcation in the comparison of building area and number of buildings (Figure 25, middle) shows some heterogeneity in the housing stock—for example, apartments and single-family detached dwellings.

Most residential mesh blocks follow a clear relationship between the number of usual residents and the built footprint (Figure 25, bottom).

Figure 25: Relationship between population and residential buildings showing patterns of homogeneity in household size and heterogeneity in housing type, Perth



Note: MB = mesh block.

Source: Author generated using data from ABS and Geoscape.

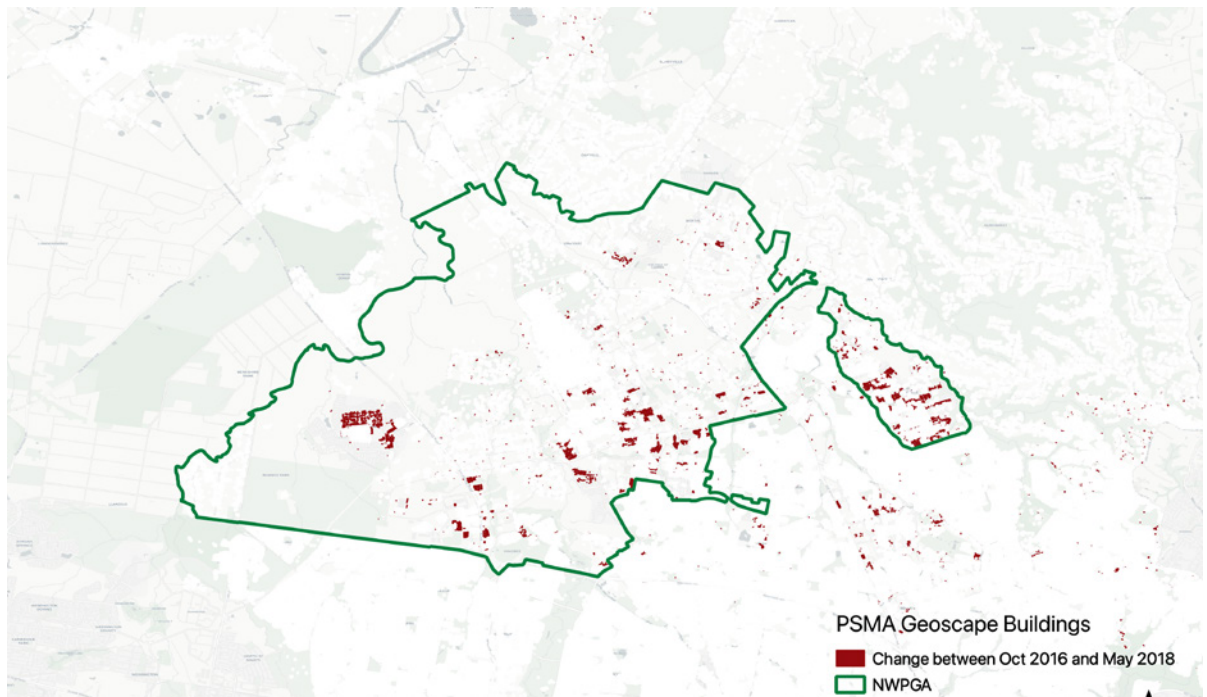
2.2.1 Change in built-form density

At the city scale, quarterly or even yearly changes in built form are not detectable. But the change becomes clear when focussing on growth areas, at the level of individual buildings.

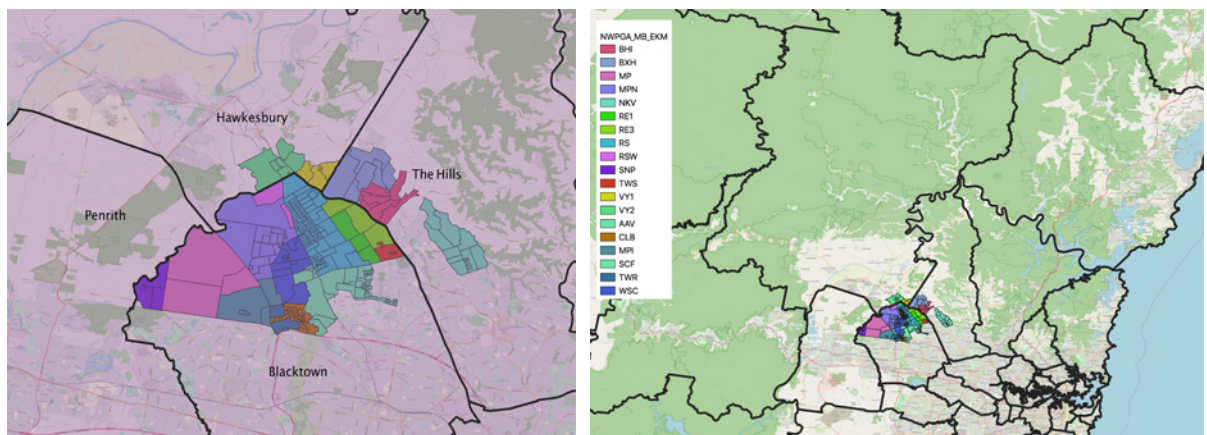
Sydney

Figure 26 and Figure 27 show that local bursts of new residential building activity happen heterogeneously, at an extremely local scale. The red residential buildings have all appeared within an 18-month period, October 2016 –May 2018. This shows that tracking the greenfield growth areas longitudinally can provide a clear snapshot of how residential growth patterns are progressing in a local area—which could be critical empirical information for the planning and delivery of social infrastructure.

Figure 26: NWPGA: building growth (top), in mesh blocks and principal LGAs (bottom left), and location within Sydney GMR (bottom right)



Note: The red residential buildings have all appeared within 18 months, October 2016–May 2018.



Source: Author generated using data from ABS and Geoscape.

Figure 27: A close-up of the Marsden Park area, NWPGA, Sydney

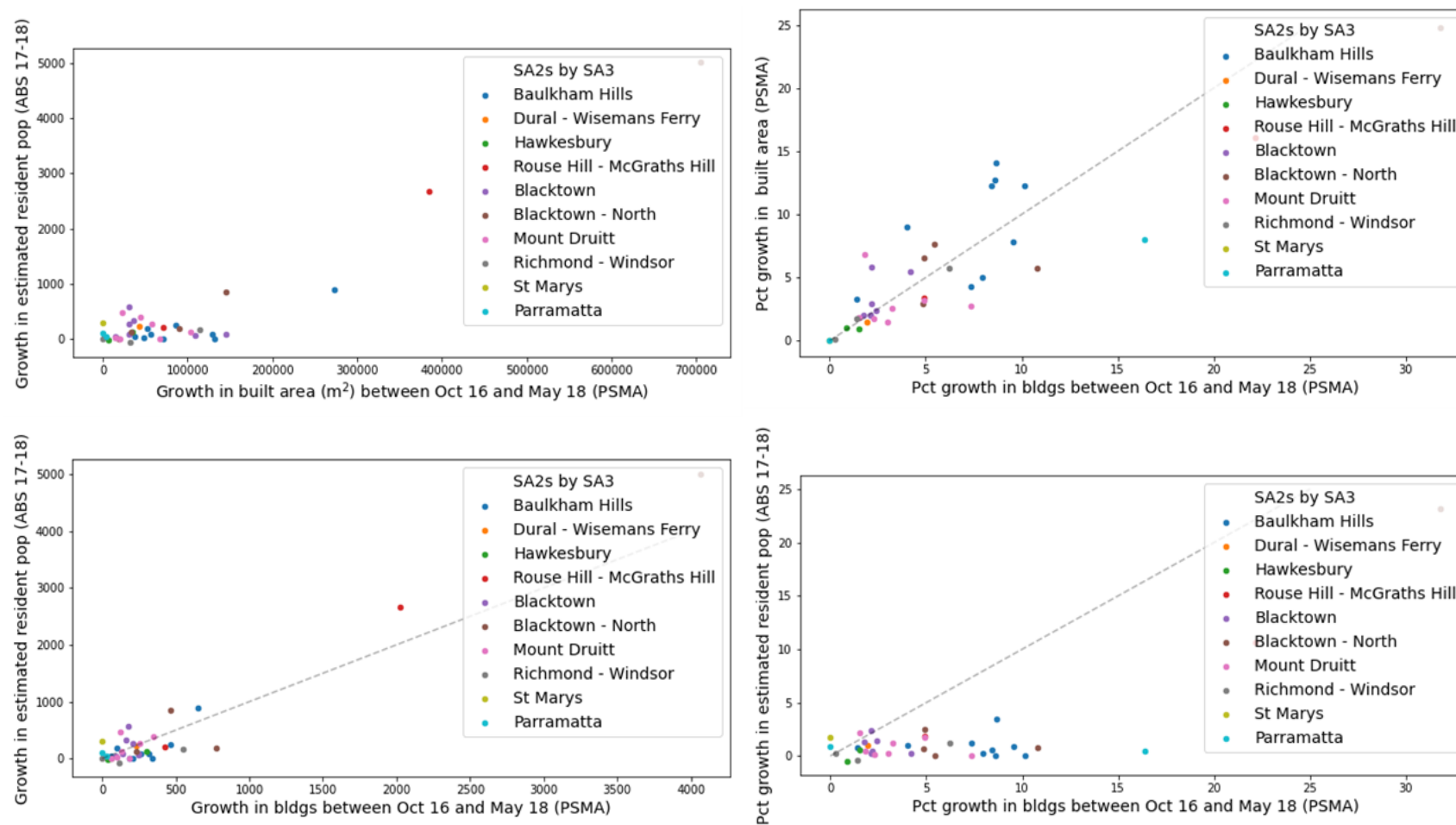


Note: Residential buildings shaded red appeared within a span of 18 months, October 2016–May 2018.

Source: Author generated using data from Geoscape.

2. Dwellings, residential built form, and change and population estimation

Figure 28: Tracking longitudinal built-form density and estimated population growth over time, NWPGA, Sydney



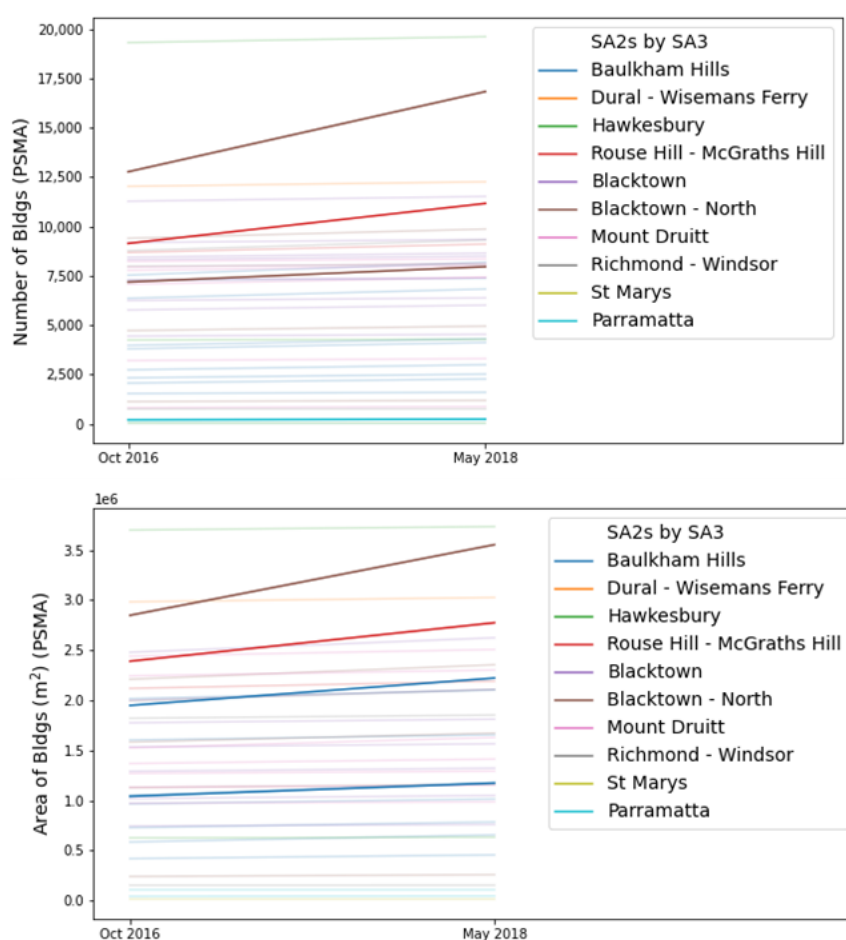
Note: Each dot in the plots is an SA2 area, colour-coded by its SA3.

Source: Author generated using data from Geoscape.

Figure 28 tracks the growth in residential built area and the number of residential buildings for the period Oct 2016–May 2018 in the NWPGA against the growth in population predicted by the ABS for 2017–2018.

It is interesting to observe that for roughly the same amount predicted of percentage growth, a very large range of residential dwelling supply is produced. In other words, for the same predicted population growth, there is a large variation in the number of residential buildings and the built areas of residential buildings in different SA2s within the same growth area.

Figure 29: Tracking absolute growth in residential buildings and areas and identifying top local growth areas, NWPGA, Sydney



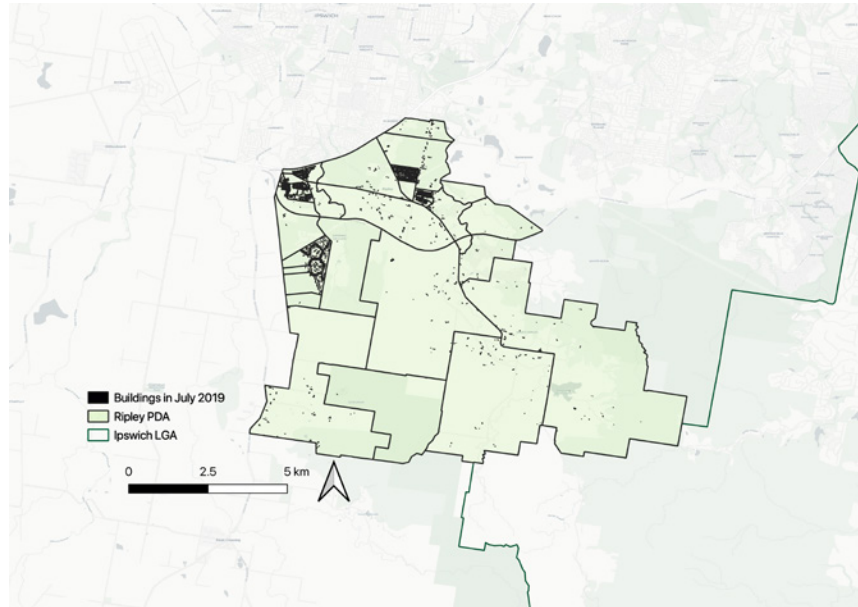
Source: Author generated using data from Geoscape.

Figure 29 shows absolute growth in the number and area of residential buildings between October 2016 and May 2018. Each line is an SA2 and is coloured by its corresponding SA3 area. Even within the NWPGA, the growth appears bursty, hyper-local and heterogeneous, with some hotspot local areas showing much faster growth than others. For example, the top growth areas were Blacktown North, Rouse Hill, McGraths Hill and Baulkham Hills.

Brisbane

Figure 30 shows the highly localised growth in priority development areas for Ripley Valley PDA. The satellite image from July 2019 shows areas with sharp boundaries that differ substantially from the organic, fractal-looking growth patterns shown in Figure 3.

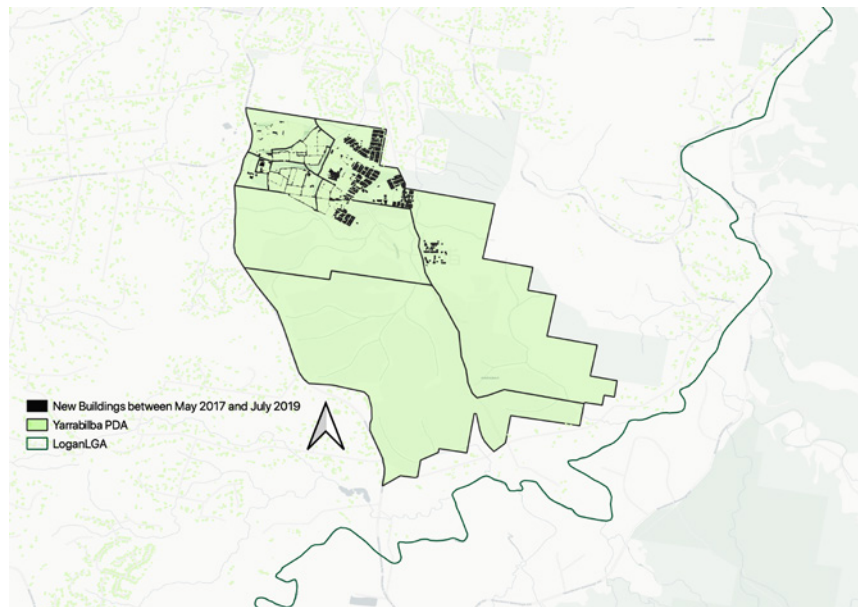
Figure 30: Map of Ripley Valley PDA, Brisbane, showing clear boundaries around planned developments



Source: Author generated using data from Geoscape.

The pace of growth is shown in Figure 31 which shows the growth between May 2017 and July 2019. This growth is concentrated at the boundary of previous growth, but there is an area of lower-density less orderly development visible slightly south and east.

Figure 31: New buildings built May 2017–July 2019 in the Yarrabilba PDA, Brisbane

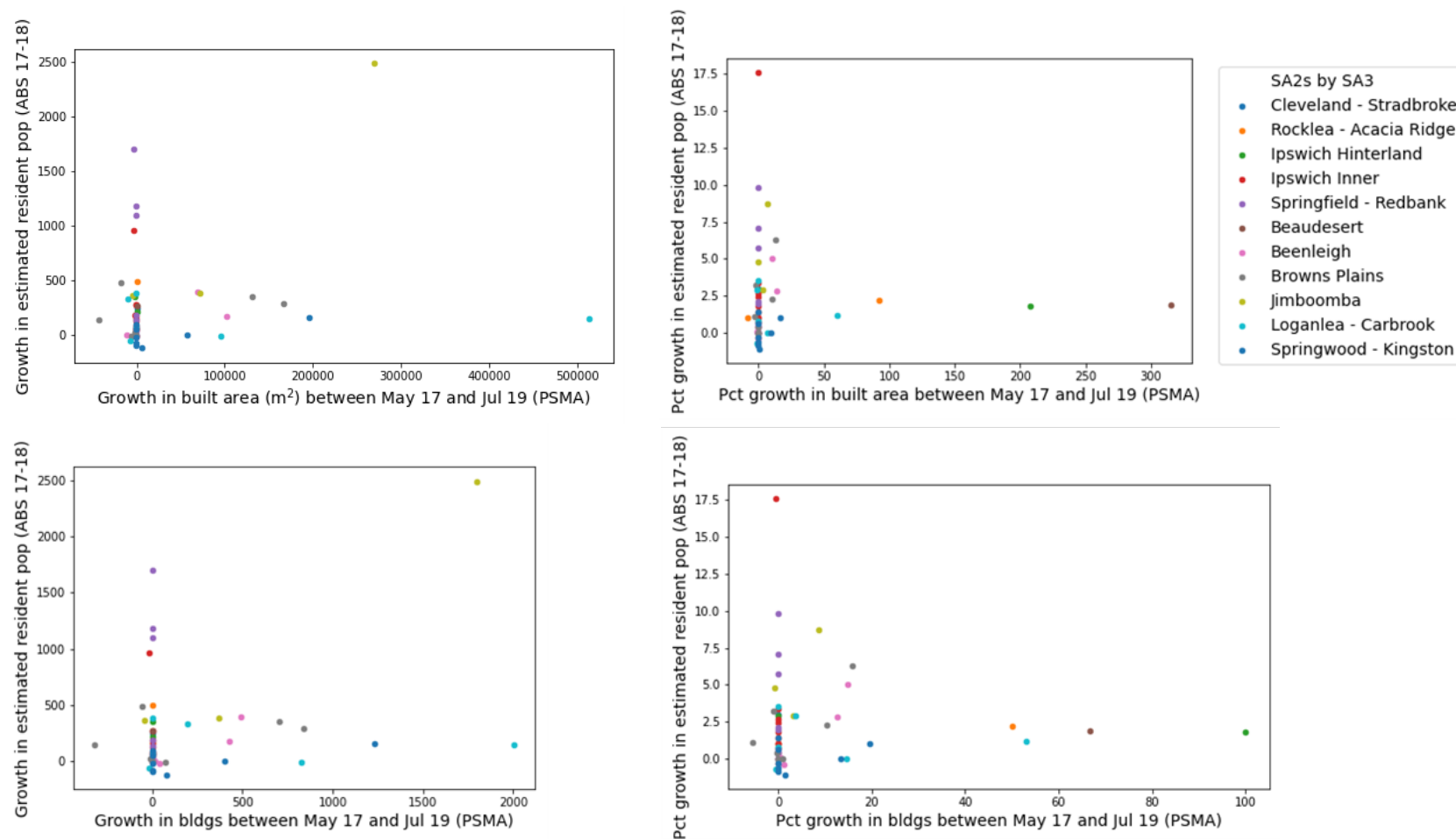


Note: The new development is adjacent to previous growth in the area, which is faintly visible.

Source: Author generated using data from Geoscape.

The growth of buildings by SA2 shows similar heterogeneity in Brisbane as for the Sydney area. As shown in Figure 32 several SA2s showed built-environment growth that far outstripped the ABS predictions for population growth. The scatter pattern shows that building growth is bursty rather than steady, and localised by SA2.

Figure 32: Growth in the number and area of buildings compared to the change in the residential population estimated by the ABS in the Brisbane growth areas

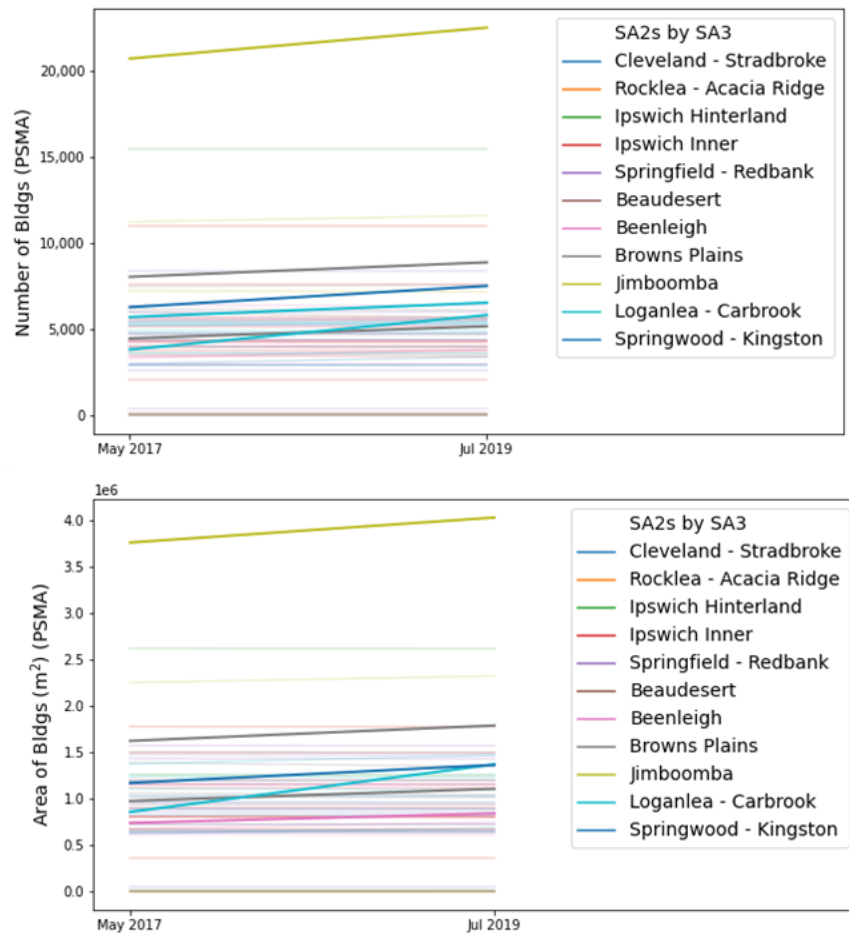


Note: The chronology of the satellite imagery (May 2017–July 2019) does not exactly match the July 2017–July 2018 timeframe for the estimated population increase.

Source: Author generated using data from Geoscape.

The relationship between absolute and relative growth is summarised in Figure 33. The fastest-growing SA2s are indicated in bold; they contain PDAs and show fast development compared to the surrounding SA2s. The fastest-growing SA2s include some areas that have already had a lot of development, such as Jimboomba, as well as areas that are less developed, such as Loganlea–Carbrook.

Figure 33: Growth in the number and area of buildings, May 2017–July 2019, Brisbane growth areas

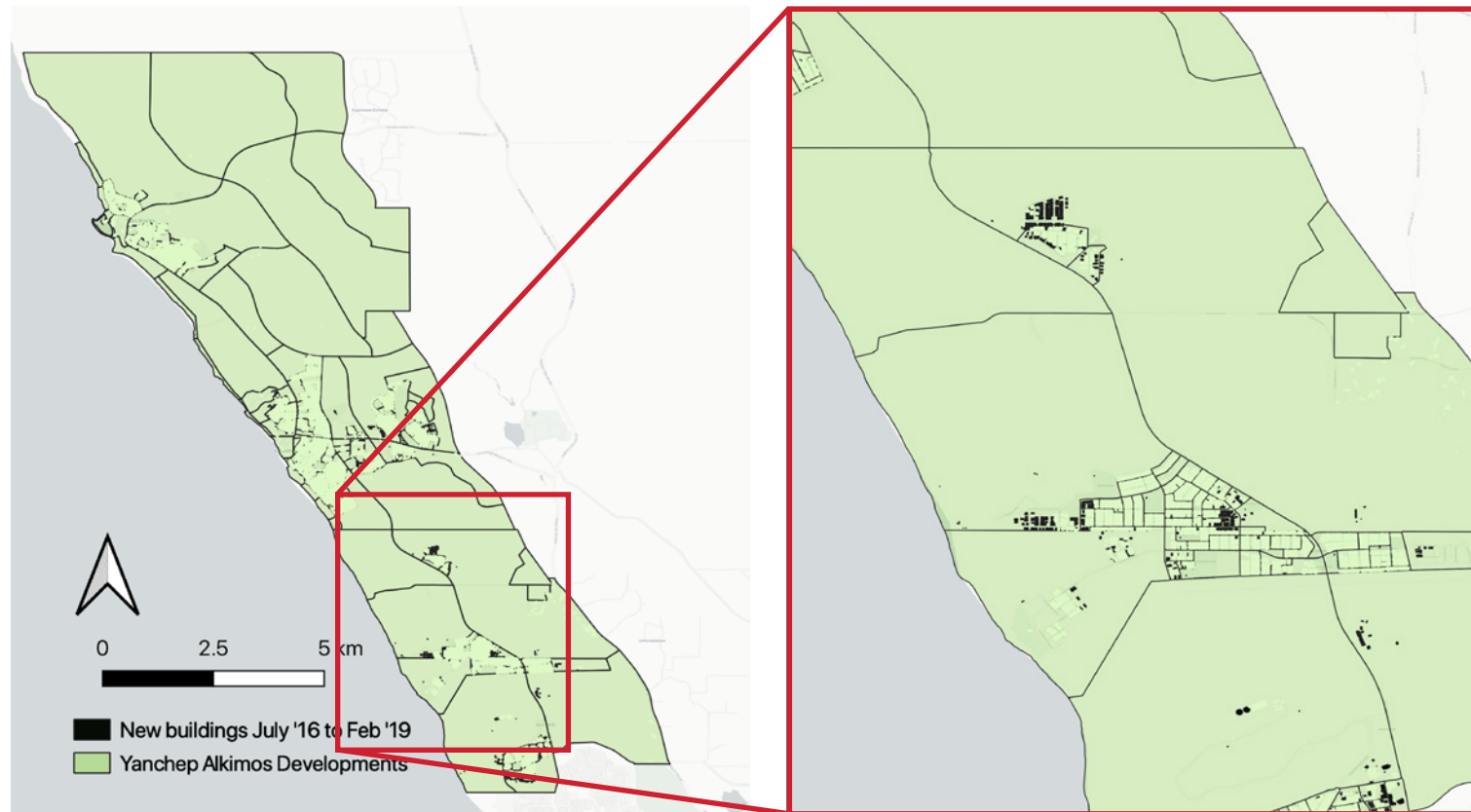


Source: Author generated using data from Geoscape.

Perth

The north-west corridor is an area of strategic growth in the Perth greater metropolitan area. As shown in Figure 34, small communities are experiencing rapid growth, percentage-wise. The right panel of Figure 34 shows the Alkimos area where the built form (shown in black) grew substantially in the period July 2016–February 2019.

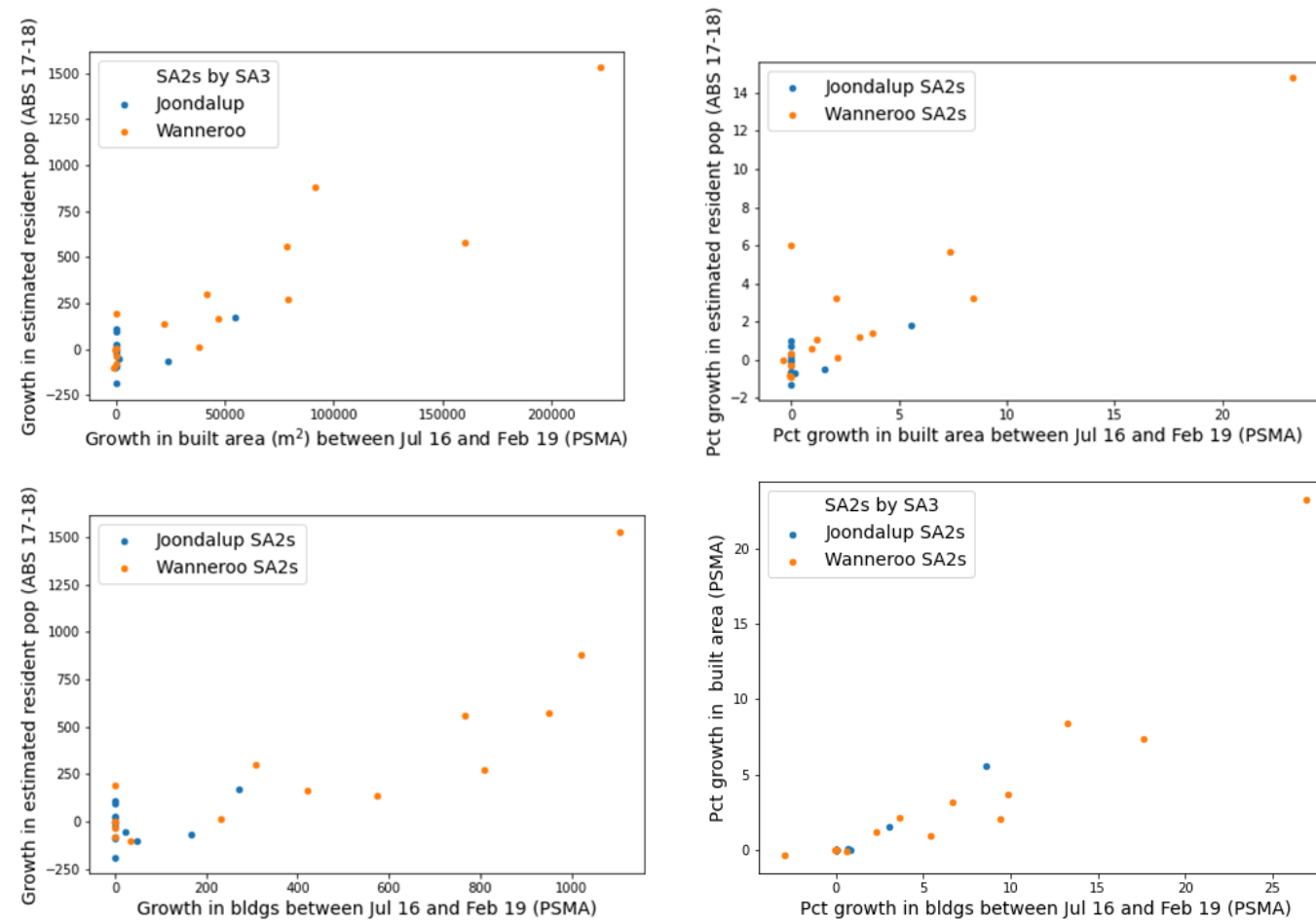
Figure 34: Map of mesh blocks in the north-west corridor showing Yanchep and Alkimos, Perth



Source: Author generated using data from Geoscape.

The comparison of built form and residential population is shown in Figure 35 Overall, high growth in population (both percentage and absolute) is associated with those SA2s that have the highest growth in building numbers and area.

Figure 35: Comparison of estimated resident population growth to growth in the built environment, Joondalup and Wanneroo SA2s

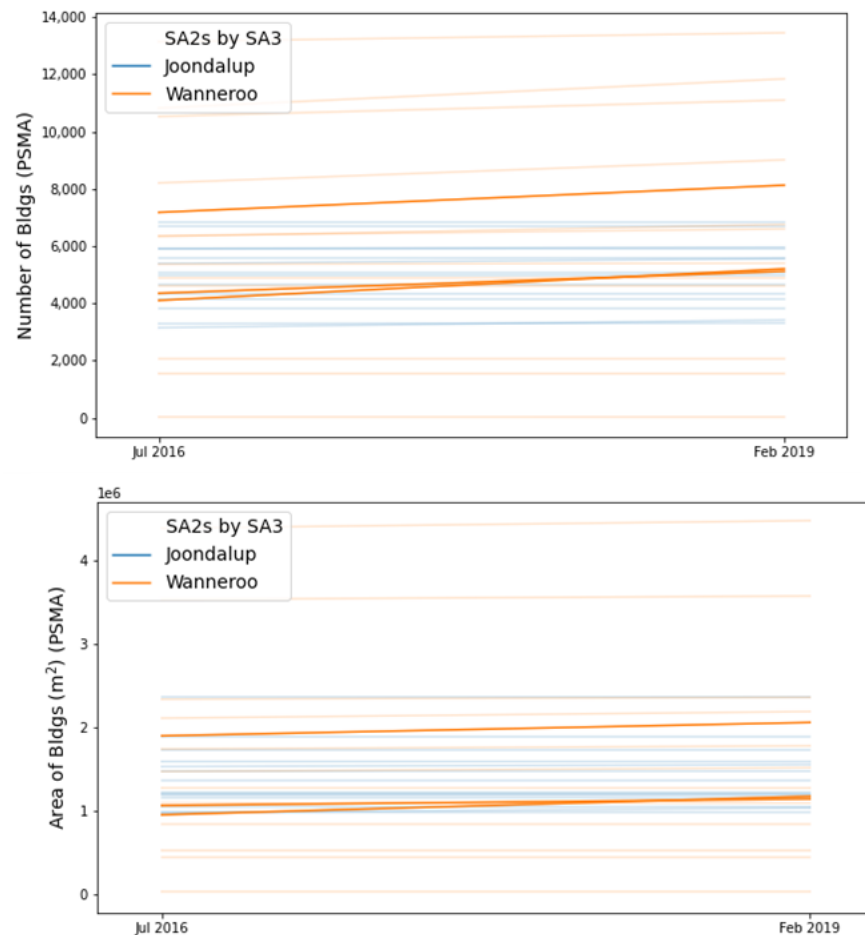


Source: Author generated using data from Geoscape.

Figure 35 shows that SA2s with high growth (absolute on left, relative on right) in estimated population growth tend to have high growth in both built area (top) and number of buildings (bottom).

Growth in the areas of Yanchep and Alkimos is further illustrated in Figure 36 which shows that these fast-growing areas were towards the middle of the range of development in 2016. The SA2s that fall within the Yanchep and Alkimos development areas are bolded, and show some of the fastest growth.

Figure 36: Growth in number (top) and area (bottom) of buildings in Joondalup and Wanneroo SA3s



Source: Author generated using data from Geoscape.

2.3 Population estimation

2.3.1 Method

The population estimations are performed using the method described in Section 1.

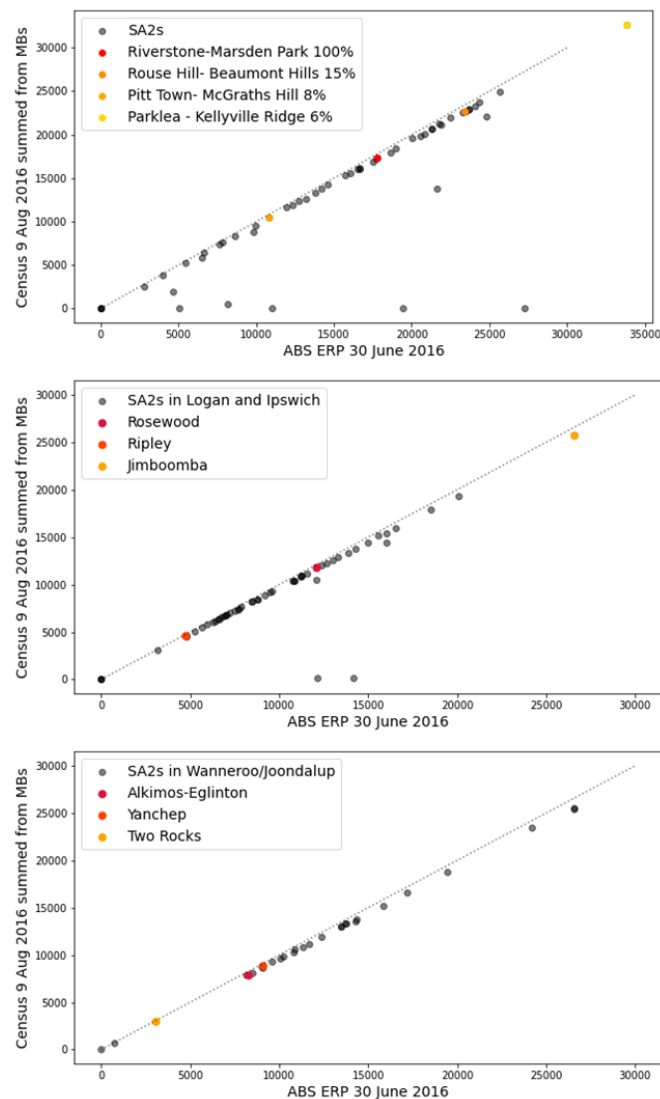
2.3.2 Validation

The ABS calculated estimated resident population (ERP) for every year from 2011 to 2019 at the SA2 level, based on expected demographic changes. To validate the accuracy of the population estimation, the mesh-block populations from the census data must be summed to the SA2. As shown in Figure 37 the baseline populations are highly consistent between the 2016 ERP and the populations of the summed mesh blocks from the census years.

Some discrepancies are visible where the mesh blocks belonging to the LGAs in our sample did not exactly align with the selected SA2s. This is expected and serves to warn that those populations cannot be estimated accurately. The coloured dots in the legends of Figure 37 and Figure 38 highlight those SA2s that overlap the priority growth areas. Where included, the number refers to the percentage of the mesh blocks in this SA2 that fall within the priority growth area (100% if not otherwise stated).

Figure 37 shows that the mismatch between LGA and SA2 boundaries causes some inconsistencies, based on mesh blocks that were outside the study areas for Sydney (top) and Brisbane (middle); however, the LGAs and SA2s aligned for Perth (bottom).

Figure 37: Verification of the 2016 baseline population showing inconsistencies between LGA and SA2 boundaries



Source: Author generated using data from ABS 2016.

Applying the estimation method outlined earlier, an updated population for each mesh block is computed which accounts for locally appropriate values of household size and mixed development. These are compared to the ABS's ERP forecasts in Figure 38.

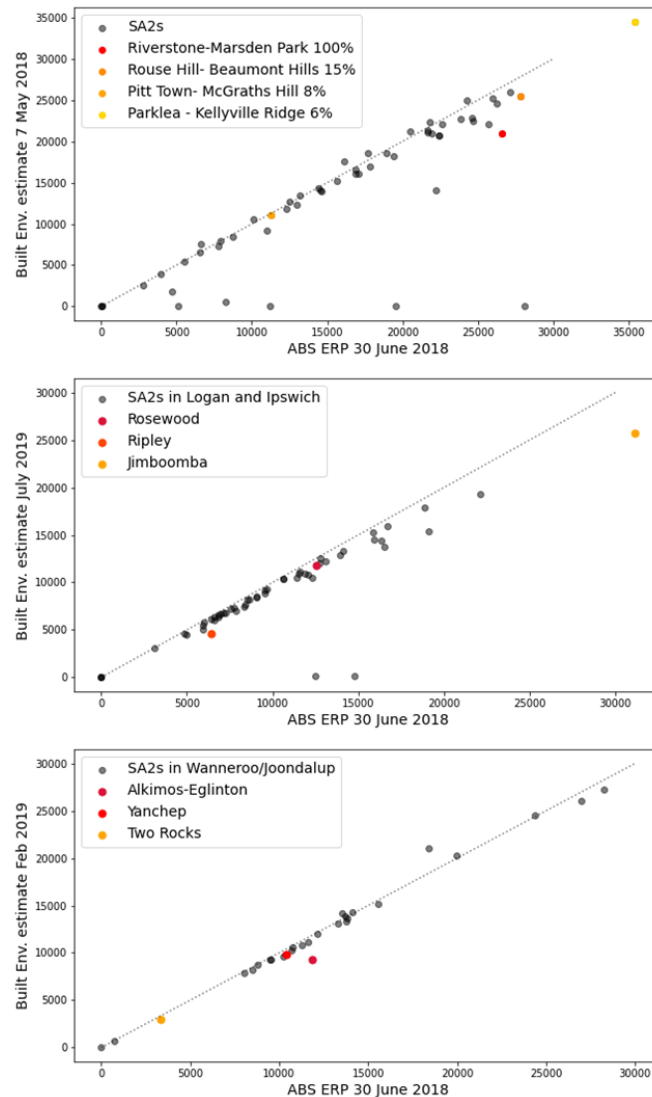
For the three study areas shown, the match between the satellite capture dates and the ABS ERP dates vary:

- **Sydney:** satellite imagery was available for both the census year and close to the ERP date of 30 June 2018.
- **Brisbane:** the two epochs are shifted—2017 and 2019 compared to 2016 to 2018. The mismatch observed for the four most populous SA2s suggests that, in this case, the bursty growth interferes with the predictions.
- **Perth:** the interval is imperfect, but there is consistency between the ABS and building growth approaches, which suggests that real development up to February 2019 is aligned with the estimates for 30 June 2018.

Both measures are estimated values, so this comparison cannot validate the methodology with certainty. In the next census year, the approach could be fully validated using census values.

As expected, the scatter in Figure 38 is higher than in Figure 37, but the clear relationships between Sydney (top), Brisbane (middle) and Perth (bottom) support the validity of the estimation methodology.

Figure 38: Comparison of the ABS ERP with the population estimated from growth in the built environment



Source: Author generated using data from Geoscape and ABS 2016.

2.3.3 Caveats

One challenge for the implementation of this method is that it relies on the presence of satellite imagery from the census year. For areas of low growth, an interval of one or two years will make little difference to the population growth estimates, which are likely to be small. Since the key application is high-growth areas with bursty and highly localised development, an interval of more than a few months may distort the estimate.

The ratio of dwellings to buildings is intended to capture the importance of mixed-use development in each mesh block. However, the presence of apartments—which have a high dwelling to building ratio—is likely to counteract the presence of mixed land use, which has a low dwelling to building ratio. Since higher-density housing and mixed land use often coincide, this measure may not be effective. An area of potential improvement is to use the PSMA address database to identify building purpose and then estimate the number of dwellings in a residential structure.

The proposed methodology is based on the number of buildings, without distinguishing between small or large footprints, number of dwellings or the floorspace ratio. An opportunity to extend this work is to use a volumetric measure of the building growth with explicit treatment for multiple addresses in the same building. Another consideration is the timeline of the land release. For each mesh block, the land is released for some fraction of the time between the census year and the year of interest. This value can be used to better model the localisation and sequencing of the development.

3. Access to social infrastructure

- This section examines *spatial access to social infrastructure*, developing a new measure. This measure evaluates access to social infrastructure by calculating person-weighted access to schools and to hospitals, and comparing access in greenfield areas with regional averages. The person-weighted measure reflects the experience of the average resident within an area.
- The analysis finds that access to the selected social infrastructures in greenfield areas lags notably behind regional averages, particularly in transit and walking access; the lag in car access appears less severe than other modes of transport. This indicates that greenfield areas are still highly car-dependent.
- On average, each item of social infrastructure examined can be accessed by fewer people in greenfield areas than those in the whole region.
- The *spatial access to social infrastructure* measure demonstrated in this section can inform planning and funding decisions, as well as evaluations of urban performance.

3.1 Understanding measures of infrastructure provision

This section focusses on RQ2:

How does accessibility to different types of social and community infrastructure facilities and services vary across diverse geographic, planning and policy contexts?

In particular, this section investigates the following questions:

- Is it possible to identify lead-lag-deficit inefficiencies and impacts of gained or lost accessibility to infrastructure and services for local communities?
- Where are existing 'infrastructure lag hotspots', where either:
 - *transport connectivity fails* because social infrastructure is available, but inaccessible?
 - *social infrastructure provision fails* because transport connectivity is good, but insufficient social infrastructure is available?
- How do accessibility profiles differ for target demographic or population groups, creating differentials of access given the same spatial distribution?

Greenfield sites provide an opportunity to investigate planning for social infrastructure in a future-focussed strategic manner. This research proposes that *accessibility*—defined as 'the ease of accessing urban opportunities and activities'—is key to planning for the spatial distribution of social infrastructure. The concept of accessibility links:

- *transport connectivity*—transport infrastructure access points, travel networks, modes (including active modes), service frequencies and travel times on different modes
- *opportunities available at any location* (Deboosere et al. 2018).

Residents at a location need to access local infrastructure—for example, schools, hospitals, parks, libraries, community centres. They also need to access networked transport infrastructure that provides access to local and wider parts of the city—for example, transport nodes, bus routes, frequencies of service. Failures and deficits can occur on either component:

- insufficient provision of at-point infrastructure
- inefficient transport access over networks and services.

Using schools and hospitals as demonstration areas, spatial accessibility profiles are created for a diverse set of travel-time thresholds. Data on schools and hospitals is open and easily available. The methods presented in this report can be easily applied to any other infrastructure dimensions as data on these facilities becomes available, such as medical centres, shopping facility locations, transport access points (bus stops and train stations), or green areas.

As outlined in Section 1, this aspect of the study targeted sites spanning growth areas in three Australian cities:

- **Sydney:** North West Priority Growth Area
- **Perth:** North-West Corridor
- **Brisbane:** Yarrabilba/Ripley.

Each of these sites captures a different aspect of greenfield development, and shows a mix of midway to well-developed stages.

3.2 Accessibility analysis

3.2.1 Person-weighted access to social infrastructures

The person-weighted access of various geographies is aggregated to larger geographical areas from the MB level, using the size of population within each MB as weight. MBs with a large number of resident persons get more weight, and those MBs with no population exert little effect on the person-weighted access of the larger geographical area. This person-weighted access ensures that the aggregated access accurately reflects the experience of the average individual residing within that area.

A notable pattern emerging from these tables is that walking and transit access to social infrastructures in the growth areas invariably lags behind the regional average in all three cities. The gaps between growth areas and regional averages are most significant in relation to transit access. For example, the average individual in Ripley, Brisbane, is able to reach 0.6 public schools in 30-minutes transit, and in Yarrabilba 1.0 public schools can be reached. These figures compare to the regional average of 3.6 schools. In the growth areas of the three cities, walking access to schools and hospitals also notably lags behind. The gaps in transit and walking access suggest:

- lack of social infrastructure provision in the vicinity of growth areas
- insufficient transit services connecting residents with social infrastructure.

The car access to social infrastructure is generally lower in the growth areas compared to the regional average, but the relative gaps are much narrower than the walking and transit modes. The absolute number of social infrastructures reachable from growth areas by car are so much higher when compared to other modes from more city-centric locations, which means that car-owning residents in growth areas do not experience major disadvantages in accessing social infrastructures. Car access to schools in Sydney's NWPGA exceeds the regional average by a slim margin—which is partly due to the congestion in Sydney's more city-centric locations.

A major explanatory factor for lower accessibility to infrastructure affecting all three greenfield areas is urban form and density. For social infrastructure provision to be economically feasible, a critical population threshold that is being served must be reached. According to the analysis of the Geoscape data in Section 2, the dominating urban form in these regions is low-density, single detached housing. This is coupled with locally heterogeneous growth, where intermittent and scattered development occurs in pockets. Thus, provision of social infrastructure lags behind, as population growth in these areas follows the building growth, and is uneven and heterogeneous.

Detailed statistics showing the extent of the access gap between greenfields and regional averages of Sydney, Brisbane and Perth are tabulated in tables 5–7 A full set of spatial accessibility profile maps is included in Appendix 1.

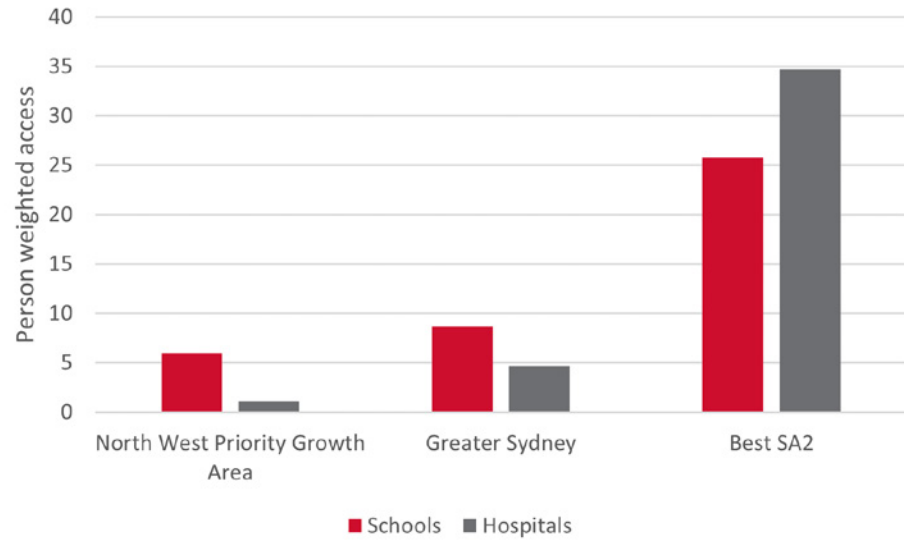
Table 2: Sydney: person-weighted access to social infrastructure

	Mode	Time threshold (min)	Person-weighted access	
			To schools	To hospitals
North West Priority Growth Area	Transit	30	6.0	1.1
	Drive	30	207.9	42.6
	Walk	20	1.0	0.1
Greater Sydney	Transit	30	8.7	4.7
	Drive	30	194.9	63.5
	Walk	20	1.2	0.6
Best SA2	Transit	30	25.8	34.7
	Drive	30	359.0	124.8
	Walk	20	3.9	9.7

Note: Higher numbers correspond to higher access.

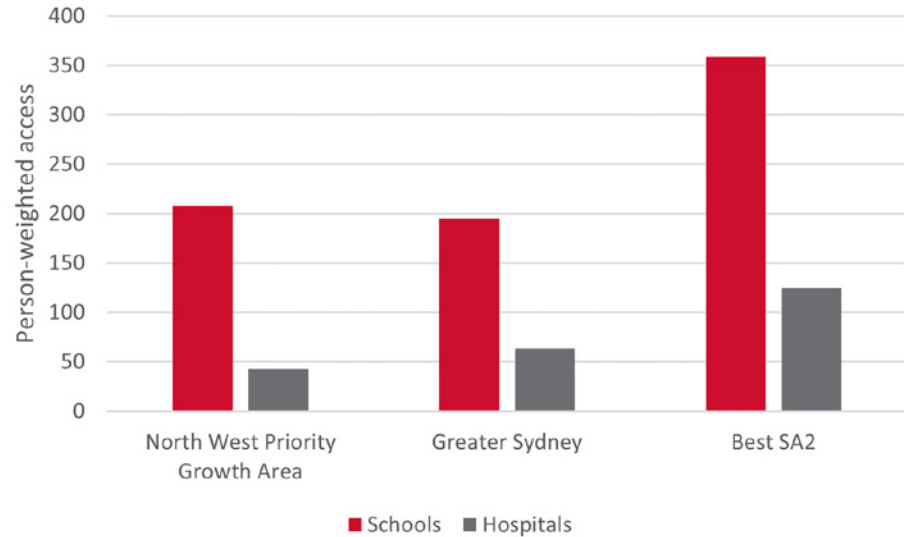
Source: Author computed.

Figure 39: Sydney: person-weighted accessibility, transit, 30-minute threshold



Source: Author computed.

Figure 40: Sydney, person-weighted accessibility, car, 30-minute threshold



Source: Author computed.

Overall, Figure 39 and Figure 40 show that transit accessibility in Sydney is particularly poor in the growth areas, whereas car accessibility is almost at par or a little better than the average values of Greater Sydney. This clearly shows that the priority growth areas need transit planning to go hand-in-hand with social infrastructure development. If not, car-based accessibility is being developed, which will encourage car-based cities rather than transit-oriented cities. The same pattern of results is echoed in Brisbane and Perth.

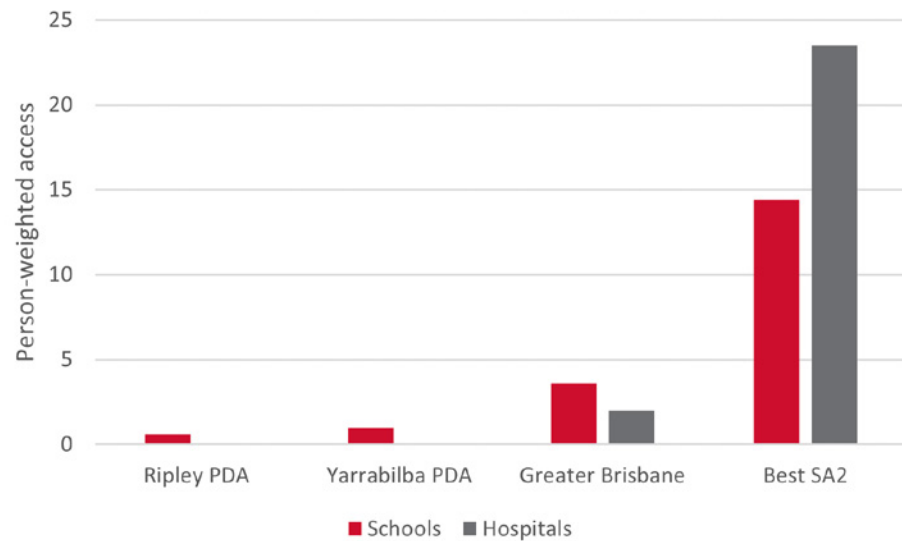
Table 3: Brisbane: person-weighted access to social infrastructure

	Mode	Time threshold (min)	Person-weighted access	
			To schools	To hospitals
Ripley PDA	Transit	30	0.6	0
	Drive	30	67.8	10.7
	Walk	20	0.4	0
Yarrabilba PDA	Transit	30	1.0	0
	Drive	30	38.4	2.6
	Walk	20	0.4	0
Greater Brisbane	Transit	30	3.6	2
	Drive	30	108.1	31.2
	Walk	20	0.7	0.2
Best SA2	Transit	30	14.4	23.5
	Drive	30	177	55.0
	Walk	20	1.8	6.6

Note: Higher numbers correspond to higher access.

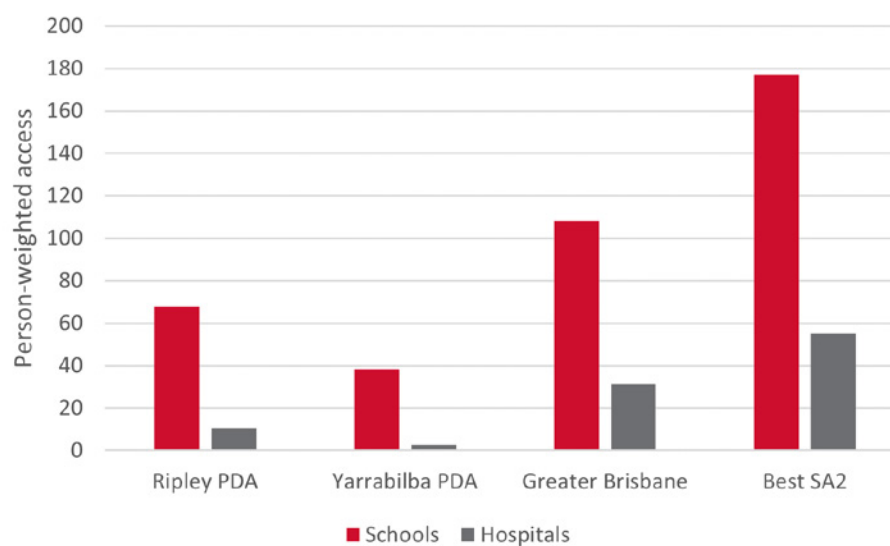
Source: Author computed.

Figure 41: Brisbane: person-weighted accessibility, transit, 30-minute threshold



Source: Author computed.

Figure 42: Brisbane: person-weighted accessibility, car, 30-minute threshold



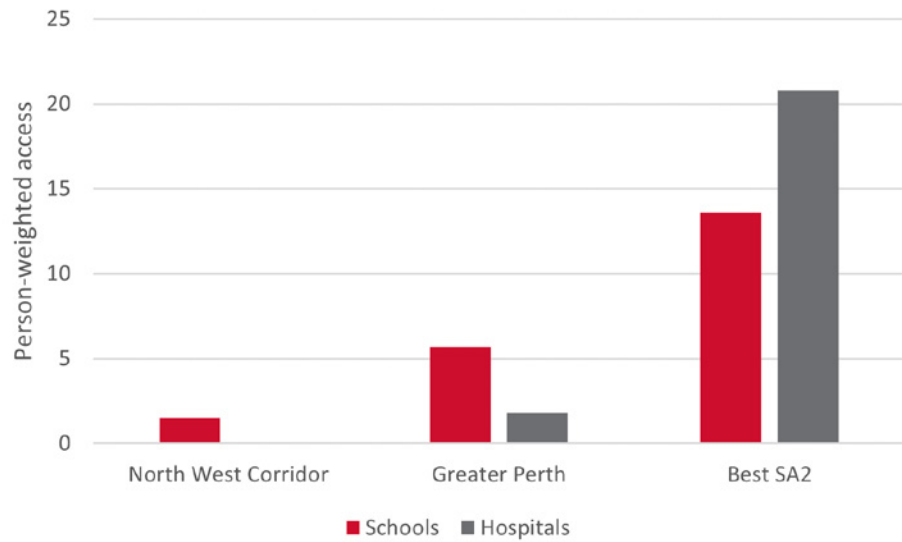
Source: Author computed.

Table 4: Perth: person-weighted access to social infrastructure

	Mode	Time threshold (min)	Person-weighted access	
			To schools	To hospitals
North-West Corridor	Transit	30	1.5	0
	Drive	30	34.1	4.6
	Walk	20	0.5	0
Greater Perth	Transit	30	5.7	1.8
	Drive	30	160.9	36.3
	Walk	20	1.0	0.2
Best SA2	Transit	30	13.6	20.8
	Drive	30	253	58.4
	Walk	20	1.9	5.3

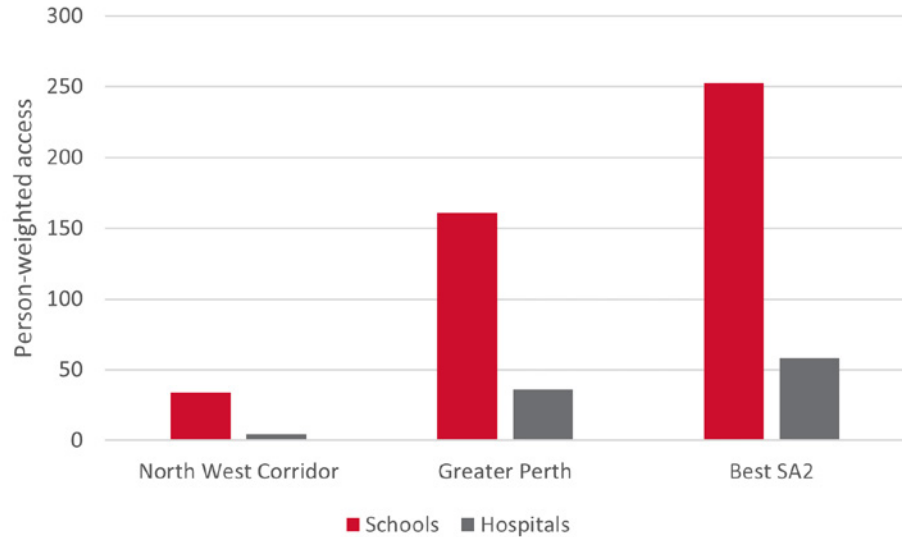
Source: Author computed.

Figure 43: Perth: person-weighted accessibility, transit, 30-minute threshold



Source: Author computed.

Figure 44: Perth: person-weighted accessibility, car, 30-minute threshold



Source: Author computed.

Using the locations of schools and hospitals as destinations, tables 5–7 tabulate the average number of people in Sydney, Brisbane and Perth who can reach social infrastructure within travel-time thresholds. No hospital is on record in the growth areas of Brisbane and Perth, so the corresponding cells are left empty.

The social infrastructure in the growth areas of the three cities can be reached by fewer people compared to the regional average. However, this does not suggest low patronage for this social infrastructure in the growth areas, as the situation creates two distinct disadvantages for growth areas:

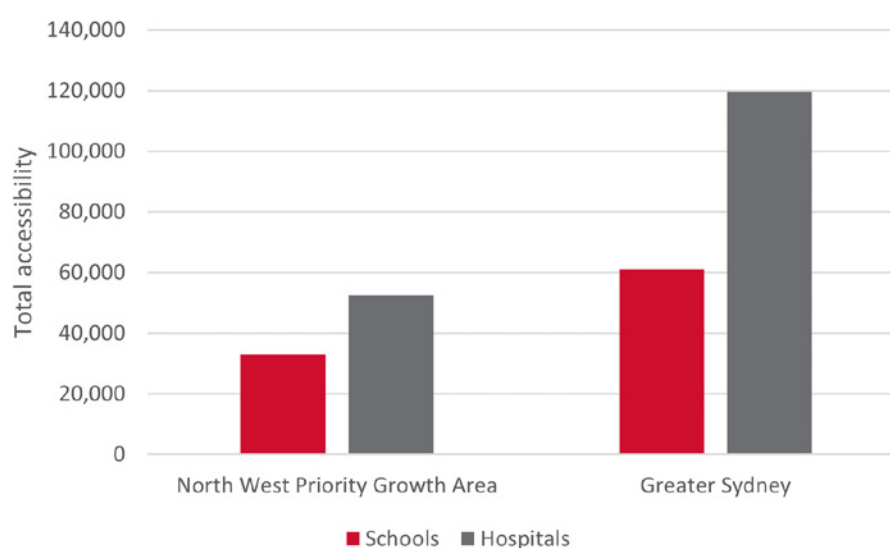
1. The potential patronage for social infrastructures in growth areas will likely concentrate on a few facilities rather than spreading over a larger number of facilities, as in more city-centric locations. This gives more pricing power for service providers in growth areas.
2. Facilities in growth areas get exposure to a smaller number of customers. This limits the extent of the market and the provision of highly specialised services—which means that the variety of essential services will be reduced. For example, access to services such as medical specialists and special purpose schools will be limited in greenfield areas.

Table 5: Sydney: people reaching social infrastructure

	Mode	Time threshold (min)	Number of people	
			To schools	To hospitals
North West Priority Growth Area	Transit	30	33,040	52,532
	Drive	30	1,191,786	1,526,819
	Walk	20	5,454	5,266
Greater Sydney	Transit	30	60,993	119,624
	Drive	30	1,360,440	1,603,997
	Walk	20	8,601	15,877

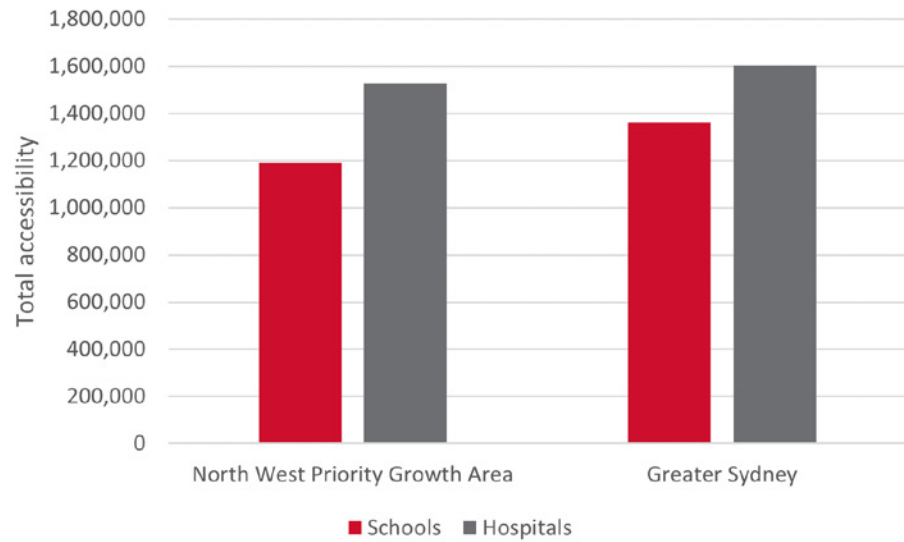
Source: Author computed.

Figure 45: Sydney: total accessibility, transit, 30-minute threshold.



Source: Author computed.

Figure 46: Sydney: total accessibility, car, 30-minute threshold



Source: Author computed.

Even in terms of absolute numbers of people reaching social infrastructure as destinations, similar results are echoed through the three cities, where accessibility by car remains much higher than accessibility by transit, and the priority growth areas perform poorly compared to the regional averages.

Table 6: Brisbane: people reaching social infrastructure

	Mode	Time threshold (min)	Number of people	
			To schools	To hospitals
Ripley PDA	Transit	30	1,174	-
	Drive	30	397,603	-
	Walk	20	930	-
Yarrabilba PDA	Transit	30	3,730	-
	Drive	30	282,389	-
	Walk	20	1,512	-
Greater Brisbane	Transit	30	22,139	66,043
	Drive	30	789,624	983,061
	Walk	20	4,955	7,159

Source: Author computed.

Table 7: Perth: people reaching social infrastructure

	Mode	Time threshold (min)	Number of people	
			To schools	To hospitals
North-West Corridor (Yanchep, Alkimos)	Transit	30	5,517	–
	Drive	30	171,911	–
	Walk	20	2,073	–
Greater Perth	Transit	30	31,274	50,978
	Drive	30	878,296	1,054,032
	Walk	20	5,325	5,959

Source: Author computed.

The accessibility analysis of greenfield areas of Sydney, Brisbane and Perth highlights the disparity in access to social infrastructure between different modes of transport. Access to cars in those greenfield areas is essential for maintaining a similar level of access to social infrastructures compared to elsewhere in the region. People in greenfield areas without access to cars lack a safe and financially sustainable means of transport.

The accessibility pattern in greenfield areas inevitably pushes the choice of transport mode in those areas towards higher car dependence. Apart from environmental concerns, the additional volume of car travel between city centres and greenfield areas adds to the congestion problem that major cities are already experiencing.

4. Panel discussion and interview results

- In order to ground truth the analytical results, methods and accessibility mapping tool developed, and to brainstorm their use in planning and policy formulation, a panel discussion, workshop and interviews were conducted with experts from local and state governments and private industry consultants.
- A number of common themes covering a wide variety of bases were identified, and these are presented in this section.

In order to gain industry insights, and to identify areas of interest and lags, a panel discussion was organised that involved practitioners from the industry and government practicing in social infrastructure from the three focus cities: Sydney, Brisbane and Perth.

A recorded three-hour facilitated discussion session was scheduled over Zoom with participants including experts from:

- **Sydney:** Department of Planning, Industry and Environment; Transport for NSW.
- **Brisbane:** University of Queensland; TAP Consulting.
- **Perth:** Department of Strategic Land Use Planning and Environment; Shape Urban.

The workshop began with a presentation by the lead researcher to showcase results of the research team's analysis, and to reveal insights drawn from it. Further, the panellists were invited to share their experience and to answer key questions:

- Do the indicative findings of analysis resonate with on-ground understandings of the research area?
- Would they use a spatial analysis tool like this in their work? If not, what would be the barriers to adoption? If so, how would it be used? Would they suggest other applications for state government/local government planners or policy makers?
- What enhancements or changes would they suggest?

Key points from the panel discussion have been summarised in this section. The section outlines the major takeaway challenges and issues that the experts commonly identified, and where they felt that the use of new data, population projection and estimation methods, and accessibility analysis, would be most useful.

4.1 Better methods for understanding future population growth and mobility

The projections made in this report rely on 2016 ABS census data, and 2018 and 2019 Geoscape data. Workshop participants—who hailed from the government institutions of three of the major cities in Australia—all asserted the importance of using data that is more ‘real-time’ than the census when tracking or predicting population growth. Similarly, participants of one jurisdiction referred to an oversupply of land occurring because of population projections that were not realised. This reflects the constantly changing demographics of the cities, which are due to:

- internal and external migration
- changing community aspirations and behaviours
- response to extreme events—such as the COVID-19 pandemic.

The model is expected to help in assessing the type of growth in terms of dwelling and changes in household types, based on expected population growth. A participant from Brisbane commented:

‘The tool developed through this study will be useful for social infrastructure planning, since several development plans, which include building schools and hospitals, are based on a minimum population threshold that can be predicted using this tool since it tracks accessibility and dwelling development along with population projection.’

All the workshop participants confirmed that they use a common platform for spatial data within their respective jurisdictions. The experts felt that the use of new data and methods—such as fine spatio-temporal tracking of buildings growth—could enhance their population projection models.

4.2 Identifying lag hotspots at fine spatio-temporal scales

A key aim in the project was the use of accessibility analysis for identifying infrastructure lag hotspots. Workshop panellists confirmed the results of the accessibility analysis for schools and hospitals by walking, driving and transit modes.

A participant from Perth observed:

‘Wanneroo, being the fastest-growing suburb in Perth, does not have a single hospital, which the maps echoed, and it shows how apparent is the lag in social infrastructure. These are exactly the problems we grapple with.’

Participants also explained barriers to timely infrastructure delivery, including:

- funding deficits
- insufficient population thresholds
- unanticipated growth patterns.

As a participant from Sydney explained:

‘A large part of the social infrastructure comes under state governments and hence the funding for the same is provided by them. But there is never forward funding. Instead, funding is always released after development has occurred, which is then followed by delivery of social infrastructure.’

Timely, fine-grained spatial data can help overcome these issues by providing early data to inform budget and capital works discussions and reviews.

4.3 Use for future planning of social infrastructure

Expert participants advised that state governments are seeking to develop new integrated planning processes to support planning and infrastructure provision across agencies. The tool developed in this project—or a similar model—may aid in these endeavours. For instance, the development of a Spatial Digital Twin four-dimensional model (3D + time) of NSW's physical environment, which is capable of recording past conditions and visualising future scenarios, could be enhanced by adding travel and mode-share accessibility criteria.

In particular, measuring spatial accessibility of health and education services would add a new and important metric to scenario planning. For example, how would spatial accessibility profiles change for the whole region if a hospital was placed at a particular location? How would accessibility change while also measuring the change in density on setting up a train station at a particular location?

The travel-time component of this tool—which provides the time that it takes to travel from point A to point B using different modes—will enable planners to analyse the impact of a new train station in its own vicinity and on other stations, but also in the areas extending up to a couple of more surrounding stations, by treating the entire system as a network. A participant from Perth confirmed the viability of the tool:

‘This tool forms the missing link between our ongoing analysis of the effect of a social infrastructure in the surrounding areas at present and in the future.’

4.4 Evaluating performance of plans

Panellists agreed that the tool could support ongoing evaluation of plans and their implementation. For example, if a plan proposes certain population or density targets, then an ongoing accessibility analysis could show whether or not the targets are being met.

Similarly, with the rapid population growth envisaged for greenfield areas, accessibility analysis of the main social infrastructure dimensions as they develop on-ground could measure the target population being served and the level of the service, on an ongoing basis. These on-ground numbers could then be compared to the target numbers and levels of service proposed in the plans.

Participants from Brisbane suggested the need for a shift to scenario-based planning instead of conventional strategic planning to build communities and create vibrant places by focussing on ‘demand’ and its drivers rather than adhering to conventional ‘need-based’ or ‘benchmarking’ approaches.

4.5 Aiding development of novel data indicators for planning

When asked for feedback and suggestions on the enhancement of the spatial analysis tool for effective use, panellists suggested the tool be developed to allow analysis of different areas, plans or travel-demand planning. They further suggested that it should adjust additional data on the variety of social infrastructure facilities. A participant from Sydney suggested that:

‘The tool should be flexible and be able to accommodate multiple layers of social infrastructure—for example, different types of health facilities, etc.—as it would bring in more precision in terms of the kind of infrastructure being focussed upon.’

Travel-time analysis can be enhanced by simultaneously calculating accessibility regarding time, distance and travel mode, which addresses the elementary but crucial concerns for establishing a facility at a given location. A Perth participant suggested that:

'Adding more dimensions to the accessibility analysis in terms of the effects of a particular social infrastructure at various distances, say 1 km or 3 km, would produce significant results in identifying the need for a social infrastructure at any particular place, facilitating effective policy planning by reducing the cost associated with duplicating any facility or committing errors.'

This response was echoed by a Sydney participant, who added: 'Since cycling is increasingly becoming a preferred mode of transport, the tool may consider including it in its accessibility analysis.' Participants also suggested using alternative data resources for real-time travel information. A participant from Sydney said, 'Using data sources from [the] public transport system, telecom companies, which track travel histories including mode of transport, travel time, etc., could be used as potential data sources.'

Participants also suggested developing a way of incorporating qualitative aspects and community characteristics of areas such as demographic profiles—from household composition to age structure and cultural background—all of which influence demand for services. It was suggested that Socio-Economic Indexes for Areas (SEIFA) indices could inform the analysis, in addition to other data from government and private sources about the range of existing and planned facilities and services within an area.

4.6 Additional uses of the tools and methods developed in this project

In summary, the panel discussion highlighted how important it is to pilot the use of the tool and methods with actual on-ground planners, policy makers and consultants. The project team is well aware of the on-ground realities, challenges and issues around the delivery of social infrastructure, so user feedback is critical to fine tune the methods, expand the capacities of the tool for forward planning, communication or coordination and, in general, better support data-driven evidence-based planning.

Further, several themes were identified from the discussion with experts. In addition to the need for data-driven insights to inform the planning and delivery of social infrastructure in the rapidly growing areas of major Australian cities, experts also identified other applications of the methods and tools developed in this project. These included:

- developing new planning indicators to measure urban performance
- enabling data transparency and contestability if information is 'open source'
- supporting public engagement and comprehension of future planning scenarios.

5. Policy development options

This research study developed an analytical tool, analysis methods and a monitoring framework to assist as policy coordination tools. Based on case studies of greenfield development sites across Sydney, Brisbane and Perth, this tool can be used to correlate the supply of new residential developments and potential population growth against the delivery, spatial density or distributions of social infrastructure, and access to that social infrastructure.

This work has the capacity to inform policy formulation and planning of social infrastructure in the rapidly growing areas of Australian cities in three key ways, outlined below.

Provide an evidence-base for existing and evolving on-ground conditions

The methods and the tools can be used to track the existing on-ground and evolving spatial patterns and geography of any chosen social infrastructure dimension, as well as their spatial accessibility profiles. By considering multiple modes of transport and resulting travel times, the tool provides:

- counts of population served
- counts of the number of infrastructure facilities reachable.

The tool computes accessibility profiles for different time thresholds, which can be varied as a parameter for any future studies: 15 minutes, 20 minutes, 30 minutes, etc. The results can be used to identify hotspots such as poorly accessible areas and poorly served social infrastructure dimensions.

The evidence-base on existing and evolving on-ground conditions for rapidly growing greenfield areas is relevant to policies and goals such as the '30 minute-city' concept, which was outlined in the Australian Smart Cities Plan (Department of the Prime Minister 2016) and the Greater Sydney Commission's plan for metropolitan Sydney (Greater Sydney Commission 2018).

Serve as a locational planning and evaluation tool

Given any future planning scenarios, the tool developed can be used to locate new social infrastructure points. By placing new infrastructure in space, the tool can then be used to recompute the accessibility profiles, thereby showing how spatial accessibility signatures across the whole of the local or metropolitan area alter when local provision changes are made. Thus, the tool can serve as a planning and evaluation tool.

Further, since a core planning and policy goal is spatial justice and equity, and the planning of integrated communities, such a locational planning and evaluation tool can be used to directly inform spatial solutions that actively work against segregation, and ensure that accessibility to all demographic groups is maximised.

Serve as a common informational platform, enabling conversations around co-planning of social infrastructure by different government organisations

The results of the tool can be used by state and local government bodies and private sector organisations involved in the delivery of social infrastructure to communicate with a common informational base. If such a tool is used across all organisations—or the results are commonly shared—then the organisations can plan for coordinated co-locations of social infrastructure. This will give the chance to optimise or increase accessibility to these services for the local population being served, and increase efficiency in planning and development processes.

The current analysis by Infrastructure Australia (Australia 2018; Australia 2019) clearly highlights the lack of coordination and information access between multiple organisations as a key challenge area in realising the optimised delivery of infrastructure across Australian cities. The tool developed in this research can, in principle, address this core operational challenge by supporting better information sharing.

5.1 The importance of novel data and spatial accessibility tools

Why is the use of novel data sources important?

The research reveals that depending on the five-yearly census data and supporting analysis is insufficient for planning and delivering services in the rapidly changing areas of Australian cities. Although the census data is still crucial, the pace of urban development is high and areas are recording fast-changing development of the built environment. Therefore, novel and reliable data sources are needed to ensure that such rapid change is captured at much finer spatial and temporal detail—which then has the capacity to enrich planning processes by providing a much more reliable and accurate information and evidence-base.

What capabilities are enabled by a spatial-accessibility mapping tool?

The spatial-accessibility mapping tool developed in this research can be used to track the existing accessibility profiles of social infrastructure at arbitrarily chosen spatial geographies, ranging from a mesh block to the entire metropolitan region. It can be used as a tool to inform and support future spatial planning of social infrastructure, and it can also be used as a policy and plan monitoring and coordination tool between several different state and local government departments and the private sector.

What insights are gained for the spatial planning of social infrastructure in greenfield development areas in major Australian cities?

The results of the analysis show that greenfield areas of major Australian cities lag behind in the timely and efficient provision of social infrastructure. While greenfield areas see rapid housing developments and resulting population growth, the ease with which the population can reach services, or accessibility to services, is lower than the regional average accessibilities across the entire metropolitan region—and significantly lower than well-developed inner-city areas.

As such, the results argue for an approach where planning for social infrastructure should precede or keep pace with actual population growth, even if it is not pragmatic to provide this infrastructure at the time of planning for residential development because of the inherent nature of social infrastructure planning. In other words, while residential development may lead the provision of social infrastructure, the actual provision of social infrastructure should not lag behind actual population growth and move-ins into a local area. To enable this approach, accurate data on spatially and temporally fine resolutions is needed, so it can be used to understand exactly how urban development is followed by population growth in a local area.

5.2 Limitations and priorities for further research

The tool and methods described in this report offer a valuable basis for urban research. However, further work in collaboration with practitioners or agencies is needed in order to operationalise the use of such a tool within planning and development practice. In order to do that, access to quality base data is critical. Datasets such as Geoscape are not in the public domain. However, it is likely that open-source alternatives will emerge in the near future. Further research should seek to extend and ground truth the potential for open-access data sources to inform wider collaborative planning efforts.

Additionally, this study has demonstrated the potential for big data to inform monitoring and evaluation of city performance on key measures such as accessibility—particularly the performance of newly developing areas. There is an opportunity to extend these approaches to enable wider urban evaluation and to inform infrastructure auditing and funding processes.

5.3 Final remarks

This research study sought to explore how big-data sources at fine spatio-temporal scales could be employed for policy-relevant research and urban-planning practice. In developing a methodology to track building and residential supply production at extremely fine spatio-temporal scales, the project has demonstrated a new approach to estimating population growth, which is critical to understanding infrastructure requirements in urban Australia.

The project further developed an innovative measure for assessing the spatial accessibility of new residential development to social infrastructure in metropolitan growth areas. Further efforts to extend the use of big data in planning and infrastructure provision will help improve Australia's housing and urban development outcomes in the future.

References

ABS see Australian Bureau of Statistics.

Angel, S. (2012) *Planet of Cities*, Lincoln Institute of Land Policy, Cambridge Massachusetts.

Arcaute, E., Hatna, E., Ferguson, P., Youn, H., Johansson, A. and Batty, M. (2015) 'Constructing cities, deconstructing scaling laws', *Journal of the Royal Society Interface*, vol. <https://doi.org/10.1098/rsif.2014.0745>.

Australian Bureau of Statistics, (2020) 'Estimated Resident Population: Methodology', ABS, vol. <https://www.abs.gov.au/methodologies/national-state-and-territory-population-methodology/mar-2020>.

Briggs, S., Elliot, D., Harvey, V., Young, A. and Heywood, P (2007) 'South East Queensland Regional Plan (2005-2026), Implementation Guideline No. 5: Social Infrastructure Planning', *Office of Urban Management Queensland Government, Department of Infrastructure*.

City of Parramatta (2017) Social Infrastructure Strategy Draft 2017. In: C. O. Parramatta (ed.) *City of Parramatta, Social Infrastructure Strategy*

Cui, M. and Levinson, D. (2018) 'Full cost accessibility', *Journal of Transport and Land Use*, vol. 11, no. 1: 661-679.

Deboosere, R. , El-Geneidy, A. and Levinson, D. (2018) 'Accessibility-Oriented Development', *Journal of Transport Geography*, vol. 70: 11–20.

Department of the Prime Minister and Cabinet (2016) 'Smart Cities Plan', *Australian Government*.

Greater Sydney Commission (2018) Greater Sydney Region Plan: A Metropolis of Three Cities.

Hansen, W. (1959) 'How accessibility shapes land use', *Journal of the American Institute of Planners*, vol. 25: 73-76.

Iacono, M. and Levinson, D. (2017) 'Accessibility Dynamics and Location Premia: Do land values follow accessibility changes? ', *Urban Studies*, vol. 54: 364-381.

Infrastructure Australia (2018) 'Planning Liveable Cities: A place-based approach to sequencing infrastructure and growth', *Infrastructure Australia*.

Infrastructure Australia (2019) An Assessment of Australia's Future Infrastructure Needs: The Australian Infrastructure Audit 2019, *Infrastructure Australia*.

Infrastructure NSW (2016) Infrastructure NSW Cultural Infrastructure Strategy.

Levinson, D. (1998) 'Accessibility and the Journey to Work', *Journal of Transport Geography*, vol. 6(1): 11-21.

Levinson, D. , Marion, B. , Owen, A. and Cui, M. (2017) 'The City is Flatter: Changing Patterns of Job and Labor Access', *Cities*, vol. 60, no. B: 124–138.

Moylan, E. and Sarkar, S. (2019) 'Defining urban centres using alternative data sets', *Transport Findings*, vol. online: 10.32866/8166.

Newman, P., Kenworthy, J. and Vintila, P. (1992) 'Housing, transport, and urban form', *The National Housing Strategy Issues Papers* 15.

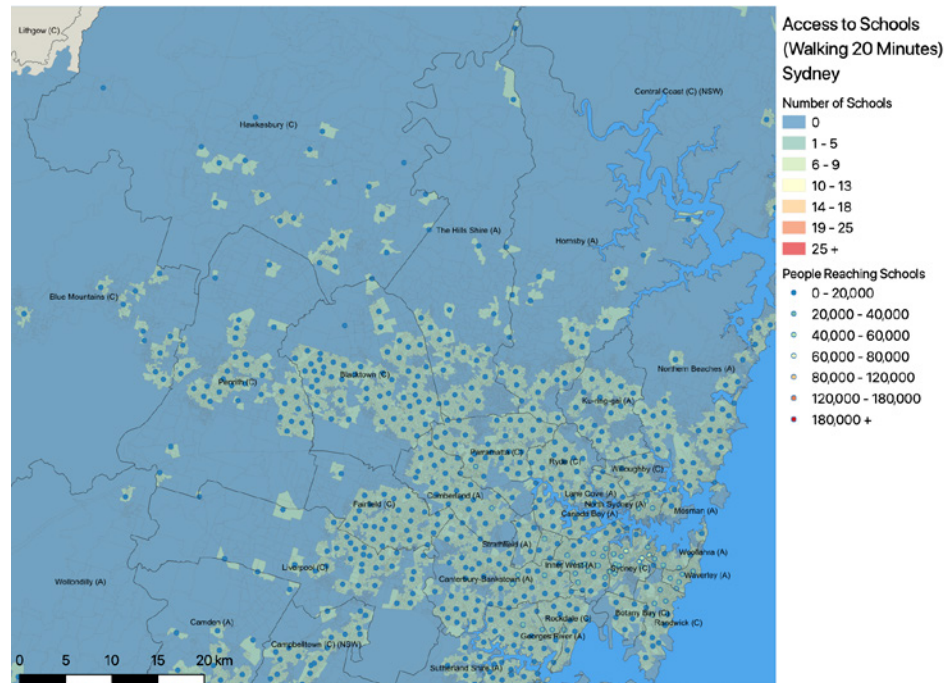
NHS (1992) 'Housing location and access to services', *The National Housing Strategy Issues Papers*, vol. 5.

NSW Department of Planning and Environment (2017) North West Priority Growth Area: Land Use and Infrastructure Strategy.

Sarkar, S., Wu, H. and Levinson, D. (2019) 'Measuring polycentricity via network flows, spatial interaction and percolation', *Urban Studies*, vol. 57(12), pp.2402-2422.

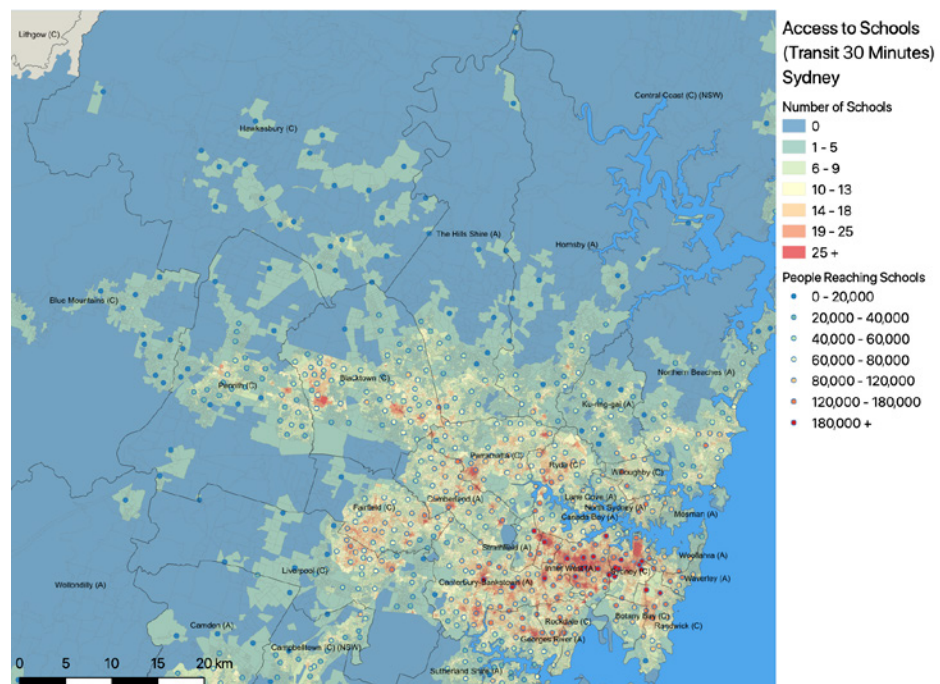
Wu, H., Levinson, D. and Sarkar, S. (2019) 'How transit scaling shapes cities', *Nature Sustainability*, vol. 2: 1142-1148.

Figure A 2: Access to Schools, Walking 20 minutes, Sydney



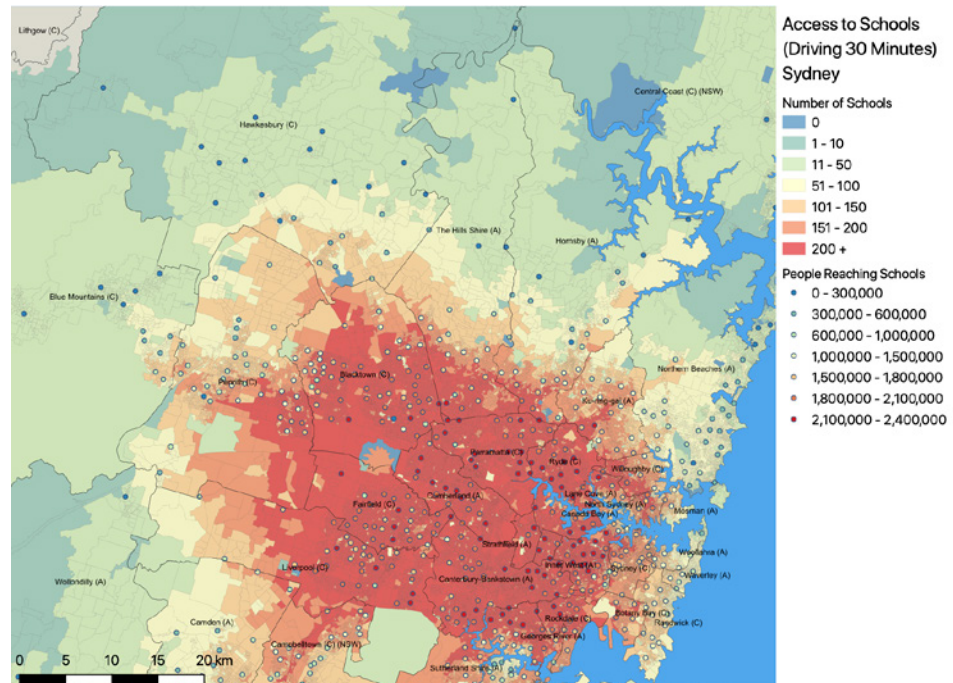
Source: Authors.

Figure A 3: Access to Schools, Transit 30 minutes, Sydney



Source: Authors.

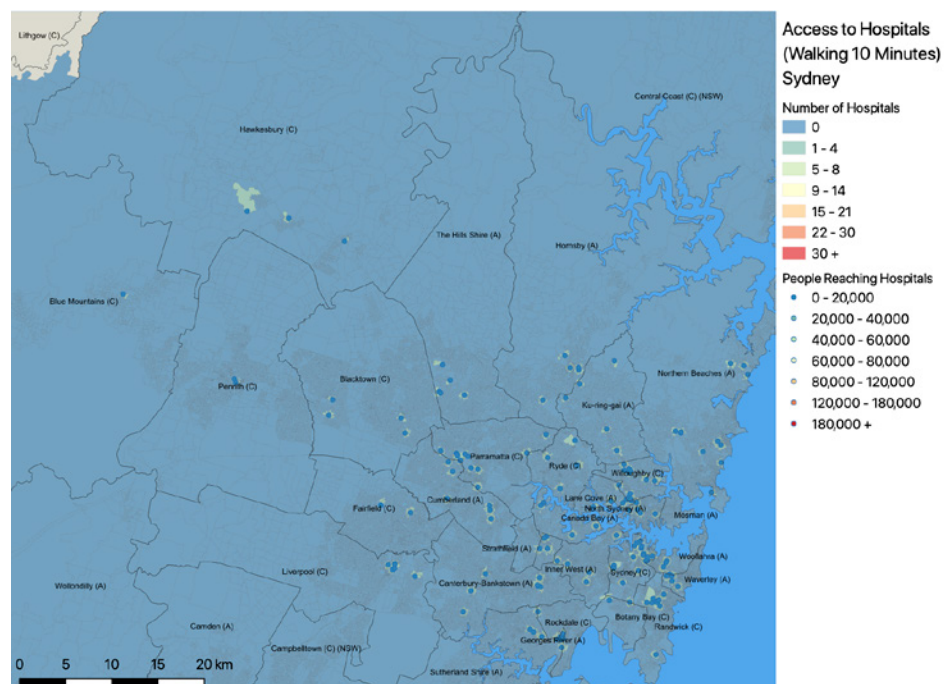
Figure A 4: Access to Schools, Driving 30 minutes, Sydney



Source: Authors.

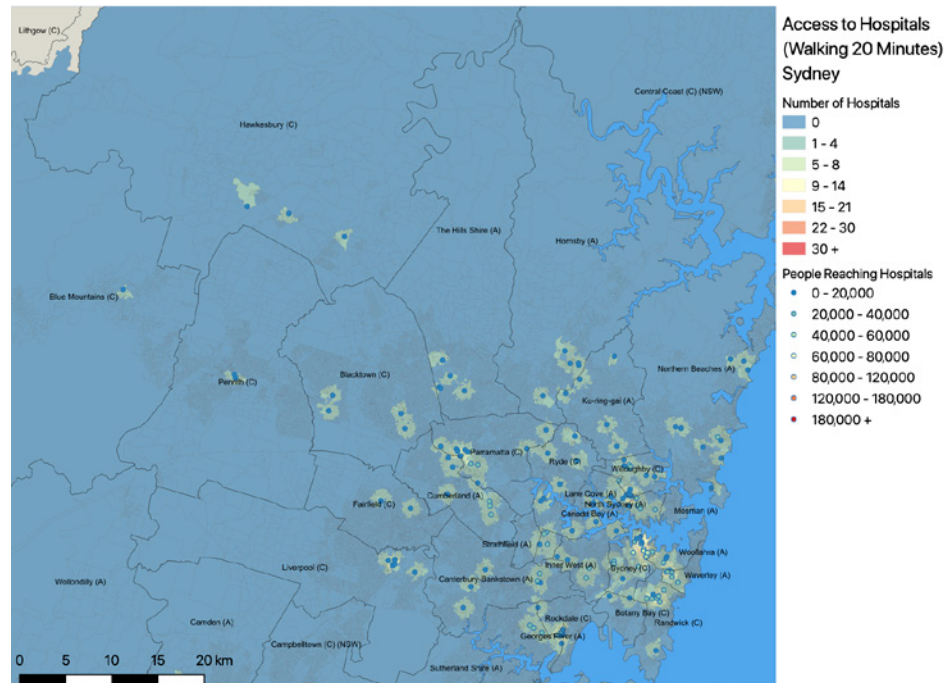
Sydney, Access to hospitals

Figure A 5: Access to Hospitals, Walking 10 minutes, Sydney



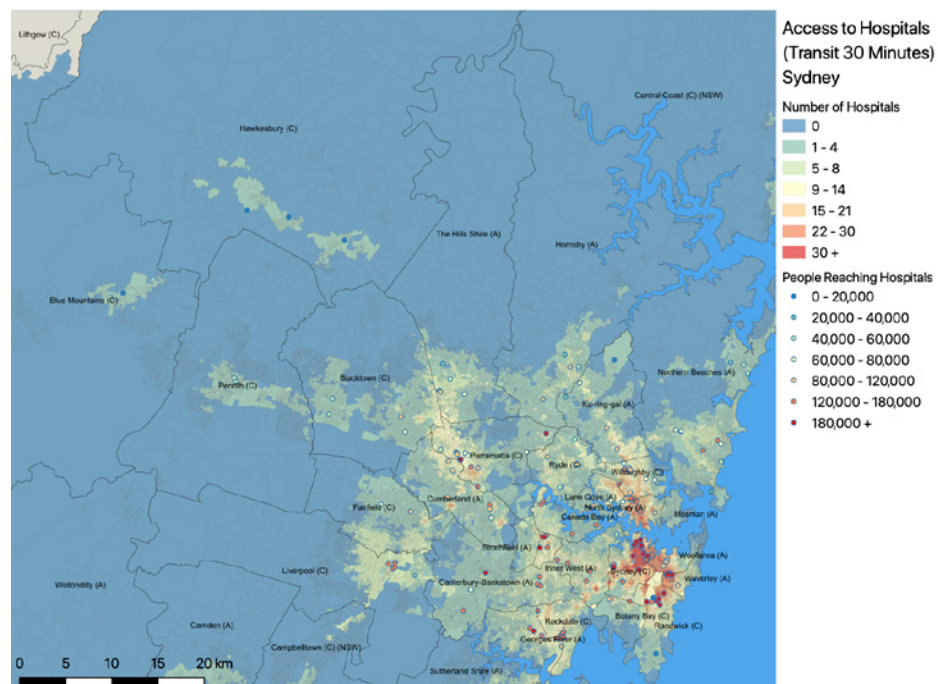
Source: Authors.

Figure A 6: Access to Hospitals, Walking 20 minutes, Sydney



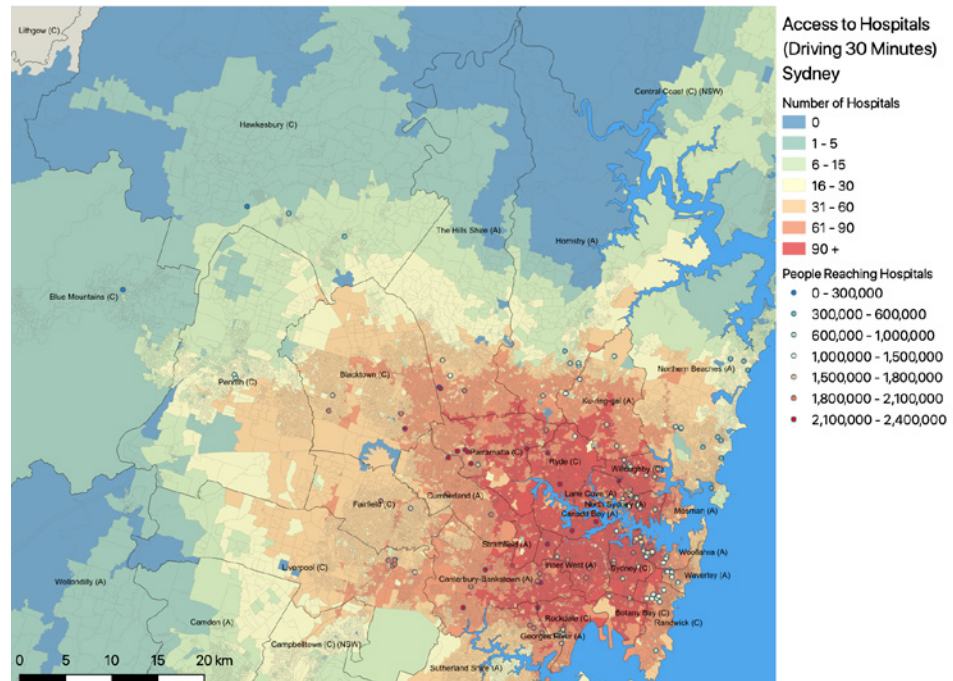
Source: Authors.

Figure A 7: Access to Hospitals, Transit 30 minutes, Sydney



Source: Authors.

Figure A 8: Access to Hospitals, Driving 30 minutes, Sydney

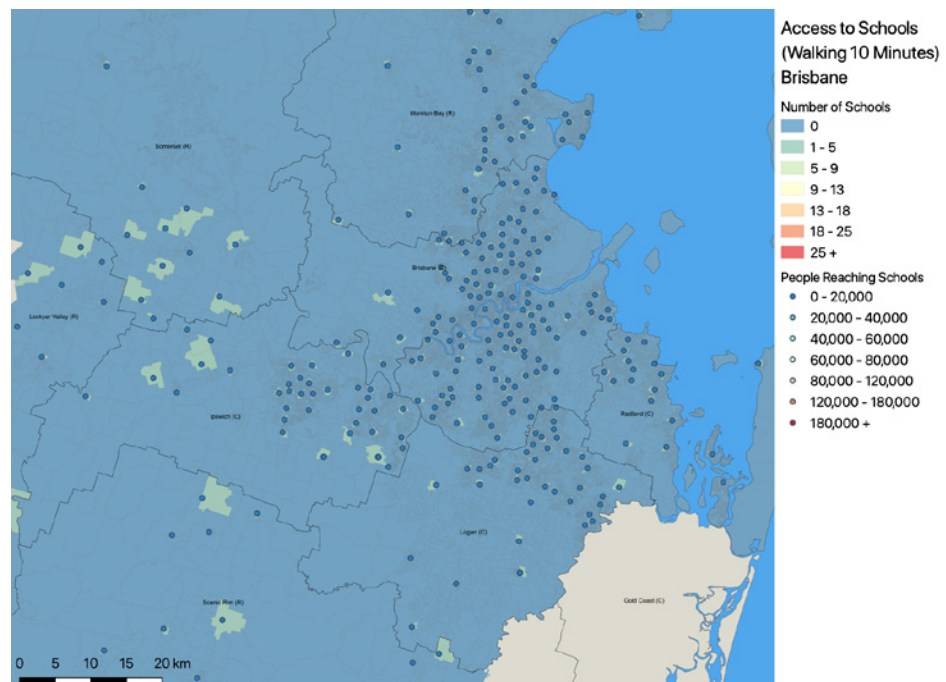


Source: Authors.

Brisbane

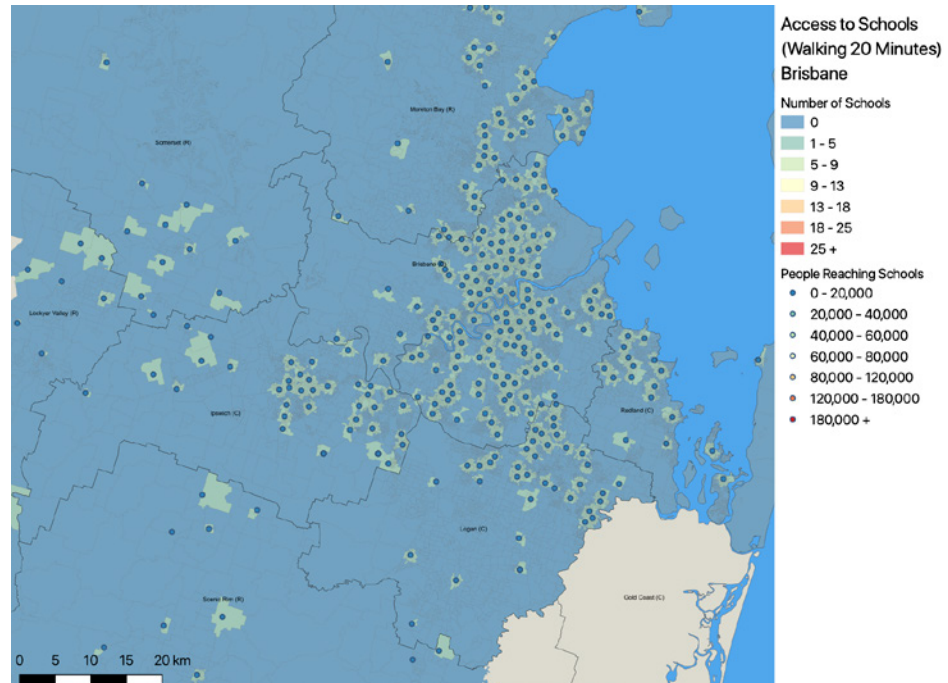
Brisbane, Access to schools

Figure A 9: Access to Schools, Walking 10 minutes, Brisbane



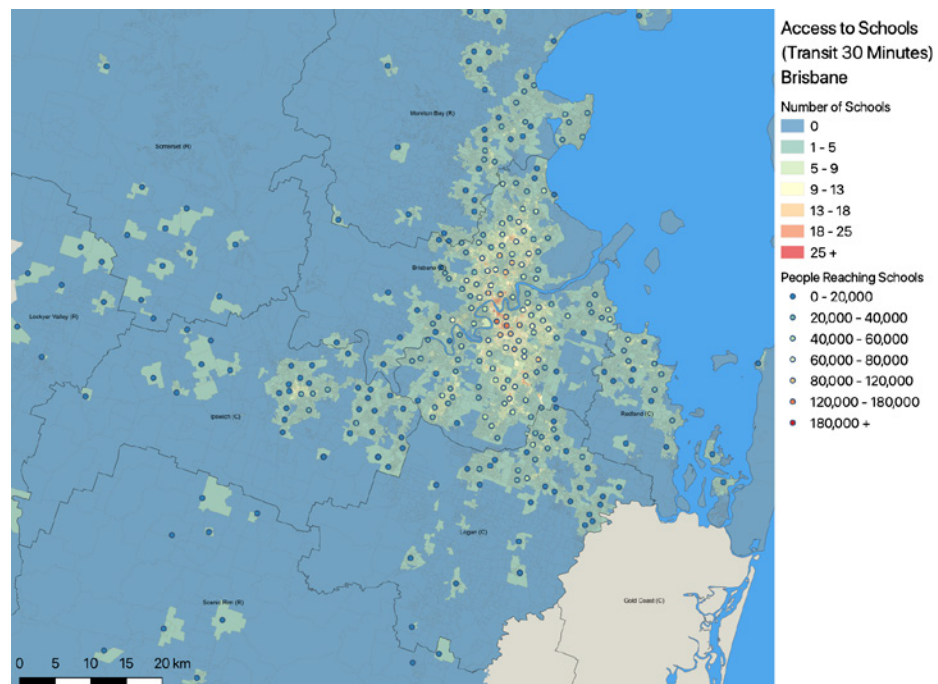
Source: Authors.

Figure A 10: Access to Schools, Walking 20 minutes, Brisbane



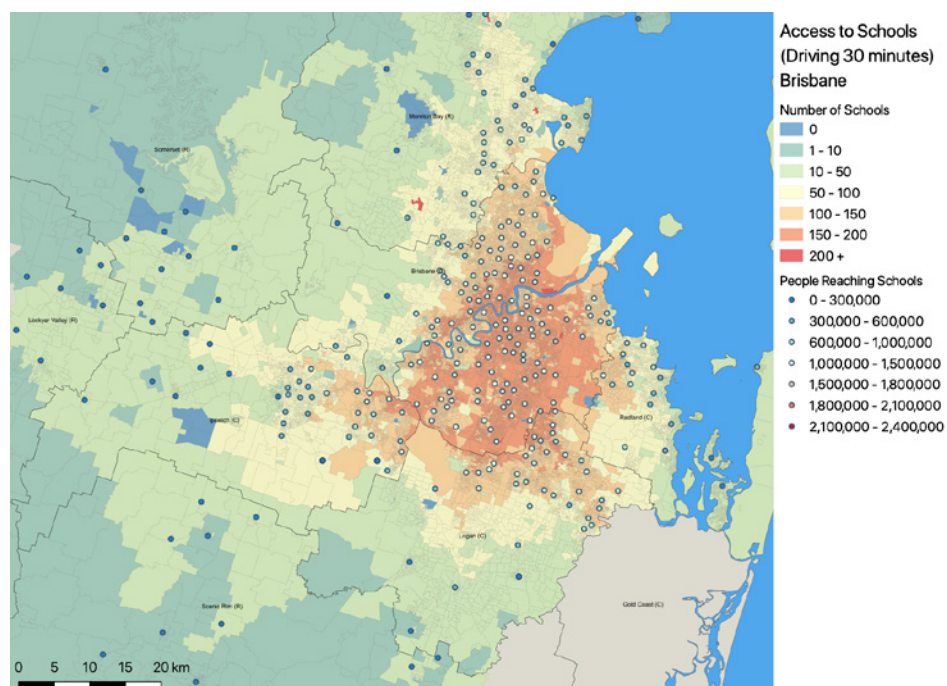
Source: Authors.

Figure A 11: Access to Schools, Transit 30 minutes, Brisbane



Source: Authors.

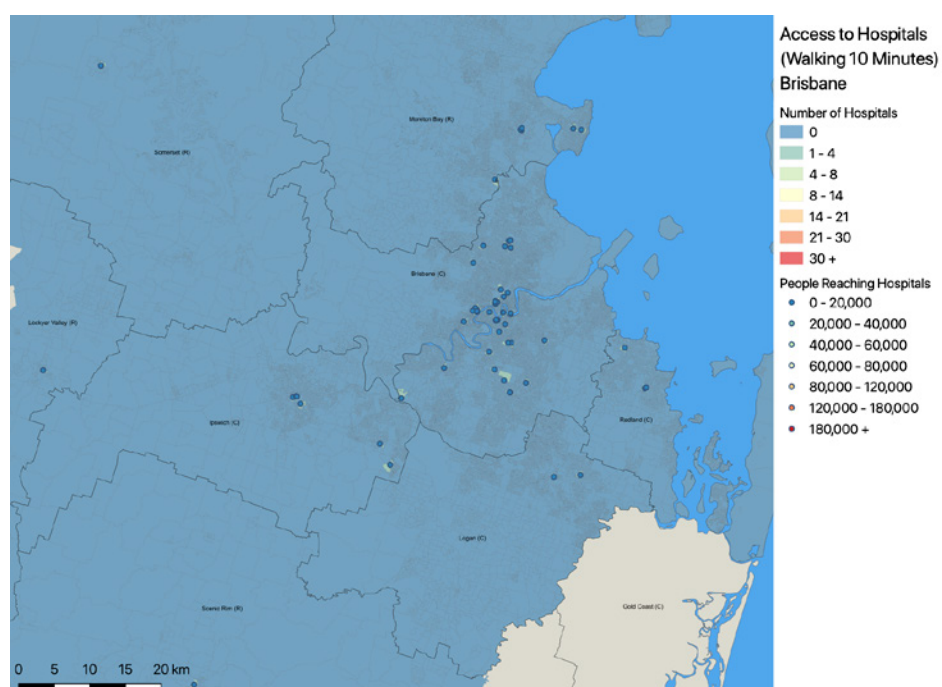
Figure A 12: Access to Schools, Driving 30 minutes, Brisbane



Source: Authors.

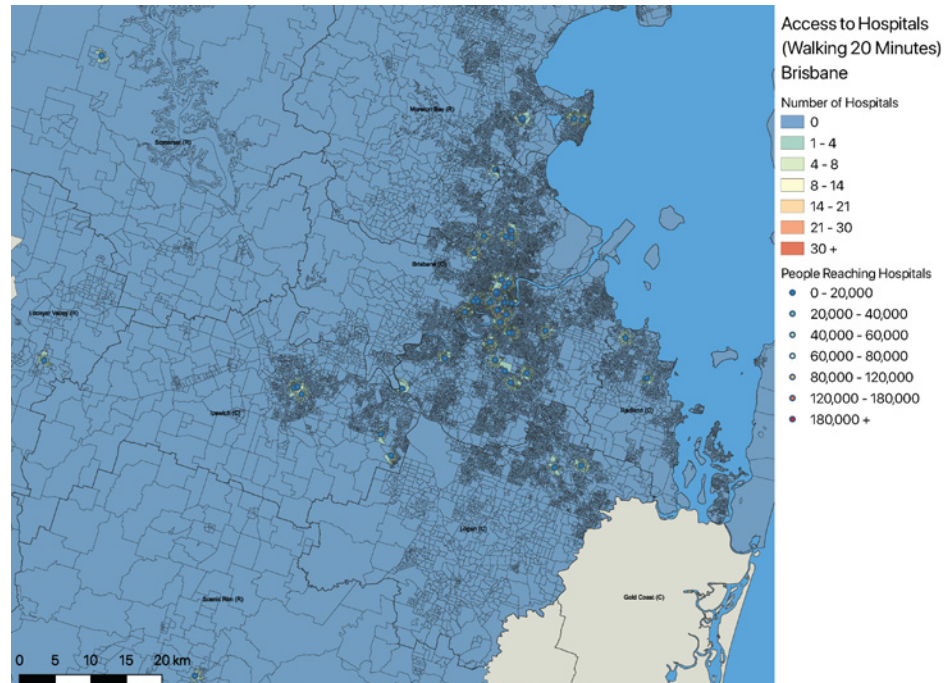
Brisbane, Access to hospitals

Figure A 13: Access to Hospitals, Walking 10 minutes, Brisbane



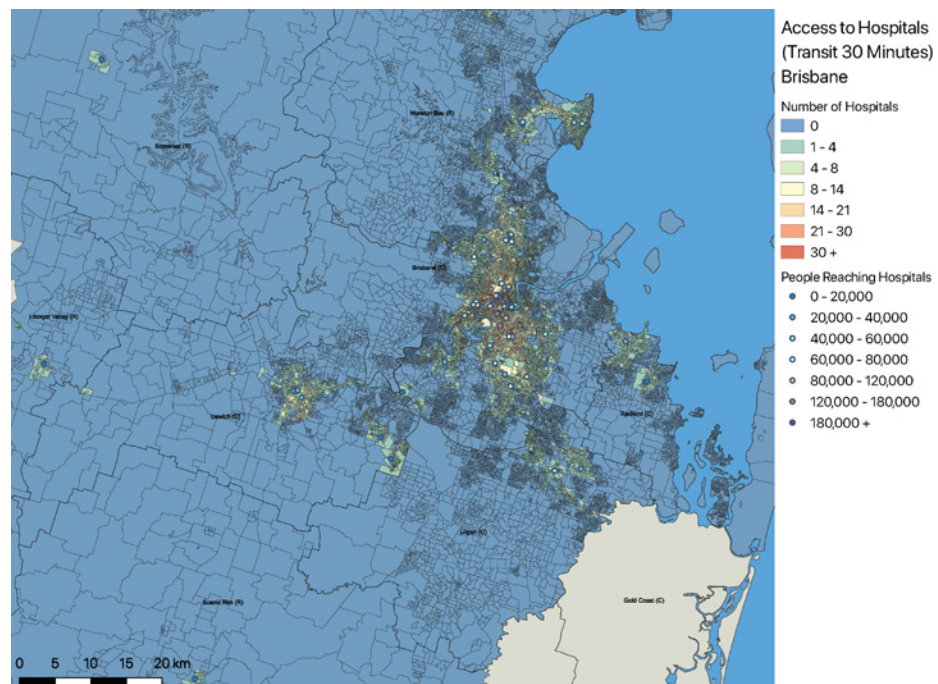
Source: Authors.

Figure A 14: Access to Hospitals, Walking 20 minutes, Brisbane



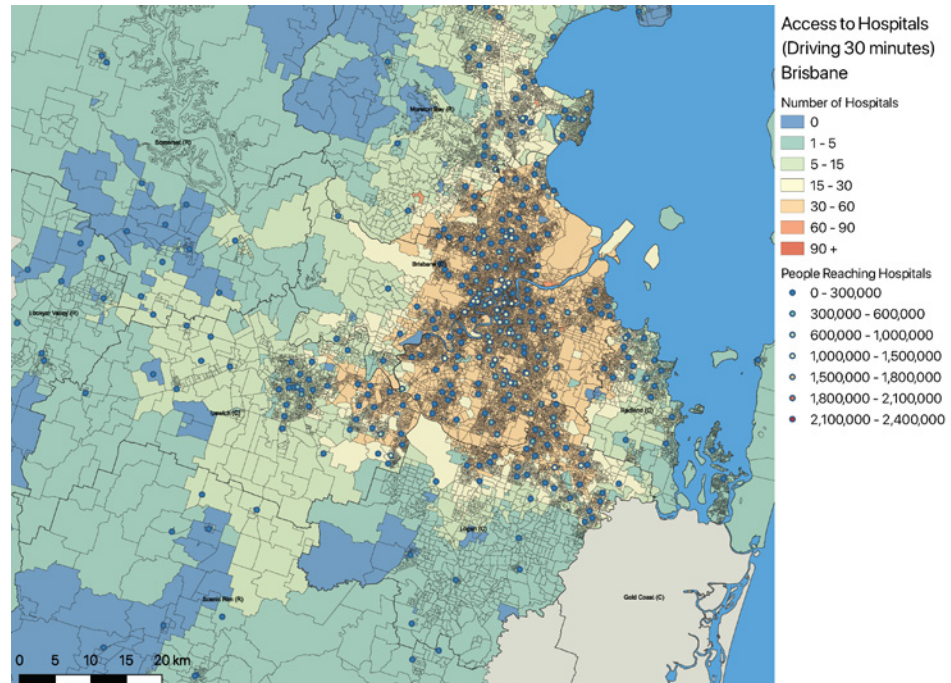
Source: Authors.

Figure A 15: Access to Hospitals, Transit 30 minutes, Brisbane



Source: Authors.

Figure A 16: Access to Hospitals, Driving 30 minutes, Brisbane

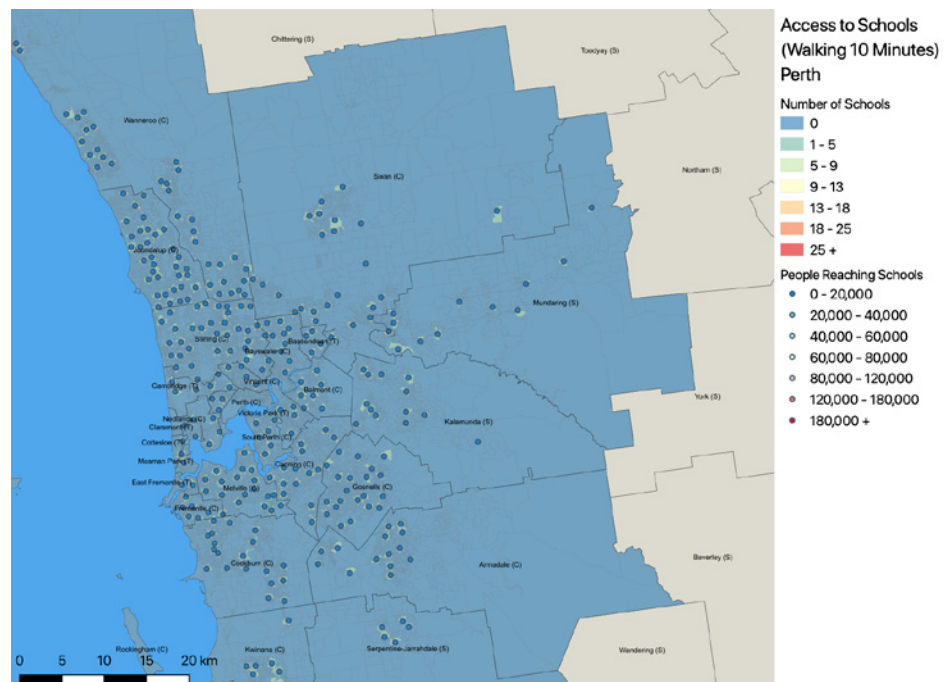


Source: Authors.

Perth

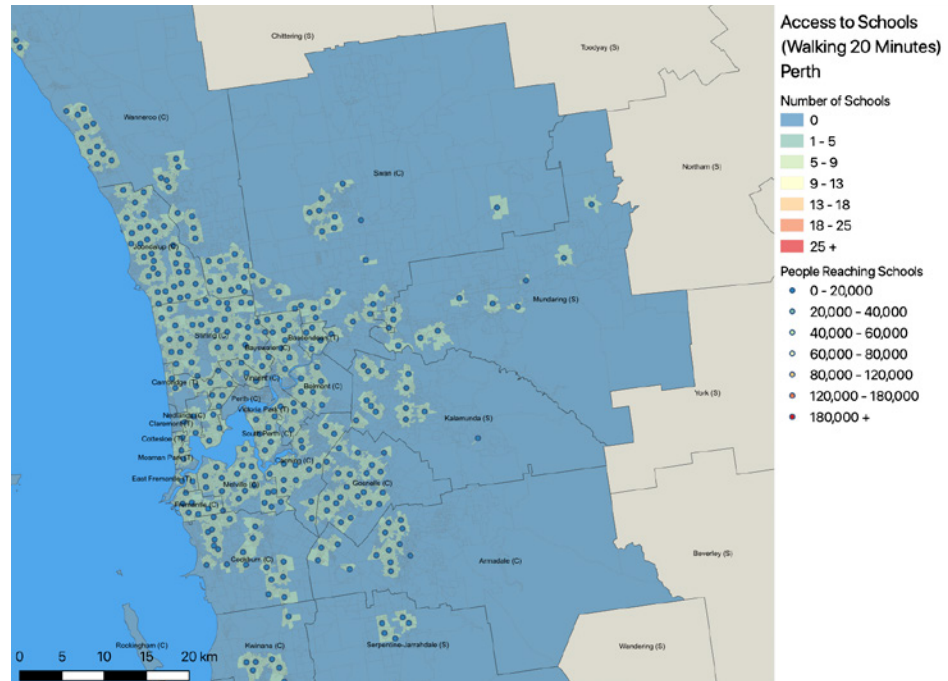
Perth, Access to schools

Figure A 17: Access to Schools, Walking 10 minutes, Perth



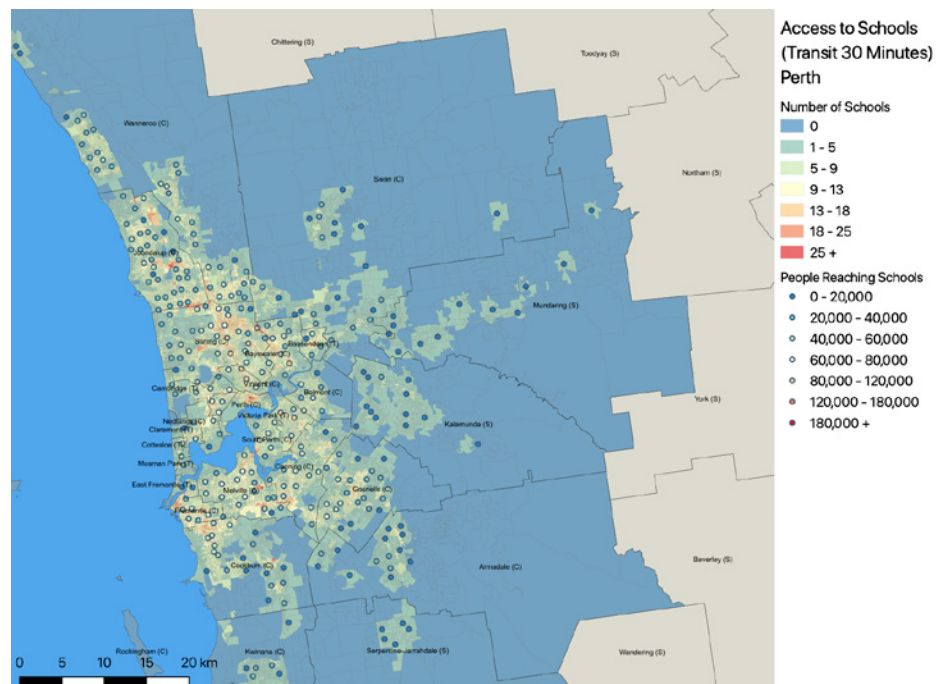
Source: Authors.

Figure A 18: Access to Schools, Walking 20 minutes, Perth



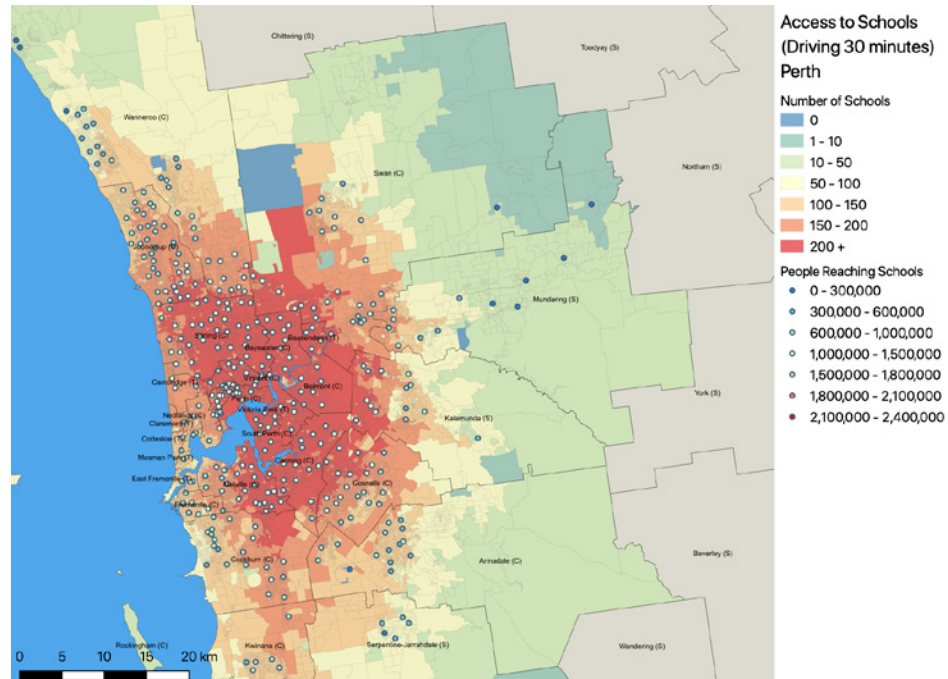
Source: Authors.

Figure A 19: Access to Schools, Transit 30 minutes, Perth



Source: Authors.

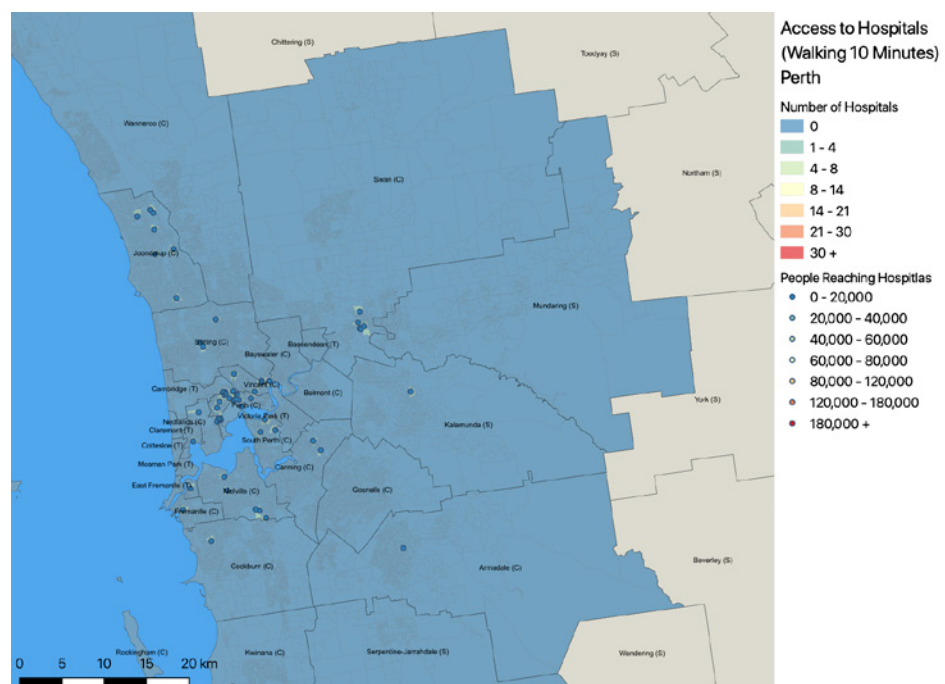
Figure A 20: Access to Schools, Driving 30 minutes, Perth



Source: Authors.

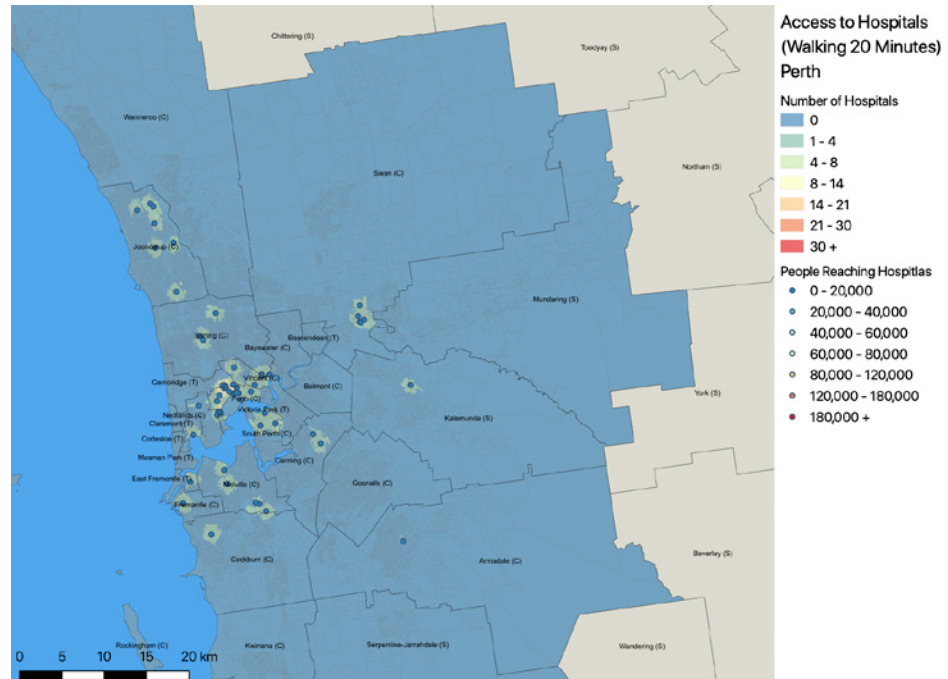
Perth, Access to hospitals

Figure A 21: Access to Hospitals, Walking 10 minutes, Perth



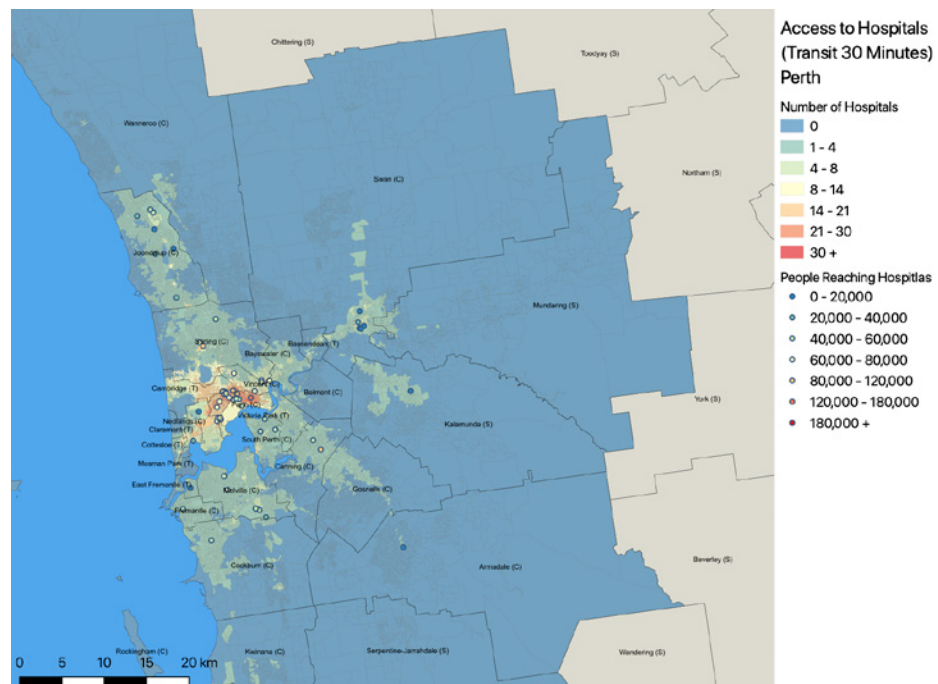
Source: Authors.

Figure A 22: Access to Hospitals, Walking 20 minutes, Perth



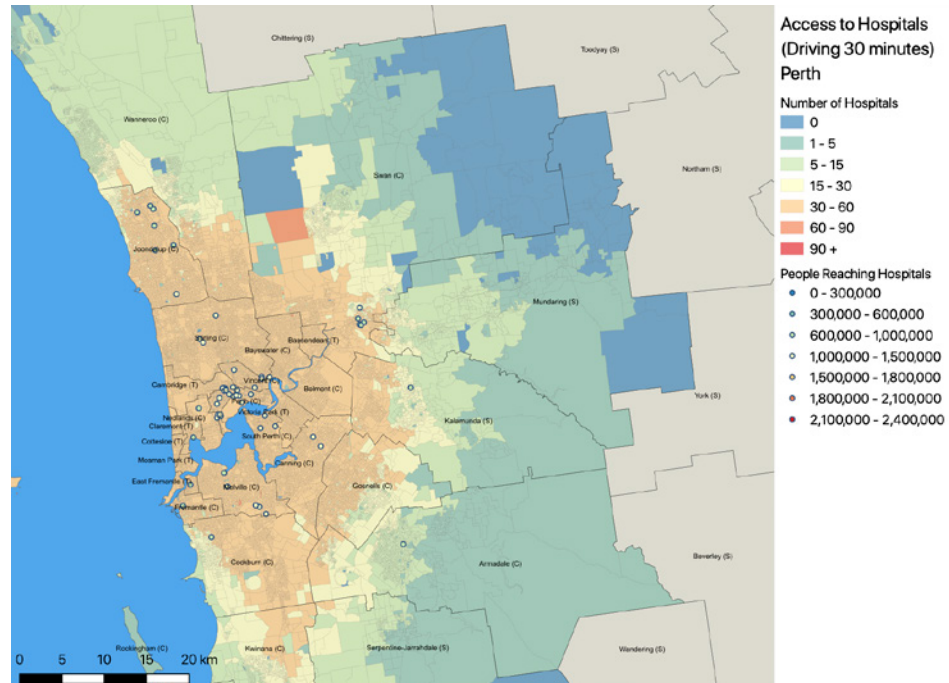
Source: Authors.

Figure A 23: Access to Hospitals, Transit 30 minutes, Perth



Source: Authors.

Figure A 24: Access to Hospitals, Driving 30 minutes, Perth



Source: Authors.



Australian Housing and Urban Research Institute

Level 12, 460 Bourke Street

Melbourne VIC 3000

Australia


+61 3 9660 2300

information@ahuri.edu.au

ahuri.edu.au

 twitter.com/AHURI_Research

 facebook.com/AHURI.AUS

 Australian Housing and Urban Research Institute