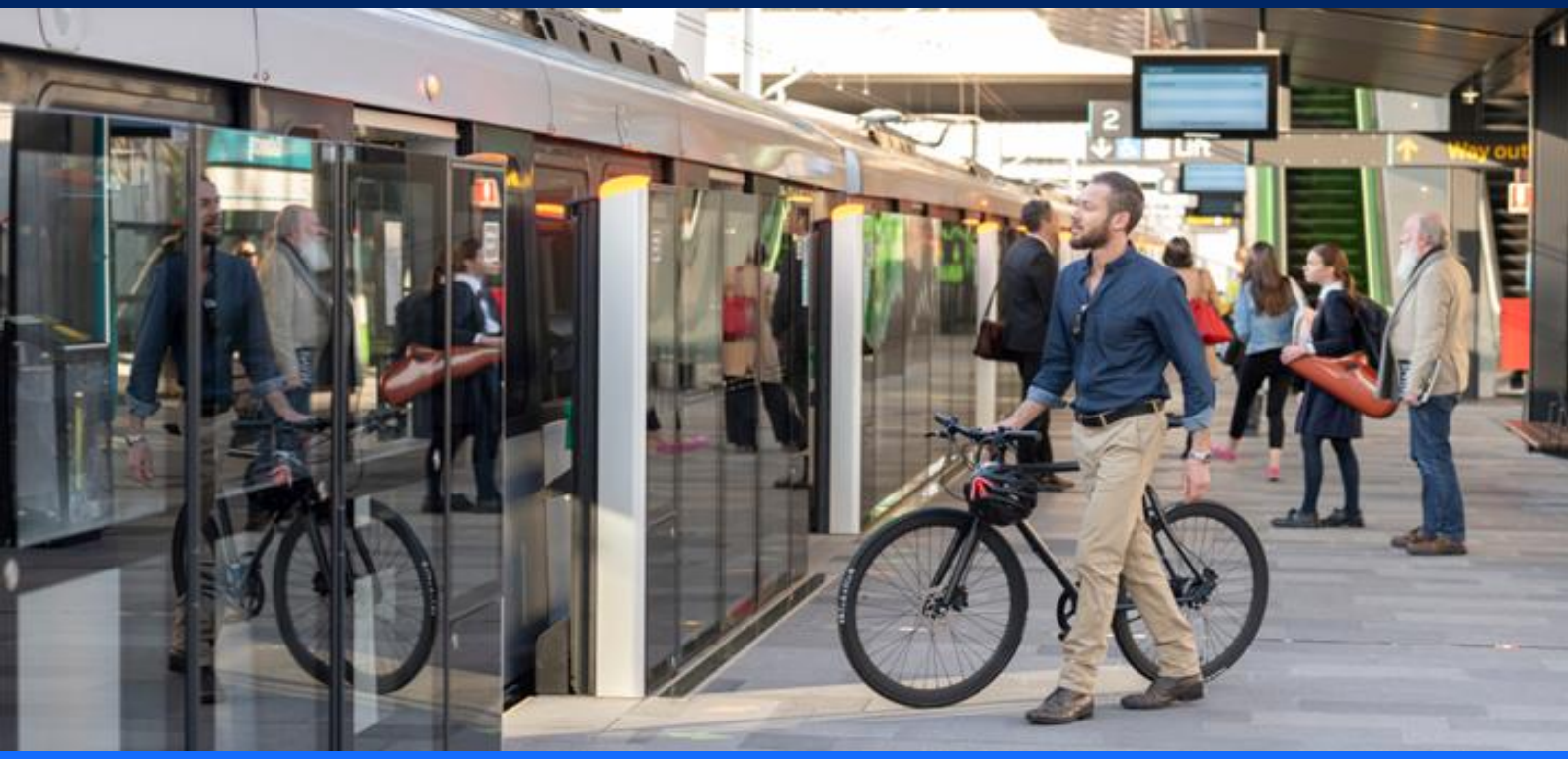
NSW Productivity Commission

Building more homes where infrastructure costs less

Comparing the marginal costs of servicing growth in different areas of Sydney

August 2023



NSW GOVERNMENT

Acknowledgement of Country

We acknowledge that Aboriginal and Torres Strait Islander peoples are the First Peoples and Traditional Custodians of Australia, and the oldest continuing culture in human history.

We pay respect to Elders past and present and commit to respecting the lands we walk on, and the communities we walk with.

We celebrate the deep and enduring connection of Aboriginal and Torres Strait Islander peoples to Country and acknowledge their continuing custodianship of the land, seas, and sky.

We acknowledge the ongoing stewardship of Aboriginal and Torres Strait Islander peoples, and the important contribution they make to our communities and economies.

We reflect on the continuing impact of government policies and practices and recognise our responsibility to work together with and for Aboriginal and Torres Strait Islander peoples, families, and communities, towards improved economic, social, and cultural outcomes.

Artwork:
Regeneration by Josie Rose

Commissioner's foreword

I love living in Sydney. A growing city is a lively and exciting place. It presents opportunities for people and businesses to flourish. But growth must be managed well, or we will undermine the many benefits a growing city offers.

More than ever, the people and the government of New South Wales know we need to provide the infrastructure that will accommodate Sydney's growing population. The city and the state can both gain a great deal from doing this effectively and with the lowest possible use of scarce resources. This is a complex challenge – and a major focus for the NSW Productivity Commission.

One of the biggest challenges we have identified so far is that our city has spread out over time. Our planning system has encouraged homes to be built away from, rather than near, the CBD where demand for housing is highest. Our previous paper, *Building more houses where people want to live*, highlights the enormous benefits of increasing housing in these high-demand areas across Sydney, instead of sprawling forever outwards.

Growing through sprawl has also been very costly. If we continue that way, then ultimately existing and future residents will have to pick up the bill through higher taxes or public debt.

With effective planning and urban design we can overcome this challenge. This paper exposes the significant variation in infrastructure costs between different parts of Sydney. It shows that picking the right places to build is crucial not just for giving Sydneysiders the opportunity to live where they want, but also reducing unnecessary costs of accommodating new people in our state.

Building more homes where infrastructure costs less provides policymakers with insights to reorient Sydney's planning system, and to help that system deliver better value for all of us as NSW residents.

At a time when governments face fiscal constraints and NSW residents face major cost-of-living pressures and housing costs are only increasing, we need to do things differently.

We need to build homes in the right places to ensure Sydney remains Australia's best city.

Peter Achterstraat AM

NSW Productivity Commissioner

About the NSW Productivity Commission

The NSW Productivity Commission ('the Commission') was established by the NSW Government in 2018 under the leadership of the state's inaugural Commissioner for Productivity, Peter Achterstraat AM.

The Commission is tasked with identifying opportunities to boost productivity growth in both the private and public sectors across the state to continuously improve the regulatory policy framework and other levers the NSW Government can pull. Productivity growth is essential to ensure a sustained growth in living standards for the people of New South Wales, by fully utilising our knowledge and capabilities, technology and research, and physical assets.

The Commission's priorities include:

- productivity and innovation
- fit-for-purpose regulation
- efficient and competitive NSW industries
- climate-resilient and adaptive economic development.

Since its inception, the Commission has undertaken several reviews on productivity matters and published the landmark *Productivity Commission White Paper 2021: Rebooting the economy*. More of the Commission's work can be found on our website: productivity.nsw.gov.au.

Disclaimer

The views expressed in this paper are those of the NSW Productivity Commission alone, and do not necessarily represent the views of NSW Treasury or the NSW Government.

Regarding the recommendations in this paper, NSW Productivity Commission recommendations only become NSW Government policy if they are explicitly adopted or actioned by the NSW Government. The NSW Government may adopt or implement recommendations wholly, in part, or in a modified form.

Abbreviations

CBD	Central business district
CIE	Centre for International Economics
DPE	(NSW) Department of Planning and Environment
DSP	Development servicing plans
GCC	Greater Cities Commission
LoI	Location of Interest
PIC	Place-based Infrastructure Compacts
SA3	Statistical Area Level 3

Contents

Executive summary

When building new homes in Sydney, New South Wales should consider the *costs*. Building in lower-cost places can save nearly $70,000 per home to deliver the roads, train services, water and wastewater, schools, and open space we need.

Sydney needs new homes

Sydney will need to build at least 550,000 more homes by 2041 just to keep up with our growing and changing population, according to the NSW Government's best estimate.

This paper is part of a NSW Productivity Commission series that considers not just how much housing we need, but where it should be delivered, for the benefit of our state.

We should build homes without unnecessary infrastructure costs

Building more homes where infrastructure costs less demonstrates how governments can better and more transparently incorporate public infrastructure costs — roads, rail, water, schools, and open space — into growth planning.

Over recent decades the growth strategy for Sydney has been to disperse both population and economic activity. Providing such a sprawling city with high-quality infrastructure services comes with significant costs.

By using taxpayers' infrastructure dollars more efficiently, we will have more government money to maintain and improve government services and to keep taxes lower.

To lower costs, we can use existing infrastructure better

Many potential Sydney home sites are already well-served by existing infrastructure that new residents can use — so the costs of the development will be low. Other sites will need much more investment to meet the infrastructure needs of new homes.

By choosing locations well-served by existing infrastructure, we can lower the costs of growing Sydney. Elements of this infrastructure strategy have already achieved results in places like Green Square, Chatswood, and Macquarie Park.

The biggest gain from this strategy is that we will minimise the extra road congestion from new homes. But costs will also often be substantially lower for water and wastewater connections and for schools.

Our analysis shows the areas where infrastructure costs are lowest include Sydney's central business district (CBD) and parts of the Lower North Shore, Eastern Suburbs, and the Inner West.

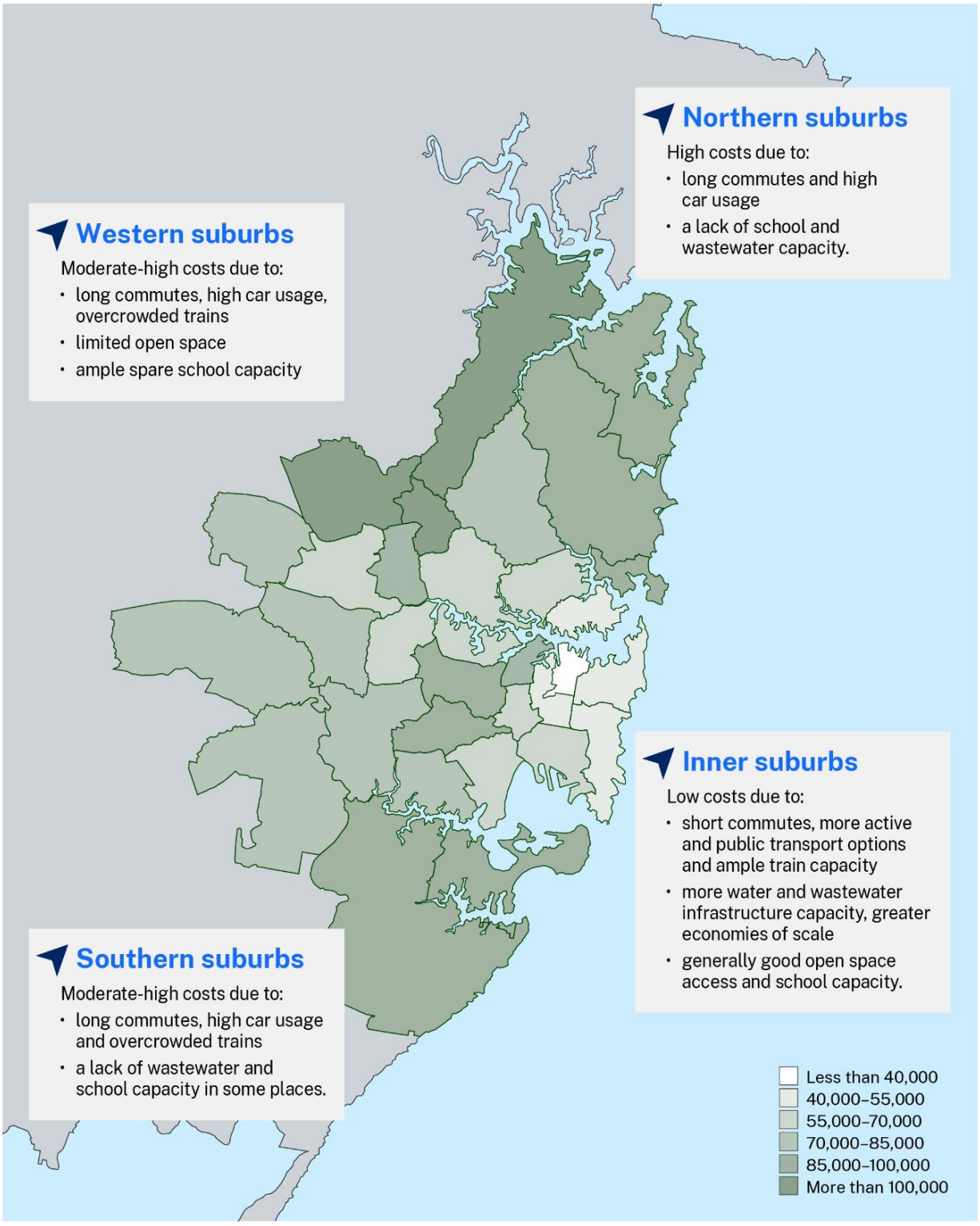
Our research suggests rethinking the way Sydney grows

Our recent paper, *Building more homes where people want to live*, highlighted the benefits from building in high-demand, high-feasibility locations. This paper suggests that the places where people want to live are largely also places with low infrastructure costs. Together, the two papers suggest Sydney has much to gain from rethinking the way we plan for growth across the city.

Our papers recognise the importance of 'doing density well'. Leveraging existing infrastructure and amenity is important to achieving good density. There are many more considerations that are outside the scope of this paper. Our Productivity White Paper highlighted how increased density can retain or even improve local character through good infrastructure and precinct planning, well-designed and well-built buildings, and consideration of public amenity.

Why are infrastructure costs so different across Sydney?

The costs of servicing new housing with infrastructure vary up to $75,000 between inner and outer suburbs.



1 Sydney's planning affects infrastructure costs

1.1 Sydney planning needs to consider costs and benefits

Sydney is growing quickly: it is adding people, and at the same time expanding its boundaries. The NSW Department of Planning and Environment (DPE, 2022a) projects Sydney's population to grow by more than a million people by 2041.

DPE projects that by 2041 we will need 550,000 new homes in Sydney (DPE, 2022b) — that is, around 30,000 new homes per year — just to meet the needs of new residents and changing demographics. To reduce the existing undersupply would likely require substantially more: the Committee for Sydney (2022) estimated in 2022 that Greater Sydney has an undersupply of 96,000 homes, while the CIS estimates an apartment shortage of 82,000 (CIS, 2023). New South Wales' biggest city needs to keep building new housing for its people.

All of these new homes will need to be well-serviced by public infrastructure – road and rail transport, utilities like water and wastewater, and social infrastructure. Adequate and timely infrastructure servicing is critical: when people oppose development in their local area, they often report concern that infrastructure is inadequate to support more residents.

NSW uses two planning tools to help it support and manage Sydney's growth:

- Strategic land use plans are the main tool the NSW Government uses to decide how to manage Sydney's growth. These plans set the long-term vision for the city; among other things, the plans estimate how much new housing we need and where it should be built.

  The Greater Cities Commission (GCC) is responsible for strategic planning for Greater Sydney, as well as for the Illawarra, Central Coast, and Newcastle. The GCC is required to deliver a strategic plan for this 'Six Cities' region in 2023. The revised plan will include housing targets and estimated infrastructure needs for each subregion.
- Strategic transport plans — such as the Future Transport Strategy (2022), prepared by Transport for NSW — take this projected growth and development into account and outline how people will be able to move around the city.

To maximise the benefits of growth and manage infrastructure costs, these strategic land use and transport plans should be based on strong evidence of the costs and benefits of different options for the economy, environment, and society.

A good understanding of the relative infrastructure costs in different locations is critical for this analysis. Population growth requires infrastructure spending wherever it occurs. But the analysis in this paper suggests the size of that spending varies across Sydney. It is lowest in inner areas of eastern Sydney – particularly the Eastern Suburbs, Lower North Shore, and Inner West.

Box 1: Building more homes where people want to live

This is the second paper in our housing series and builds on the first, *Building more homes where people want to live*, published in May 2023. The first paper argues that to make housing cheaper, Sydney must build more of it. The best evidence is that a 10 per cent increase in supply leads to a 25 per cent reduction in housing costs.

The paper recommends raising housing supply by allowing greater density in the areas of highest demand, particularly high-amenity and convenient suburbs closest to the Sydney CBD, which would generate the greatest benefits for households and be most feasible for industry.

Our housing series and *Productivity White Paper* also recognise the importance of density being done well. The White Paper (Box 7.3) showcased Central Park, a recently developed precinct in central

Sydney. It was previously a 5.8-hectare industrial site which had been home to breweries from 1835 until 2003 when the Carlton United Brewery closed its doors.

Despite strong local opposition in the early stages, Central Park has been lauded for its well-designed buildings, preservation of several historic buildings, and sustainability measures. It is recognised as a success story because it demonstrates that high density development in a convenient location can not only improve local amenity and character, but also allow many more people to enjoy it.

1.2 Infill development has lower infrastructure costs

'Greenfield' developments (see Box 2) create new communities largely from scratch – so they require entire new sets of infrastructure. These new communities need water and wastewater connections, stormwater facilities, electricity connections, new local roads, upgraded arterial roads, new and upgraded public transport facilities, new and upgraded community buildings, and public space.

'Infill' development increases urban density to make more efficient use of scarce, well-located land. At the same time, it can have lower infrastructure costs than greenfield developments because much of the supporting infrastructure is already present:

- Infill development can make use of spare capacity in nearby infrastructure. It can use existing water mains, open spaces, train stations and rail services, and arterial roads.
- Existing infrastructure can be upgraded cost-effectively where land is already available. For example, we can widen roads and expand existing schools to take more students.
- Existing infrastructure can be repurposed. We can convert car lanes or parking to bicycle lanes or open space where we previously lacked the demand to justify such spending.
- New infrastructure becomes far more cost-effective. A new metro station near apartment buildings benefits more people than a station surrounded by detached houses.

Box 2: Different development types face different challenges

Greenfield development is any development on previously undeveloped land, usually rezoned agricultural land. Greenfield development needs a comprehensive program of new infrastructure.

Infill development is development on land that has been previously developed. Depending on the condition of individual sites and redevelopment proposals, existing infrastructure may need to be improved to support greater residential use. But in most cases existing infrastructure can be leveraged to lower the overall cost and improve the quality of redevelopment.

Brownfield development is sometimes used to distinguish infill development on previously industrial or commercial land. Brownfield development generally has more infrastructure capacity than greenfield. Depending on the amount of land being redeveloped and expected growth, infrastructure may still require substantial investment. Contamination may also be present from previous uses and may require remediation.

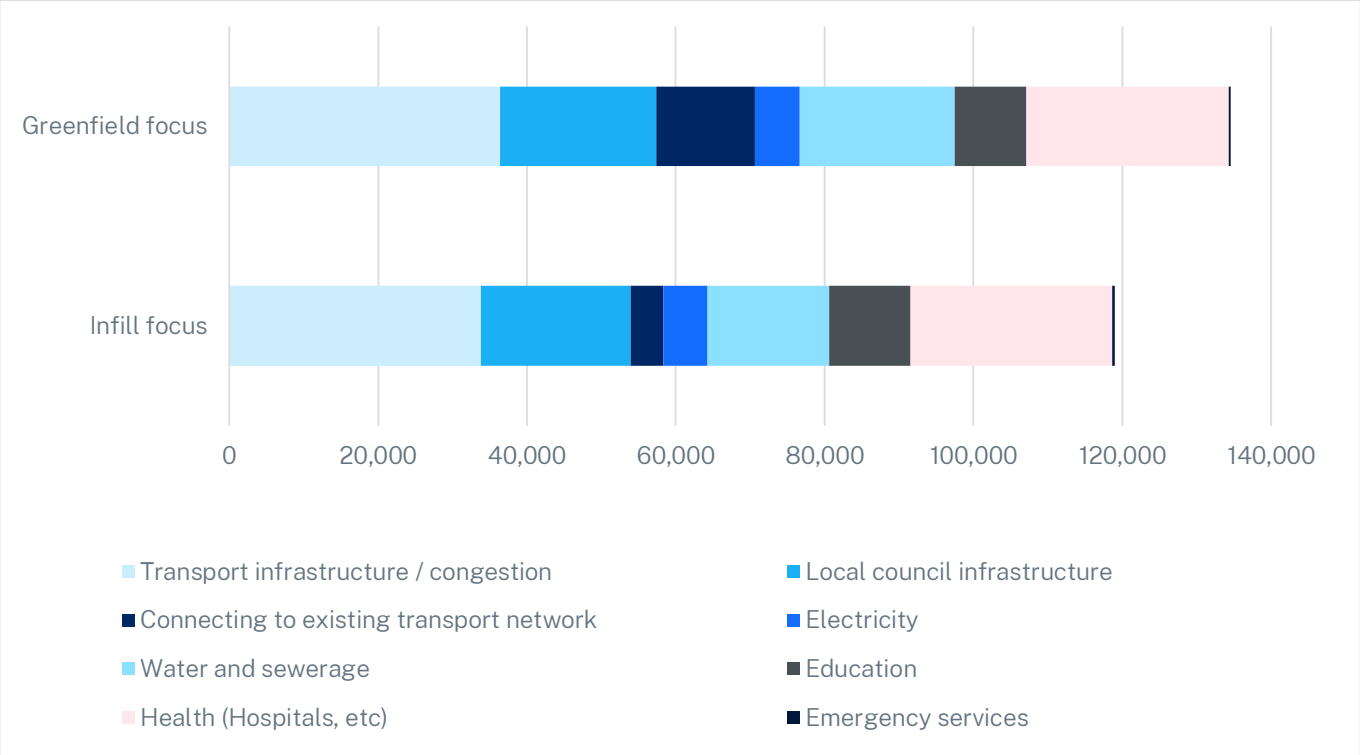
In an extensive literature review, SGS (2016) estimated that the infrastructure for greenfield housing typically costs two to four times what it does in infill sites. While greenfield costs were broadly consistent across different sites, the costs of infill development depended largely on the amount of existing infrastructure capacity in the specific locations.

In a Sydney-specific scenario analysis, the Centre for International Economics (CIE, 2010) likewise found that homes in infill-focused growth pathways would be less costly. A pathway evenly split between infill and greenfield housing was estimated to cost around $98,000 per home, compared to $86,000 per dwelling for a 90/10 infill scenario (Figure 1). That was a difference in 2010 of around $12,000 per dwelling ($16,000 in 2023 dollars), or 12 per cent (CIE, 2010). Higher transport infrastructure costs in the greenfield scenario — such as new main roads and public transport expansions — made up three-quarters of the cost difference.

Based on these estimates, Sydney infill infrastructure typically appears to cost approximately $39,000 per property less than greenfield, though costs vary widely by location (Box 3).[1]

Figure 1: Previous research shows infill is generally cheaper than greenfield developments

Estimated per-dwelling infrastructure costs under alternate growth paths, 2011-2035, in 2023 dollars, adjusted for producer price index inflation, dollars per dwelling



Source: CIE (2010); ABS (2022), NSW Productivity Commission.

The analysis by CIE described earlier in this section shows the large difference in costs between two different growth paths for Sydney — one based on greenfield and the other based on infill. However, to date there has been little focus on understanding which areas across Sydney can add *infill housing* at low costs, and which will have high costs. This is an important knowledge gap, and it should be considered when we plan for the extra housing Sydney needs.

The location of development in Sydney can deeply affect the infrastructure-related costs of development, because:

- existing infrastructure capacity is not distributed equally between different areas of Sydney
- building new homes in some areas of Sydney will require more new infrastructure than others.

These costs can even vary in relatively nearby parts of Sydney (Box 3).

[1] Extrapolating from the 90:10 and 50:50 greenfield to infill ratios and adjusting to 2023 dollars.

Box 3: Detailed analysis demonstrates costs vary widely by location

The GCC's Place-based Infrastructure Compacts (PIC) program shows how costs differ even in neighbouring parts of Sydney. CIE evaluated the economic costs of the Western Sydney PIC and examined a scenario where the GCC's Western Parkland City vision was realised, centred on the Western Sydney Aerotropolis. The evaluation found developing established centres such as St Marys, Kingswood and Werrington, and Penrith Centre would cost around $50,000 per additional person. In neighbouring suburban areas such as Penrith West, St Clair, and South Penrith and Glenmore Park, these costs increase by around 50 per cent to $75,000 per person (CIE, 2020a).

Greenfield precincts see considerably more costs and variation. The Aerotropolis Core and Mamre Road had the lowest greenfield costs, at $110,000 per additional person. At the other extreme, North Luddenham, Western Sydney Aerotropolis, and Kemps Creek exceeded $350,000 per person. The average cost across all greenfield areas was $174,000 per person (CIE 2020b).

A similar analysis by Infrastructure Victoria in 2019 compared infrastructure costs between infill and greenfield development in Melbourne. For infill sites they estimated that costs ranged between $11,800 and $160,800 per dwelling, while for greenfield they ranged between $79,800 and $214,000. The largest differences in costs between infill and greenfield were for civil construction (such as site preperation, stormwater, and easements), and for water and sewerage. The large range of the infill estimates was shaped by the availability of existing schools and community facilities, as well as capacity of essential services (Infrastructure Victoria, 2019). Importantly, Infrastructure Victoria's analysis did not consider transport costs.

1.3 We modelled the marginal cost of infill development

Sydney needs tens of thousands of new homes a year and there are hundreds of potential infill locations across the city. The decision to build an additional home in a high-infrastructure-cost location rather than a low-cost location has a real economic impact. It is important to understand these costs.

It would be unfeasible to consider the specific infrastructure needs for all the possible combinations of development. Therefore, we have taken a simpler approach based on the *incremental cost* of adding a moderate amount of new housing — 2,500 households in 2,500 homes — to an infill area. We do this for each SA3 in Greater Sydney.

To allow us to cast the net wide we focus on *economic* costs of growth, from the community's perspective. While related, this is not the same as financial costs to government. Costs to government will vary, depending on:

- the number and type of projects required
- whether cost recovery mechanisms are in place to either fully or partly offset servicing costs, including user charges and developer contributions.

This paper holds that it is up to governments to determine the appropriate funding and pricing strategy for selected infrastructure projects, based on sound public finance principles.[2]

For some of the infrastructure types, however, our modelled cost is closer to the government's financial cost. For example, we estimate the cost of upgrading schools where additional capacity is needed to accommodate new students — this is a cost to the NSW Government.

The five infrastructure types we investigated are listed in Table 1, along with a description of how we estimated them. A more detailed discussion of each infrastructure type is included in Chapter 3.

[2] If the costs of growth can be recouped from those who benefit from it — such as tolls for motorways or developer charges for water — governments can reduce their fiscal exposure. Pricing can also influence decision-making and thereby optimise social welfare (for example, by encouraging travel at off-peak times, or development in lower-cost locations).

Table 1: Estimating the cost of growth for selected infrastructure types

Infrastructure type	How we estimated costs
Roads	The cost of time lost through congestion
Trains	Cost of time spent in an overcrowded train carriage
Schools	The cost of upgrading schools to manage increased enrolments
Water and wastewater	The cost of connecting new households to Sydney Water infrastructure
Public open space	The cost of land required to improve access to open space

We considered including other infrastructure types such as electricity infrastructure, hospitals, and public safety infrastructure (such as police stations). However, from reviewing earlier analyses such as CIE's 2010 report we found the costs of these infrastructure were either very small at the margin (for instance, the additional housing would not impact the need for police) or varied less by location. Including these other types would be unlikely to change the findings of our analysis.

Our goal has been to identify areas across Greater Sydney with available infrastructure capacity, rather than to undertake a detailed urban planning study of how to manage future growth. More complex analysis — such as using Transport for NSW's Strategic Transport Model and best-practice project cost estimation — should ultimately determine how growth should be accommodated across urban space and through time. This more detailed analysis would also consider the ideal sequencing and location of new infrastructure investment under different scenarios.

Large, city-shaping infrastructure projects (typically transport projects) are also out of scope for this paper. Large projects are typically designed to cater for much larger changes in population than the marginal analysis in this paper.

1.4 Growth costs are lowest in inner-ring suburbs

Based on our analysis, we found it would be more cost-effective to look to more central suburbs to accommodate additional households.

The lowest-cost area we modelled was the Sydney CBD (which includes surrounding residential areas like Redfern and Potts Point). Here, the infrastructure we modelled costs less than $40,000 per dwelling. This was followed closely by parts of the following areas (see

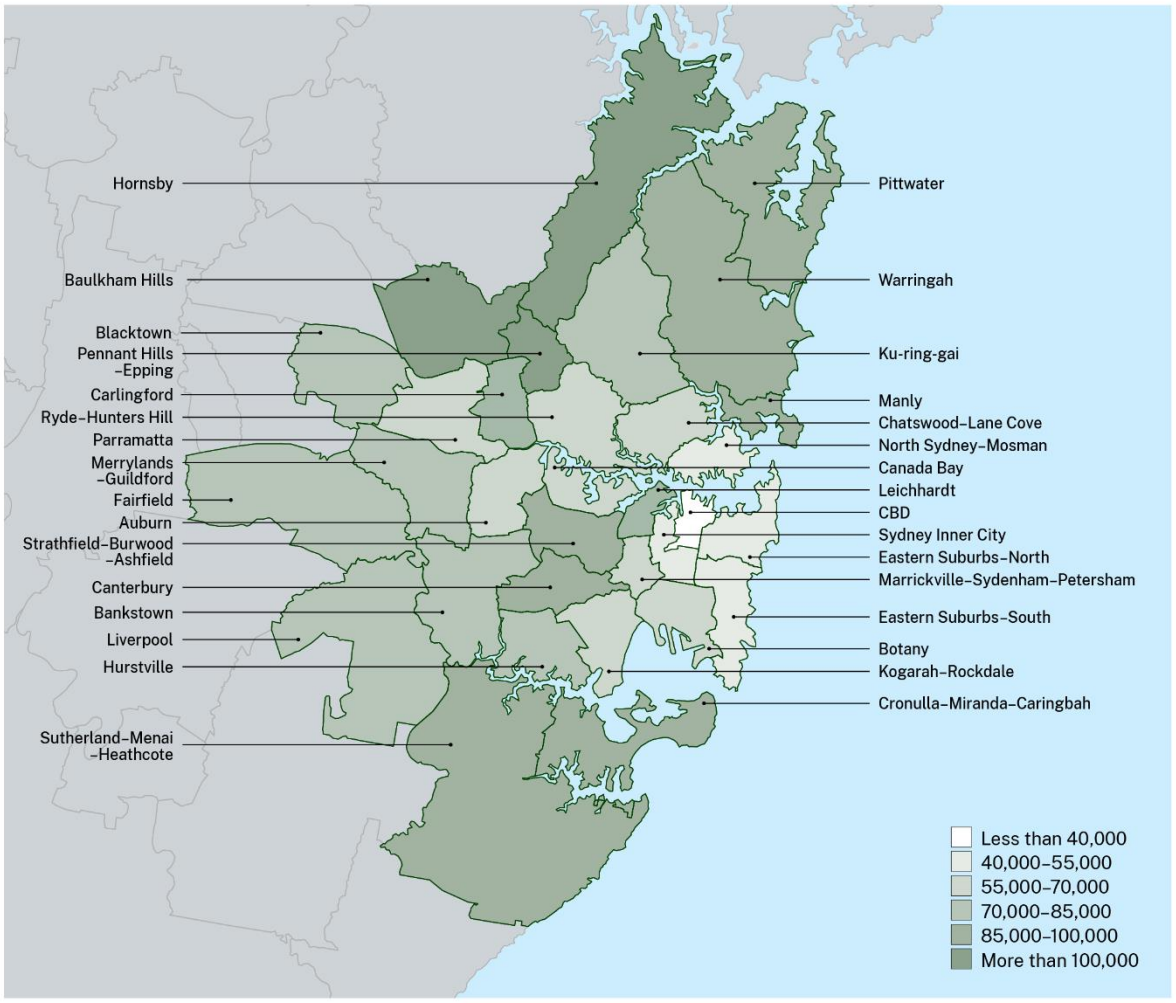
Figure 2):

- the Eastern Suburbs (focusing along the existing T4 Eastern Suburbs Line and in Randwick)
- the Inner South and West, which includes areas such as Newtown, Waterloo, and Alexandria
- the Lower North Shore, including North Sydney, Crows Nest, and Chatswood.

As we moved further from the Sydney CBD, particularly to the north and south, the cost of infrastructure to accommodate growth increased. The highest-cost areas were parts of the Sutherland Shire, the Hills Shire, Hornsby, and the Northern Beaches local government areas. Costs in some of these areas were up to $75,000 per dwelling *higher* than for inner-city areas. This mostly reflected higher traffic congestion and water and wastewater costs, but was also affected by the costs of expanding school capacity in some areas.

Figure 2: Growth in inner suburbs costs less

Total infrastructure costs, $ per additional dwelling



Source: NSW Productivity Commission analysis.

1.4.1 Commuter congestion was the largest cost in most areas

Congestion reduces productivity and damages health and quality of life. Road congestion adds to the time — and hence the cost — that people spend travelling to their places of work, and makes it harder for employers to attract employees. Congestion also makes it more costly to get to places of education and other amenities. Peak-period transportation, particularly in the 8-9 am hour, continues to be a major challenge in Sydney, even with some lasting shifts in travel behaviours arising from the COVID-19 pandemic.

In our analysis, road congestion was the largest cost of adding extra housing for most areas. This reflects the high value of lost time that results from sitting in excessive traffic, particularly at peak times. Road congestion also accounts for most of the *variation* in cost between areas (Figure 3). Commuter congestion and crowding costs are easier to manage for areas close to the CBD.

During the morning peak there is a large movement of workers from the west of Sydney to the east; that reverses in the evening peak. Around a third of commuters travel to major employment hubs in a corridor that stretches from Macquarie Park, through North Sydney and the CBD, to Port Botany

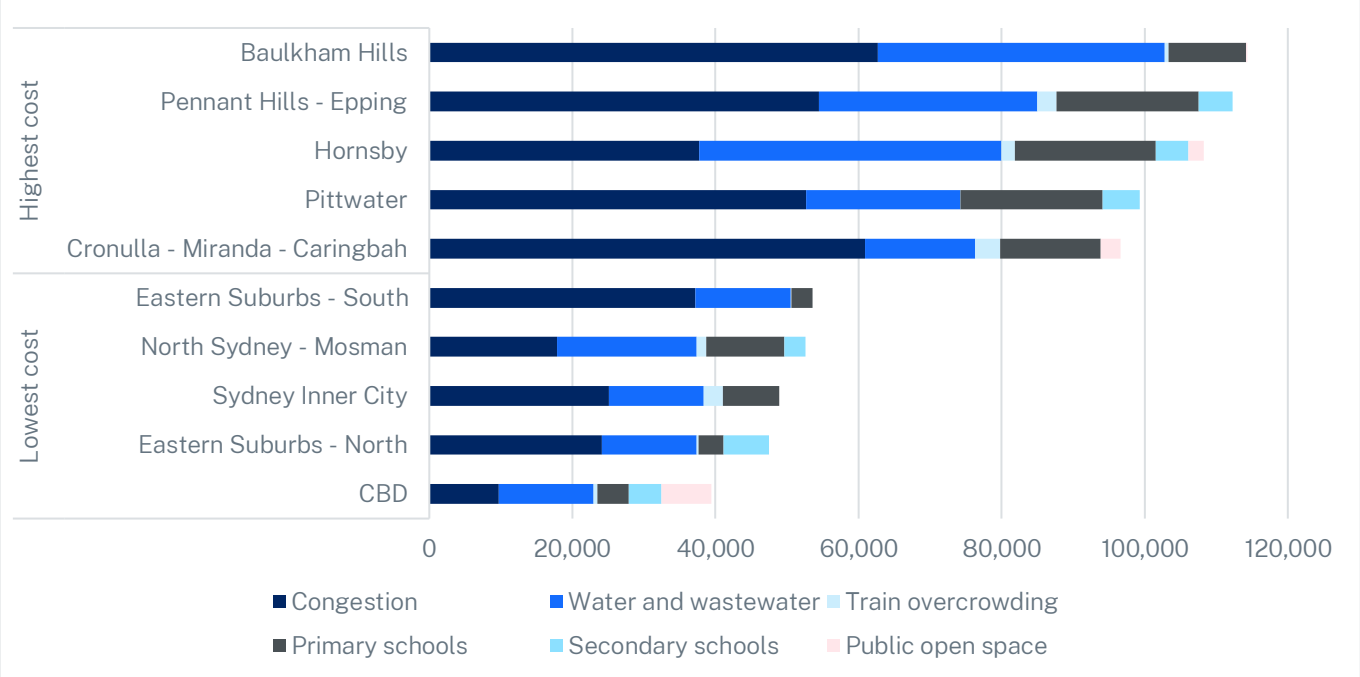
and Sydney Airport. The remainder travel to dispersed locations and many of these workers drive.[3] This pattern is reflected in the large congestion costs we measured for additional housing in outer suburban areas of Sydney.

Areas close to the city had much lower congestion costs from additional housing. Several factors combine to create this result:

- Areas close to the city are well-serviced by transport infrastructure, including Sydney Trains, light rail, buses, ferries, footpaths, and cycleways.
- They are closer to jobs, and shorter travel distances encourage active transport, especially walking.
- Where inner residents of these areas need to travel to distant locations by car, they have easy access to arterial roads and are often travelling in the opposite direction to most traffic.
- Where residents do need to drive on congested roads, their commutes tend to be short. Therefore, they do not lose as much time to congestion as a driver from Western Sydney, even if the roads they drive on have similar levels of congestion.[4]

Figure 3: Road congestion costs largely drive the geographic variation in costs

Infrastructure costs per additional dwelling, in dollars, for five highest and lowest cost SA3s



Note: The most and least costly five SA3s are depicted. SA3s usually have populations of 50,000-150,000. A full table of this data is presented in Appendix A:.

Source: NSW Productivity Commission analysis.

Most of the crowding on Sydney's rail network occurs as commuters travel to employment centres during peak hours:

- Crowding can increase time spent standing on station platforms, and thus can raise travel times for individual services.

[3] See section 3.1.3 for further analysis.

[4] For example, a trip from Randwick to Pyrmont takes 18 minutes without traffic and 40 minutes with traffic, with the commuter losing 22 minutes to congestion. In comparison a commuter from Westmead to Pyrmont takes 28 minutes without traffic and 65 minutes with traffic, losing 37 minutes to congestion.

- Overcrowding can reduce the capacity of the entire network, because even advanced signalling technology requires hard limits on the number of services that can be run on individual lines.
- In extreme cases, overcrowding can prevent passengers from boarding (if a train is already full) and can make trips more of a burden even for those commuters who are able to board. This can discourage commuters from taking public transport altogether.
- Finally, crowding can impact the reliability of the network, increasing uncertainty about departure and arrival times.

The costs of train crowding are typically smaller than traffic congestion. Still, the availability of rail services is critical to efficiently moving large numbers of Sydney commuters over high-demand corridors. These rail services have the additional benefit of containing road congestion and demand for parking capacity at key destinations.[5]

Train crowding costs are highest along already congested train lines to the south, west, and south-west of the CBD (that is, the T1 Western, T3 Bankstown, and T8 South lines). Crowding costs are higher for stations further from the city because commuters boarding at these stations spend more time in crowded carriages, compared to those who board closer to the city.

The Eastern Suburbs line is an outlier in our analysis: unlike other lines, it operates well below seating capacity during peak periods.[6] Accordingly, there would be no additional overcrowding costs from a marginal increase in population at locations that use this service.

The NSW Government is currently delivering the Sydney Metro network. The North West line opened as a shuttle to Chatswood in 2019 and this is due to be extended, with the City and Southwest line scheduled to open in 2024. The Metro West line from Central to Westmead is scheduled to be operational by 2030, and the Greater West line between St Marys and Badgerys Creek by 2031.[7]

Sydney Metro and other rail investments underway offer significant opportunities for efficiently accommodating population growth. This is not factored into our analysis but will deliver a substantial amount of capacity for housing on the Lower North Shore, and in the Inner West and Inner South West.

Box 4: New rail projects will add substantial capacity and increase access to jobs

The Sydney Metro will greatly improve transport opportunities in many areas, giving many suburban areas a rapid connection to the CBD and other employment hubs such as Macquarie Park. New Metro stations provide an opportunity to provide significant additional housing while minimising congestion impacts. And by duplicating the rail access on the Lower North Shore and replacing the T3 Bankstown line, the Metro will significantly reduce congestion across the heavy rail network, allowing Sydney Trains to run more services on other lines.

As an example of the impact of the Sydney Metro, we looked at the new station at Five Dock on the planned Metro West line. Currently Five Dock residents must travel by bus along heavily congested roads such as Parramatta Road and Victoria Road. We estimate that commuters in Five Dock can currently access only around three per cent of the jobs in Greater Sydney by public transport within 30 minutes. With a Metro service in place, Five Dock commuters could reach transit hubs like Parramatta and the CBD quickly and would be able to reach up to 45 per cent of Sydney's jobs within 30 minutes.

[5] Growth in locations without train lines (such as the Northern Beaches) adds little to train crowding, instead generating larger road congestion costs.

[6] A train is considered at 100 per cent capacity when all seats are full. Because commuters stand once seats are full, a train can operate at 150 to 170 per cent of its seated capacity. The Eastern Suburbs line often operated at 80 per cent of seated capacity before the COVID-19 pandemic, compared to more than 170 per cent of seated capacity on the T1 Western Line.

[7] A review of Sydney Metro is currently underway, with the final report and recommendations due in late 2023.

1.4.2 Water and wastewater infrastructure is a major cost

Connecting new developments to water and wastewater infrastructure is often costly. They require new pipelines and pumps. Where capacity is constrained, new developments can also mean new or upgraded treatment plants.

Infill development generally creates lower water infrastructure costs. This is because most of Sydney's established areas have the necessary infrastructure, lower ongoing operating costs, and favourable geography for water provision[8], and because these areas benefit from economies of scale.

Sydney Water has recently exhibited development servicing plans (DSPs) which include the costs of connecting new properties in different areas of Sydney (Sydney Water, 2023). Using data from these DSPs, we estimate the combined water and wastewater cost in established areas south of Sydney Harbour to be approximately $13,000 per dwelling. This increases to around $19,000 per dwelling in most areas north and west of the harbour.

Costs increase significantly in areas away from the coast or with difficult geography, including:

- Pennant Hills – $31,000 per dwelling
- Baulkham Hills – $40,000 per dwelling
- Hornsby – $42,000 per dwelling.

These costs are still much lower than for greenfield areas, where they reach as high as $96,000 per dwelling for distant developments like Appin and Gilead.

1.4.3 School infrastructure makes growth in the north-west and south more costly

Schools are essential social infrastructure, and poorly coordinated growth can create significant challenges for families and lead to community pushback.[9]

This paper focuses on ensuring adequate capacity in public schools within appropriate distances from the new dwellings (1.5 kilometres for primary and four kilometres for high schools). Where adequate capacity is not available, costs increase because children need to travel to schools further away, local schools require upgrades, or new schools are required.

The cost of meeting school infrastructure needs shows a striking north-south divide. Older parts of Sydney, especially the Inner West[10] and Canterbury-Bankstown, have more schools, and these schools tend to be less full.

The Fairfield SA3 had the lowest school-related costs we modelled at less than $10 per property. This was because almost all of the area's public schools have available capacity, and because schools tend to be in convenient locations. Canterbury-Bankstown, parts of the Inner West, Inner South, and Eastern Suburbs also had costs of less than $3,000 per dwelling.

In contrast, the North Shore and North West have fewer public schools. These areas were built as low-density residential suburbs, where it was expected students could travel long distances to

[8] Being located 'downhill' from water supplies and being able to discharge wastewater into the ocean lowers operating costs considerably.

[9] Schools have been central to new residents' concerns about infrastructure delays in Sydney's North West Growth Area (Baker, 2022). Likewise, a lack of additional school infrastructure to accommodate infill growth in Wentworth Point has raised concerns about overcrowding (Chrysanthos, 2022).

[10] The Eastern Suburbs also has the highest concentration of private school enrolments in Sydney, almost double the rate of other areas of Sydney. This has contributed to the high public school capacity as the demographics of the region have become more affluent.

school by car or bus. Recent rapid development in these formerly low-density areas has led to very high enrolments in some schools, especially primary schools. Our modelling indicates adding new students in those areas will be much more costly, due to the need to perform more school upgrades. In the Pennant Hills-Epping, Manly, Pittwater, and Hornsby SA3s, the combined costs of primary and secondary school infrastructure was more than $20,000 per dwelling.

Importantly, a larger increase in population would clearly require development of new schools in any location (although existing school land was able to absorb the marginal growth modelled here). Further, private schools are not included in this analysis but would likely absorb some growth, reducing the fiscal cost of accommodating growth in the Eastern Suburbs and North Shore especially.

1.4.4 Most established Sydney suburbs have good access to open space

Public open space provides amenity and environmental benefits to neighbourhoods and improves the health of residents. It also gives people space for socialising, community activities, and sports.

Recent draft urban design guidance from the NSW Government Architect[11] focused on ensuring that residents have ***access*** *to* quality open space rather than a minimum area per person (NSW Government Architect, 2021a).[12] Locations are considered to have good access if they have, for example, a small park within 200 metres of homes, a local park within 400 metres, and a large district park within 1,600 metres. For large developments, the guide recommends a rule of thumb that 15 per cent of developable area should be open space, regardless of the density of housing.

This paper adopts a similar approach. We identify which areas meet this benchmark minimum of 15 per cent of the developable area within 1,600 metres of their home — roughly a 15-minute walking radius. Where this benchmark is met, we assumed there is adequate green space for existing residents.

Where the area fell short of the 15 per cent benchmark, we estimated the cost of a modest contribution towards improving access to public open space for new dwellings. We calculated this cost as the lower of the cost of purchasing a modest amount of land per dwelling in the local area, or the relevant developer charge in the relevant Local Infrastructure Contribution plan.

Most of Greater Sydney's potential infill areas already have good access to public open space either in the form of public parks, beaches, nature reserves or national parks. So the marginal cost of increased density for most of Sydney is low.

The clear outliers are parts of the Inner West (roughly from Marrickville to Strathfield). Existing households in these areas have some private open space, but minimal public space. Figure 4 shows the visible difference in open space between the low-density suburban areas in Burwood and the larger and more diverse open spaces in older, denser areas close to the city.

The cost of increasing open space in these areas is high due to the lack of open space and the value of land in these locations; in Strathfield it would cost $24,000 per dwelling, and in Marrickville it would cost $17,000 per dwelling. Other areas in southern, western, and north-west Sydney have costs between $2,000 and $10,000 per dwelling. Most inner-city areas, except for the CBD itself, had adequate open space access already.

Importantly our analysis focuses on land costs and does not consider all costs related to open space. Some open space assets may already be used at close to capacity at peak times, reducing effective access. Playing fields, for example, face limits on capacity: you cannot fit more than two soccer teams of 11 people on the same 0.7 ha field for a 90-minute period. Addressing this

[11] The NSW Government did not ultimately proceed with the NSW Government Architect's design guidance and it is not government policy.

[12] Historically quantity-focused rules of thumb have been used as a starting point for green space requirements. The most famous of these is the 7 acres/2.83 ha per 1,000 people standard that reportedly originated in the early 20th century UK (Veal, 2012; free version).

accessibility shortfall, or achieving other policy objectives (such as urban cooling), will attract additional expense.

Strategic planning in any specific area will need to consider open space needs in more detail.

Figure 4: Public open space access varies even within the Inner West

Left: A low-density suburban area near Burwood in the Inner West contains relatively little public open space, with most land area taken up by houses. Right: A medium- to high-density residential area in Erskineville has a variety of differently sized open spaces interspersed with residential and commercial buildings.

Source: Google Maps (2023).

2 Policy implications from our findings

2.1 New homes need smart infrastructure planning

2.1.1 Infrastructure needs to be coordinated to boost the supply of housing

Sydney is a vibrant, productive, and liveable city and this is only possible because of its great infrastructure. As the city grows, new and existing households and businesses must have access to the infrastructure they need to be productive and have a good quality of life.

When infrastructure provision is poorly coordinated with growth, new and existing residents suffer directly, and opposition to further growth rises.

This coordination between growth and infrastructure can be improved in two ways. Firstly, when building in areas with less existing infrastructure, we need to improve the timeliness and adequacy of new infrastructure. This paper, however, focuses on the second and more overlooked way: we can increase density to make the most of the infrastructure that we already have.

2.1.2 We can increase the efficiency of infrastructure spending

The NSW Government spends large sums every year building infrastructure to accommodate our growing population. At the same time, the NSW Government's financial position has weakened after the COVID-19 pandemic, floods, and bushfires. We need to use scarce infrastructure dollars to drive housing supply as efficiently as possible.

The 2022 State Infrastructure Strategy recommends reconsidering and being more selective with city-shaping transport 'megaprojects' (INSW, 2022). These projects strain the capacity of the construction sector — including to deliver housing. They also overrun cost and time targets concerningly often. Taxpayers can save hundreds of millions of dollars if the NSW Government postpones or foregoes inefficient large infrastructure projects and avoids building them all at once. The Grattan Institute identifies fixing maintenance backlogs and strategically expanding capacity as much more cost-effective alternatives (Terrill, Emslie, and Moran, 2020):

> *'Megaprojects should be the last, not the first resort … The first resort should be efficient usage of the infrastructure we already have.'*

We can reduce the burden on taxpayers substantially by prioritising growth in high-quality locations that are already well-serviced by infrastructure, without necessarily abandoning growth in other areas. These results are consistent with past NSW Government-commissioned cost-benefit analysis (CIE, 2010). This paper supports this view: we have significant opportunities to better use our existing infrastructure capacity.

2.2 Planning should consider the costs of sprawl

2.2.1 Past planning has sought to disperse Greater Sydney

In 2018, the (then) Greater Sydney Commission strategic region plan — *A Metropolis of Three Cities* — adopted a 'three-city' approach to rebalance the distribution of population and jobs across Greater Sydney.

The plan adopted a '30-minute city' commute time objective and proposed significant transport investments. Its housing targets sought to distribute growth across each of the three cities, including greenfield areas within a north-south commute of this 'Aerotropolis' and the middle-ring suburbs around Parramatta and Sydney Olympic Park.

Its increased focus on the Parramatta CBD and an additional economic and population centre based around Sydney's second airport at Badgerys Creek aimed to encourage more business activity in the west.

All this would relieve Eastern Sydney of the burden of population growth and make jobs more accessible (Greater Cities Commission, 2018):

> *'The [Metropolis of Three Cities] brings new thinking to land use and transport patterns to boost Greater Sydney's liveability, productivity and sustainability by spreading the benefits of growth.'*

Over the past century, Sydney has mostly dealt with the city's growing population by encouraging dispersed settlement patterns – or as it is more often known, sprawl. It has enabled that with transport infrastructure, particularly arterial roads, motorways, and railways.

2.2.2 Increased density offers lower costs *and* larger benefits

Continuing to disperse growth will require ever-increasing capital expenditure to let people move around the city and to encourage businesses to move closer to where people live. Inner Sydney is an attractive location for prospective residents because of its iconic natural assets, job opportunities, and rich social networks.

The analysis in this paper demonstrates there is substantial variation in the costs of growth in different areas. But cost savings are only one part of the picture. Strategic planning that leverages the city's existing attributes can raise productivity, living standards, and quality of life by encouraging more housing and jobs growth in areas where development is most feasible. Our analysis also provides a step towards using a greater range of evidence to inform strategic planning.

The first paper in our housing series, *Building more homes where people want to live*, outlined some of the private benefits of increased density in high-demand locations, both to households and businesses. The results in this paper suggest that several of the locations with the highest unmet demand for housing — the Inner City, Eastern Suburbs, North Shore, and Inner West — are also able to accommodate growth at the lowest cost. Further work will expand on the social, economic, and environmental impacts of density.

The rest of this paper examines the specific infrastructure costs in greater detail.

3 Costs of key infrastructure items

3.1 Road congestion

3.1.1 Traffic congestion is inevitable in a sprawling city

Traffic congestion causes Sydney a range of expensive problems, especially during weekday peak periods and on weekends. Congestion cuts into worker productivity, reduces commuters' time with family, and affects our health and wellbeing. It also shrinks both the pool of workers from which businesses can draw employees, and the pool of employers from which workers can access more satisfying and better-paying jobs.

Sydney's low density, geography, and large size leave it heavily reliant on car travel. The most recent Transport for NSW Household Travel Survey found 70 per cent of transport journeys in Sydney are by private car.

Many of us drive to our workplaces. And although peak-hour commuters are not typically destined for the CBD, they must share arterial roads with CBD-bound drivers and buses to get where they need to go.

Unchecked, congestion will only become a bigger problem for Sydney. The approximately 550,000 new households expected to call Sydney home by 2041 could bring with them around 900,000 more cars (DPE 2022b, ABS 2022b, NSW Productivity Commission analysis).[13]

3.1.2 Congestion costs are much lower for development close to the city

While building new infrastructure can provide relief, the location of housing matters for congestion. Effective city planning can play an important role in giving residents efficient access to services and employment and can reduce congestion and commuting time.

This analysis suggests that, at least at the margin, we can lower congestion costs by locating more people closer to where they want to travel. The economic cost of congestion resulting from having 2,500 more households in an SA3 is estimated by calculating the effect of traffic on their journeys to work (and the effect of their journey on traffic):

- Journeys to work are mapped using Census data based on the employment breakdown and commuting behaviour of the existing population in each SA3. We assume the additional households will proportionally commute to the same jobs and in the same way as existing households.
- The traffic (or congestion) impact is calculated as the excess travel time that results from travelling at peak hour (8 am) relative to off peak (midnight).[14]
- The time cost is translated to an equivalent dollar cost using standard metrics for the opportunity cost of time.
- A multiplier is then included for the costs imposed on fellow motorists.[15]

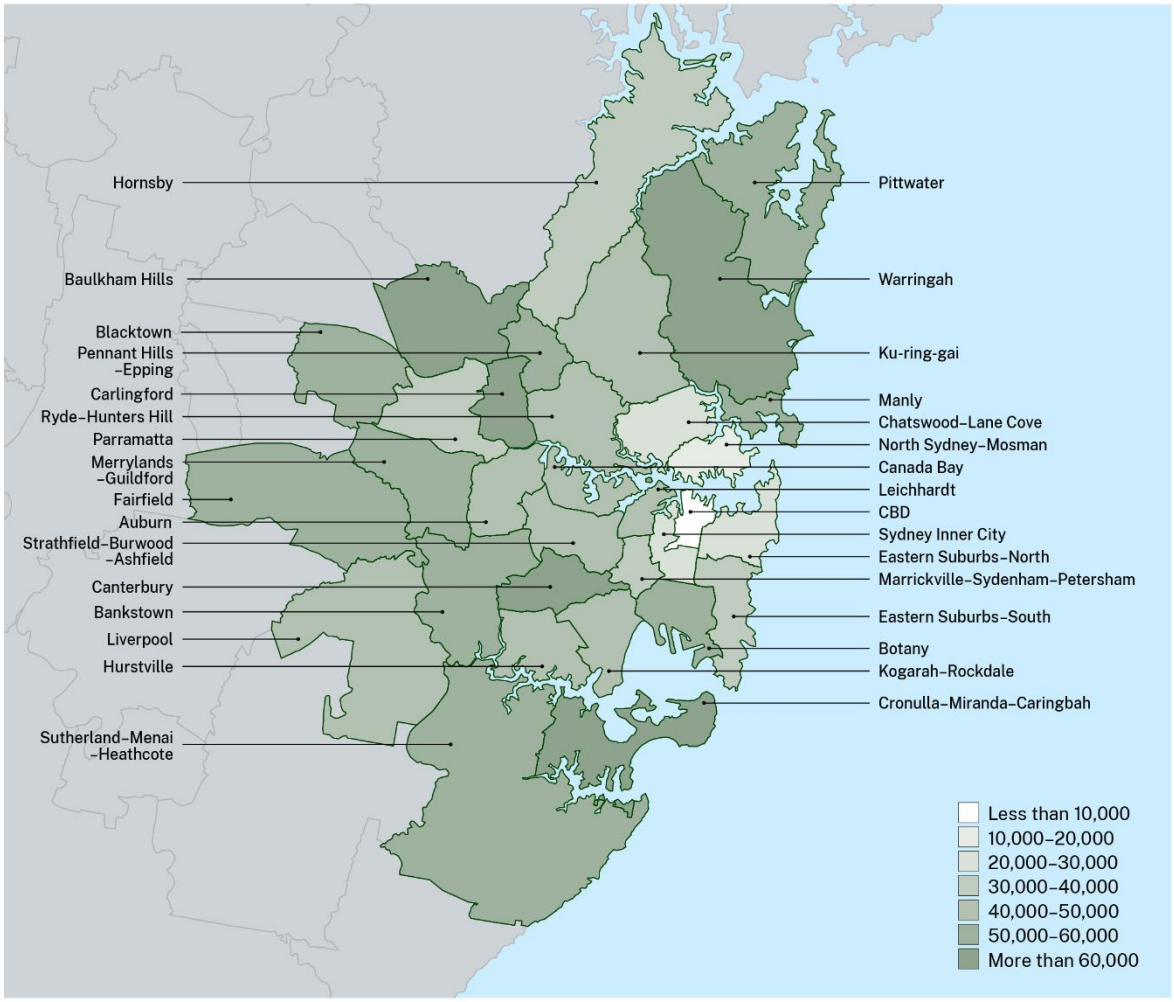
[13] Assuming car ownership remains at the 2021 rate of 1.6 per household in Greater Sydney.

[14] Travel times are calculated with Google Maps. Data was based on travel in December 2022.

[15] Our methodology does not consider that the impact of congestion on other commuters grows exponentially as road capacity nears 100 per cent. Consequently, we may be underestimating the impact of adding more commuters to an already at-capacity Sydney CBD street compared to a congested but not at-capacity road in the suburbs.

Figure 5: Congestion costs are lowest when building close to the CBD

Road congestion cost, $ per additional dwelling



Source: NSW Productivity Commission analysis.

Congestion costs are lowest in inner suburbs and generally increase moving further from the city centre. The CBD and adjacent areas like Redfern and Pyrmont are estimated to be the lowest-cost locations to accommodate growth. at around $10,000 per dwelling. [16] Congestion costs are also low in the Lower North Shore, Eastern Suburbs, and Inner West.

The highest-cost area we looked at is Carlingford, where congestion costs around $65,000 per dwelling. Congestion costs are also high in other parts of the North West, the Northern Beaches, and Canterbury. These results indicate that over the long term, a new dwelling in Carlingford would result in nearly seven times more commuter time being lost to congestion than a new dwelling in the CBD.

Our work suggests high congestion costs in middle and outer suburbs reflect that:

- Commutes from outer suburbs tend to be longer in distance and therefore, for a given 'severity' of congestion, leave people sitting in traffic for longer.

[16] This and succeeding figures are the net present value of future yearly costs in each area.

- Workers living in inner-city areas can easily access middle- and outer-suburban jobs by travelling 'against the flow' of traffic.
- Commutes from Western Sydney lose proportionally more time to congestion than those workers travelling from areas east and north of the CBD.[17]
- Commuters in inner-city areas are more likely to work in employment hubs, such as the CBD, which they can easily access by train or active transport. Outer Sydney residents are less likely to use public and active transport to get to work than those further in. For example, 67 per cent of workers in Cabramatta drive to work, compared to 23 per cent in Camperdown, according to the 2016 Census.

While we focus here on congestion's effects on commuting times, long commutes impose costs on people regardless of the congestion they encounter. Research suggests links between long commutes and poorer mental health, poorer physical health and obesity, less time spent with family and friends, worse emotional and social development of children, and lower productivity.[18] Broader societal impacts will be discussed further in an upcoming paper.

Box 5: Why are congestion costs so much higher in the west than the east?

Our modelling shows the economic cost of congestion from adding 2,500 additional dwellings is many times higher in the west of Sydney than in the east. This is not necessarily because roads in Western Sydney are more congested. The lower congestion costs we observe are mainly due to other factors, including mode of travel, commuting distance, and location of employment.
To demonstrate, we compare a high-cost location, Carlingford ($69,000 per dwelling), with a low-cost location, the northern part of the Eastern Suburbs ($25,000 per dwelling).

Location of employment

We found workers who live in the east of Sydney are more likely than those further west to work near where they live. Eastern Sydney residents are also more likely to work in major employment hubs like the CBD, North Sydney, Paramatta, and Macquarie Park, which have good public transport and road links, as well as higher parking charges which discourage driving.

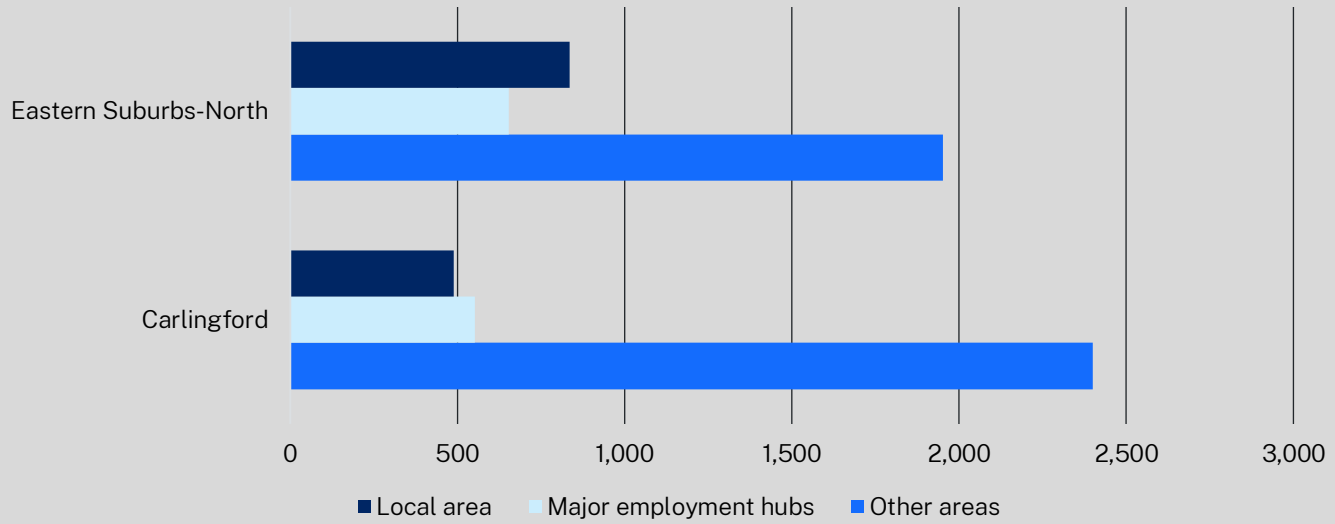
As Figure 6 shows, based on current employment patterns, around 24 per cent of additional workers in the Eastern Suburbs-North SA3 would work in the local area compared to 14 per cent in the Carlingford SA3. We also found 19 per cent of Eastern Suburbs workers would work in major employment hubs, compared to 16 per cent for Carlingford.

The higher proportion of workers in the Eastern Suburbs employed locally and/or in employment hubs means commuters have options other than driving and thus spend less time in traffic, lowering congestion costs.

[17] For example, for a commuter travelling to the CBD from Bondi Junction, peak-hour congestion adds about 70 per cent to their travel time, while for a CBD worker driving from Westmead, congestion adds 150 per cent to their travel time. This could be because more distant commuters spend a higher proportion of their journey on heavily congested arterial roads.

[18] For example, see Clark et al (2019), Bai et al (2021), Li & Pollmann-Schult (2016), Ma & Ye (2019).

Figure 6: Location of employment for workers from 2,500 additional dwellings



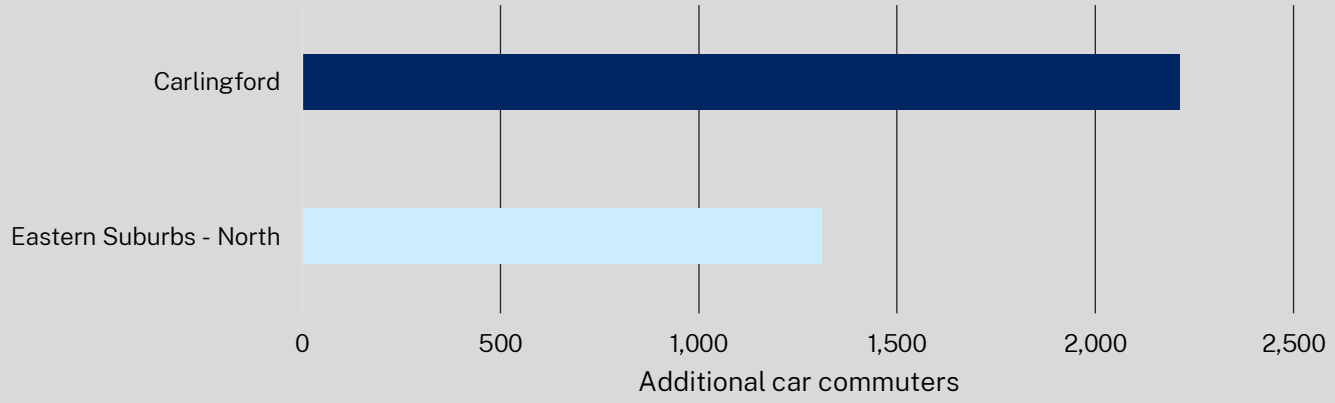
Source: ABS 2016 Census, NSW Productivity Commission analysis.

Mode of travel

We assumed new residents moving into an area would make similar travel mode decisions to existing residents in that area. For example, if 30 per cent of existing residents who work in the Sydney CBD choose to drive to work, we assume 30 per cent of new residents would also choose to drive. Only workers who travel by car can lose time to traffic congestion, so locations which generate fewer drivers will have lower congestion costs.

In our example, Carlingford is very car-dependent, with a very small proportion of workers travelling by public or active transport. On the other hand, workers in the Eastern Suburbs are much more likely to use public transport or walk to work. As Figure 7 shows, our model indicates adding 2,500 dwellings into the northern parts of the Eastern Suburbs would create about 1,300 new car commuters, while in Carlingford adding the same number of dwellings would generate about 2,200 new car commuters.

Figure 7: Additional car commuters from 2,500 additional dwellings



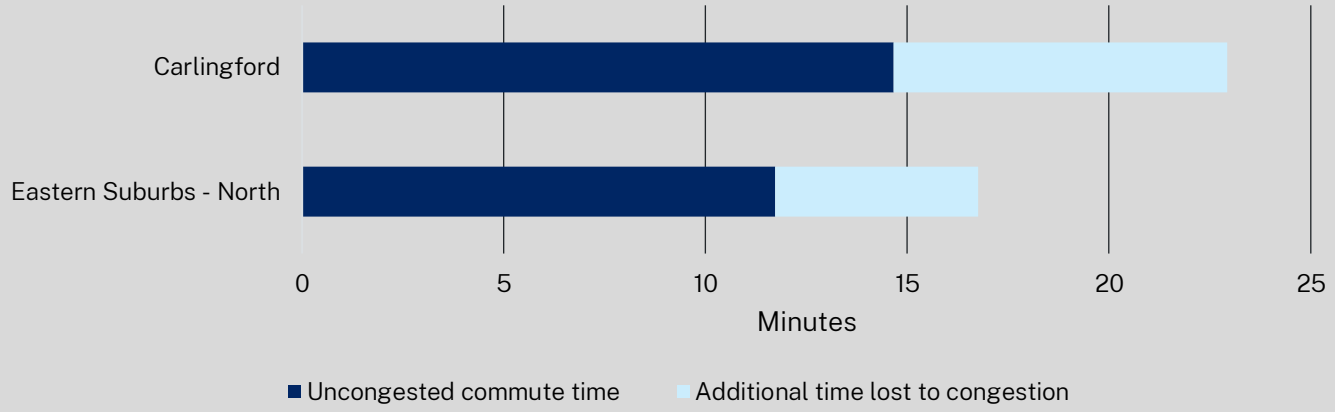
Source: ABS 2016 Census, NSW Productivity Commission analysis.

Commuting distance

Carlingford commuters typically live further from where they work than their counterparts in the Eastern Suburbs, and therefore have longer commutes. And because driving distances are longer, Carlingford commuters spend more time on congested roads, creating higher congestion costs. As Figure 8 shows, average commute times are significantly longer for Carlingford residents, and so they spend more time in congestion. The dark blue section shows their driving time without congestion, and the light blue section shows the average amount of extra time their commute takes due to congestion.

Figure 8: Average commute times for additional commuters

Comparing average uncongested commute time and additional peak time congestion for additional workers who would drive from Eastern Suburbs – North and Carlingford SA3s



Source: ABS 2016 Census, NSW Productivity Commission analysis.

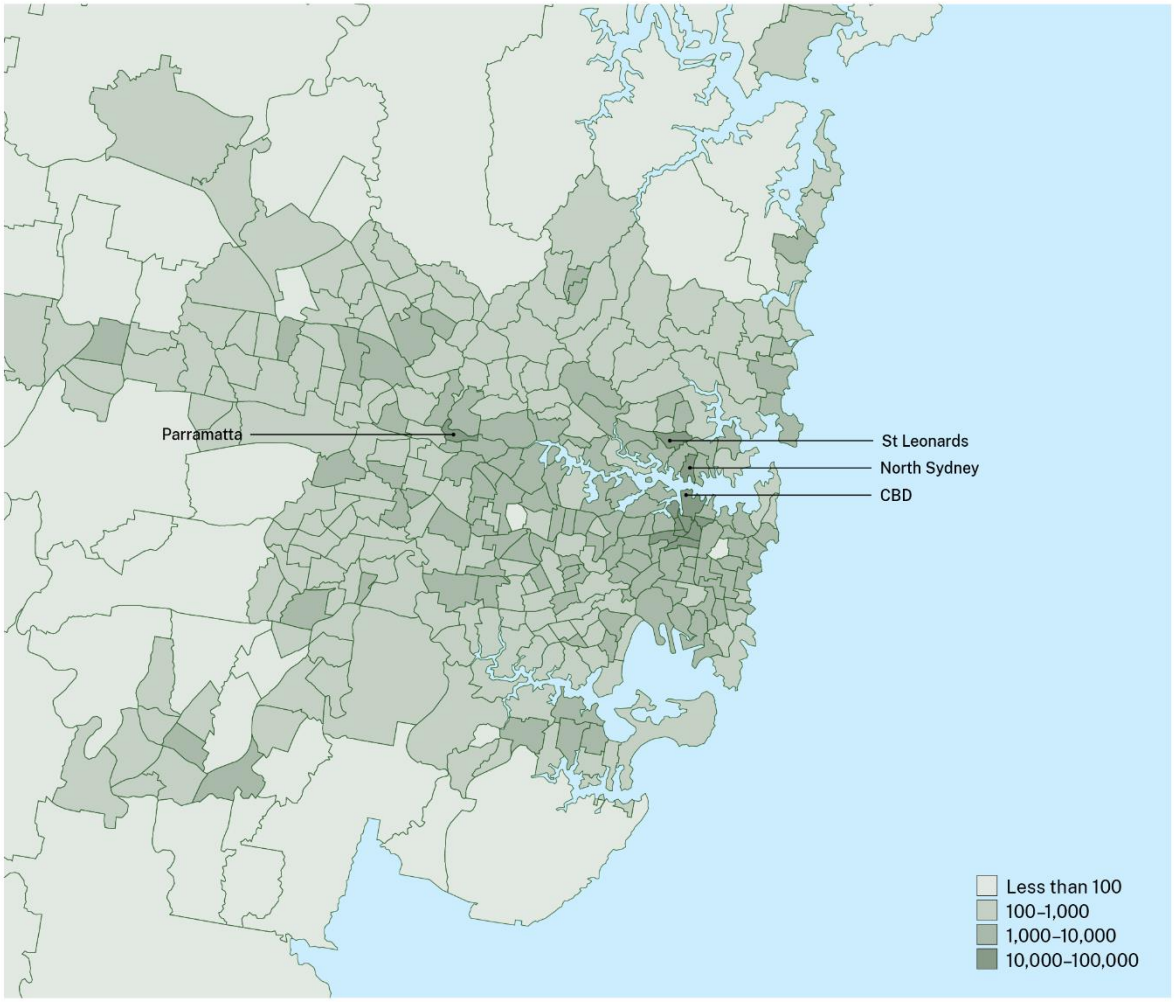
3.1.3 Weekday commuter congestion is driven by suburb-to-suburb eastbound trips

Sydney contains a small number of very dense employment centres; the largest are the CBD, North Sydney, and Parramatta. Major employment centres, however,[19] provide only around 30 per cent of total jobs in Sydney (ABS 2016). Most jobs are spread across the broad suburban areas around Sydney Harbour. This spread of employment means many people must commute from one suburban area to another (Figure 9).

[19] For our analysis we define employment hubs as the CBD (and surrounding areas like Pyrmont and Ultimo), North Sydney, Parramatta, and Macquarie Park.

Figure 9: Many of Sydney's jobs are in suburban areas

Map of the number of workers employed in different locations of Sydney; jobs per km^2



Source: ABS Census 2016.

Less than 20 per cent of CBD commuters drive to work (ABS 2017). Major public transport routes (mostly rail lines) efficiently move large numbers of people from across Sydney to the CBD. This convenience, combined with the range of costs of driving, encourages the use of public or active transport.

Away from employment hubs, the story is very different. Sydney's largely monocentric transport network makes public transport inconvenient and slow for suburb-to-suburb commuters, as they will require multiple transfers to reach their destination. Many may find it almost as cheap to drive a car as to take the bus: they can park their car for free at their destination, and their car's marginal operating costs are relatively low. These commuters funnel onto major arterial roads, generating a large portion of Sydney's congestion.

3.1.4 Non-work journeys will also generate considerable congestion

The 2021/22 Transport for NSW Household Transport Survey found only 12 per cent of all trips in Greater Sydney are commutes or work-related journeys (Transport for NSW, 2022). Most trips address non-work needs, such as recreation or social events (29 per cent), shopping (18 per cent), and education or childcare (10 per cent).

We lack the data to quantify these trips and their impact on congestion. But non-work trips form a vital part of the NSW economy and social fabric; they let us do everything from visiting relatives to buying groceries and dropping kids off at school. The low density of Sydney's housing makes these essential trips longer and more likely to require a car.

The impact on congestion from these non-work trips is likely large, but it is uncertain compared to commuter congestion costs. These trips are more dispersed, with a higher number of origins and destinations than commutes, so they do not cause congestion at the same times and places that commuters do. But since most trips are of this type, they can place strain on the road network in different places and at different times (around shopping centres, sport fields, schools and so on).

Our analysis is limited by the data available – the start and end points of home-to-work journeys from the Census. More comprehensive transport models, such as those run by Transport for NSW, are better suited to calculating the impacts of growth on non-work-related congestion in different locations. This Transport for NSW analysis will be important to consider when deciding where to construct new housing.

3.1.5 There are many ways to address the economic cost of congestion

The congestion costs estimated in this analysis are *economic costs* to society.[20] These costs are distinct from *financial costs* to households, firms, and governments. For example, the economic cost of congestion could be addressed by building a new road.[21]

The congestion cost should be the maximum amount that government should spend to alleviate the additional congestion created by the 2,500 additional households. Spending any more would indicate that the costs of the project outweigh the benefits (at least purely on congestion grounds).

The economic cost of road congestion can be reduced through projects that improve or increase traffic throughput.

Relatively small road upgrade projects are generally the most cost-effective at increasing traffic flow. Transport for NSW's Pinch Point Programs identify sections of roads or intersections that create traffic bottlenecks and improve them through road widenings, lengthening turn bays, and intersection upgrades. Between 2012 and 2020, such projects are estimated to have generated benefits exceeding twice their costs (Transport for NSW, 2020).

Public transport measures can also increase traffic throughput. Initiatives like transit lanes, bus priority lanes, and bus rapid transit can make buses faster and more reliable, and so entice onto public transport many people who would otherwise drive. Such measures can restrict road space and risk worsening traffic for remaining cars, but they usually allow a higher total number of people to travel.

Infrastructure 'megaprojects' allow more substantial increases in the number of travellers. As discussed earlier, the complexity of these megaprojects implies greater risks, and they commonly experience cost overruns (Terrill et al, 2020). Financing these transport projects will require significant borrowing or increased use of toll roads.

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[20] When we discuss congestion costs in this paper, we are referring to the economic opportunity costs of congestion. This is the value of extra time spent in traffic which could be spent more productively working, relaxing, or socialising.

[21] That would create financial costs – that is, for a government, budgetary costs. But if that government chose to make that road a toll road, it would move that cost onto motorists.

Finally, government can use demand management to reduce congestion. Congestion itself helps to manage demand: the delays and congestion created at peak times encourage people to shift travel modes, to travel at other times, or to avoid travel altogether. Likewise, road user or congestion pricing can ration demand by making drivers pay for the congestion costs they impose on society when they choose to drive (ACIL Tasman, 2012).

3.2 Train overcrowding

3.2.1 Crowded trains create economic costs

Sydney has an expansive suburban rail network, which is the backbone of the city's public transport system.

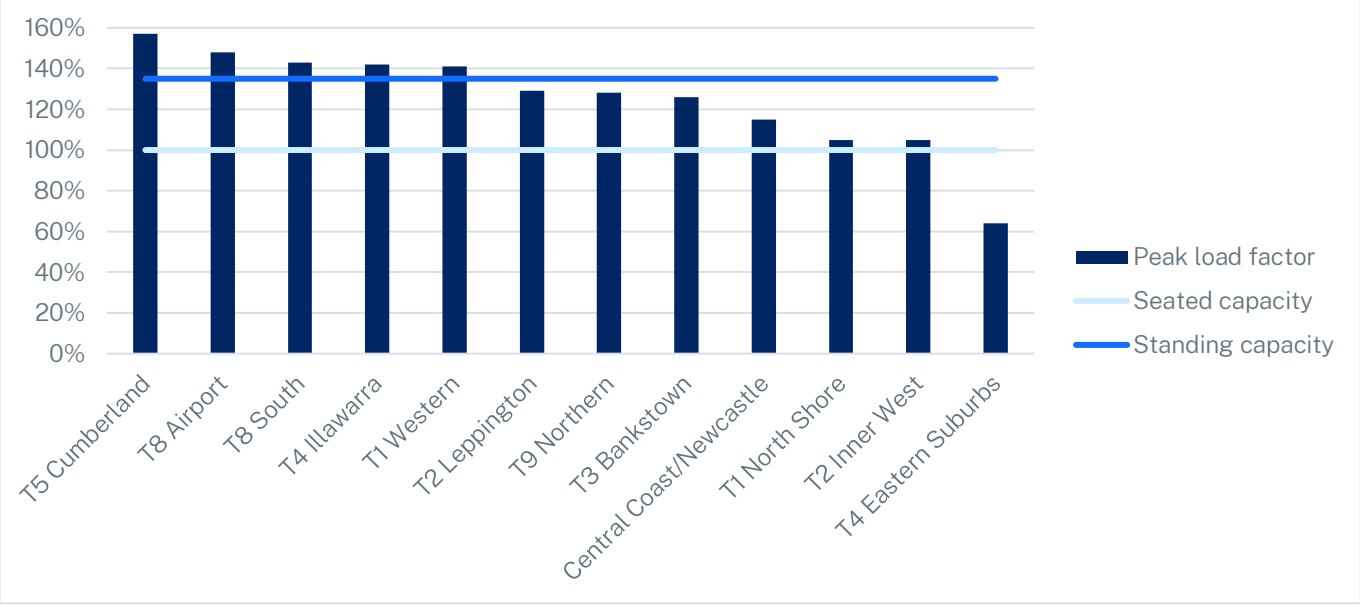
In general, heavy rail transit systems like Sydney's are most efficient for high-volume routes, rather than the suburb-to-suburb journeys that make up most Sydneysiders' travel. Sydney's system is designed primarily to transport workers from distant areas to the CBD. The rail system also connects to other employment hubs, such as Parramatta and Macquarie Park, although most commuter train trips are routed through the CBD.

Given the commuter focus of the rail network, it is most heavily used during the morning and evening peaks, with low ridership outside of these periods. Before the COVID-19 pandemic, many trains in Sydney ran above capacity during peak periods (Figure 10). Commuters would often stand in overcrowded carriages in uncomfortable conditions for extended periods. Where train travel becomes inconvenient or unpleasant, commuters may choose to drive instead of taking public transport, further adding to road congestion.

Since the COVID-19 pandemic, peak ridership (and capacity utilisation) has been lower. The option for many office-based employees to work from home instead has created an additional 'travel' option and appears to have taken more of the burden off the rail network than the roads (O'Sullivan, 2023; O'Sullivan & Singhal, 2022). Ongoing contagion concerns may be amplifying this change.

Figure 10: Only the Eastern Suburbs line had not reached capacity pre-pandemic

Sydney train lines' average load factor for the morning peak, September quarter 2019



Peak load factor compares the number of passengers to the number of seats on the train at times of peak demand. A load factor of 100% means all seats are taken.

Source: Transport for NSW.

Train overcrowding has economic costs. The most direct effects are the added discomfort and inconvenience for passengers. But severe overcrowding can also generate delays, increasing time costs for commuters.[22]

To estimate the train crowding cost of adding 2,500 dwellings into different SA3 areas in Sydney:

- We model the number of additional train journeys that would be taken, based on 2016 journey-to-work information for the SA3.
- We then use a Transport for NSW 'crowding multiplier' to translate the discomfort and inconvenience of the additional trips into equivalent additional minutes of travel time, based on pre-COVID capacity utilisation levels.
- Finally, we translate the additional minutes into a dollar value based on an accepted multiplier for the value of private time ($0.33[23]) per minute.

3.2.2 Crowding costs are highest in the western and south-western suburbs

Accommodating additional households in the CBD or northern areas of the Eastern Suburbs would impose almost no additional crowding costs. This is because trains on the T4 Eastern Suburbs line typically operate well below capacity, while commuters in the CBD and adjacent suburbs typically walk to work or use trains for only a short time.

Inner suburbs also tend to have lower train crowding costs. When commuters from areas nearer to the city do board already-crowded trains at peak times, they spend much less time in the carriage than if they boarded further up the line.

Crowding costs are highest for areas at the outlying end of heavily congested train lines, especially in Parramatta (on the T1 Western line) and south-west Sydney (on the T3 Bankstown and T4 South lines). Commuters from these areas spend the longest time in crowded trains because they have the longest overall journeys.

The highest-cost SA3s we model are in Kogarah ($8,600 per dwelling), Hurstville ($7,500 per dwelling), and Paramatta ($7,100 per dwelling).[24]

These costs are small in magnitude compared to the road congestion costs we measure. However, we have not considered other potential costs of train overcrowding. For example, commuters may struggle to exit trains quickly when they are crowded or the number of people leaving the train is greater than planned, forcing the train to stay at the station for longer. In extreme cases, trains might be completely full and customers would have to wait for another train.

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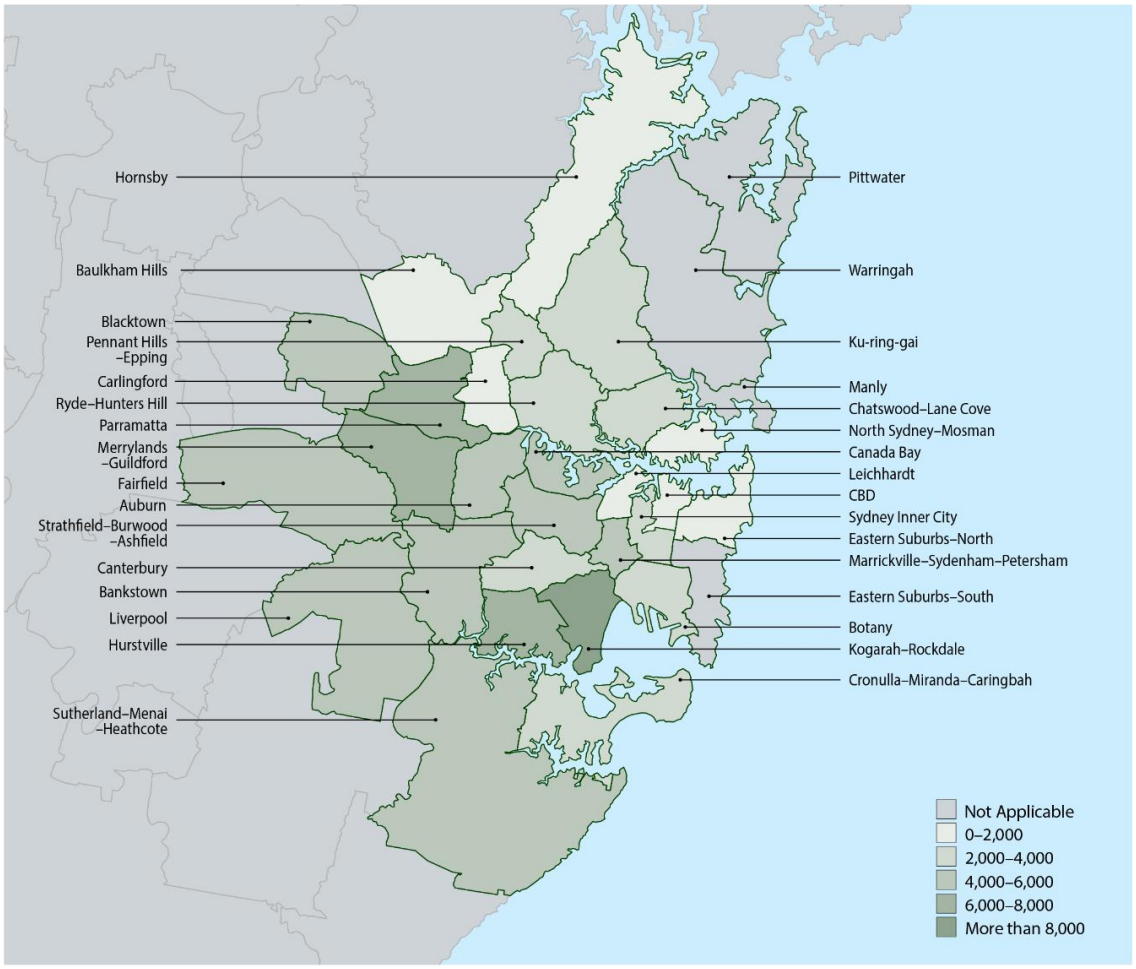
[22] Overcrowding can cause delays which cascade across the network. Commuters may struggle to exit trains quickly when crowded or the amount of people leaving the train is greater than planned, forcing the train to stay at the station for longer. In extreme cases, trains might be completely full, forcing customers to wait for subsequent trains. We do not have data on the contribution of train crowding to delays, so we have not included it in this analysis.

[23] Calculated based on Austroads' value of travel time for light vehicle occupants. This was calculated as 40 per cent of hourly wages. NSW average weekly earnings adjusted by the growth in CPI for the September 2022 quarter were used, assuming a 38-hour work week.

[24] As in the analysis of road costs above, these and succeeding figures are the discounted values of future yearly costs in each area.

Figure 11: Overcrowding is an issue in Sydney's south-west

Train overcrowding cost, $ per additional household



Note: Does not include the Light Rail or Sydney Metro.

Note: There are no train lines to the Southern Eastern Suburbs and Northern Beaches SA3s, so we assumed that adding houses does not add train crowding costs resulting in an NA result.

Source: ABS Census 2016, NSW Productivity Commission analysis.

3.2.3 Low overcrowding costs means we should maximise train usage

Compared to congestion costs, overcrowding costs are relatively low. The close-to-zero costs in many areas suggest there is opportunity to better utilise our existing train capacity by building higher density housing in those areas to reduce more expensive road congestion.

Allowing more people to live close to trains gives them affordable, fast, safe transport and reduces their need to drive (at least to specific destinations). When stations are co-located with other services such as retail stores (as stations often are), residents can further reduce their need to drive. Greater ridership also reduces the per capita cost to government of operating the public transport service.

Limited additional investment is needed to enable density and better use our existing trainlines. Sydney Metro lines, including those completed since the 2016 Census (North West) and still under construction (from the Lower North Shore through to Bankstown and in the Inner West) will create substantial capacity but also will free up capacity on existing train lines. Cost-effective initiatives such as improving signalling can also greatly increase train frequency.

3.3 Water and wastewater

3.3.1 Water and wastewater infrastructure is a large cost of growth

Water and wastewater services are the most vital infrastructure for enabling new dwellings. In Sydney, water and wastewater networks are managed by Sydney Water. Large investments, in a new treatment plant or major pipeline, are infrequent but can be very costly. So we have taken a longer view of water infrastructure than of other infrastructure types.

Sydney Water's recently-exhibited development servicing plans (DSPs) include the costs of building and running the infrastructure needed to service growth in different areas. In this paper we have used cost and dwelling growth forecasts from the DSPs to calculate the additional infrastructure needed to service 2,500 homes.[25]

In general, charges are lower where less capital is required, and where there are more dwellings to share the cost between. In contrast, high-cost areas tend to have high wastewater treatment requirements (high capital and ongoing costs), and have less forecast growth, so must split the cost between fewer dwellings.

Our modelled costs do not include the cost of 'bulk water' assets like dams and desalination plants which are less location-dependent.

3.3.2 Inner areas have lower water and wastewater costs

Our analysis shows water and wastewater services are important infrastructure costs across infill areas. The costs are roughly similar in most areas of Sydney, but they jump in parts of outer Sydney.

Looking first at wastewater, we estimate the cost of new wastewater connections are similar for most infill areas of Sydney at around $12,000 per dwelling. This is because most existing areas discharge wastewater through one of the three large coastal ocean outflow treatment plants, at North Head, Bondi, and Malabar. Wastewater costs are a little higher in the North West — around $16,000-$23,000 per property — because of the large amount of capital expenditure required and higher treatment standards for discharging into the Hawkesbury River than the ocean.

Accommodating population growth costs much more in areas with small, isolated, wastewater treatment plants. Development in some areas of Hornsby, for example, creates costs of around $59,000 per dwelling, similar to some greenfield areas like Greater Macarthur.

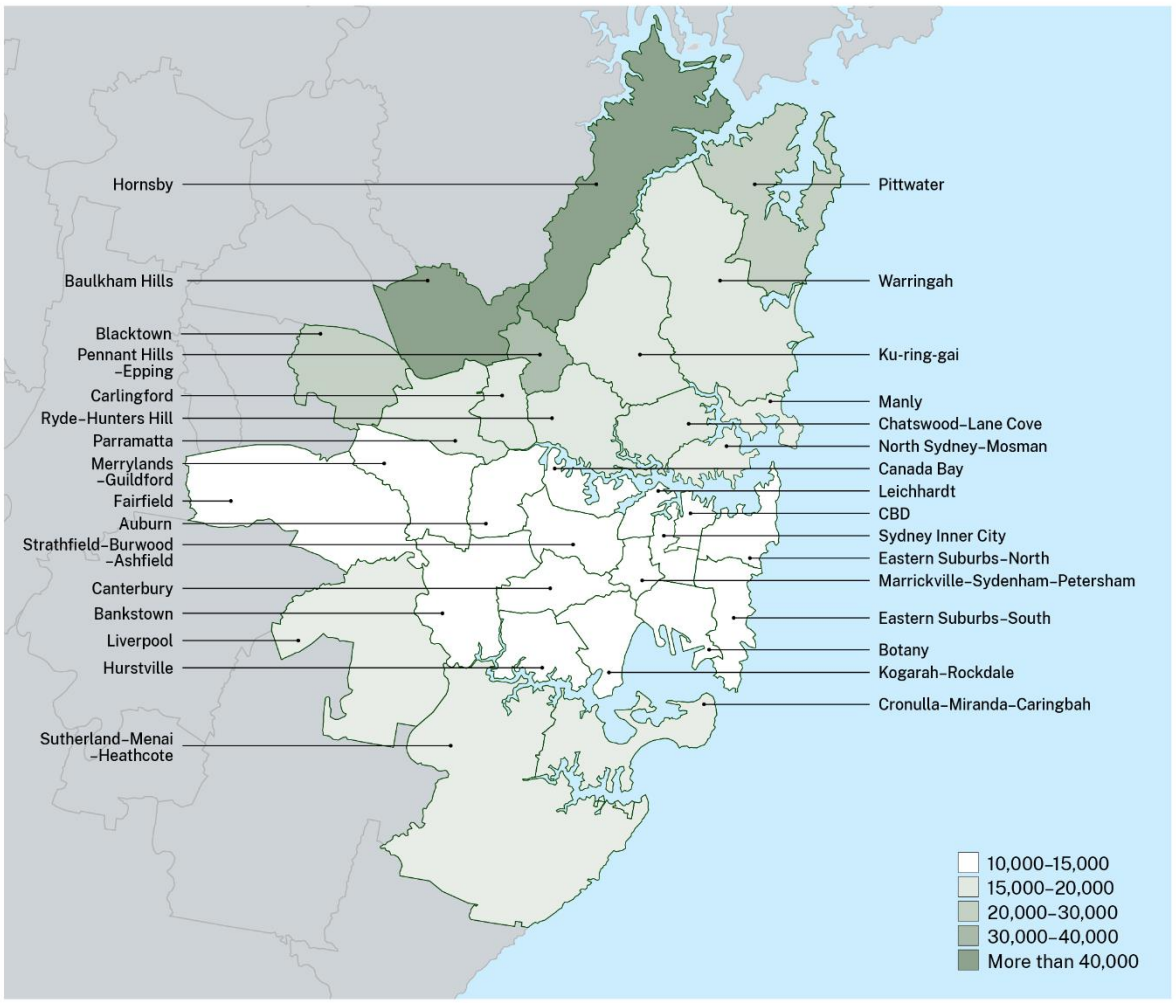
For water supply, Sydney Water's DSPs suggest adding new properties in most areas of Sydney creates additional costs of around $7,000 per property. However, properties in the Potts Hill and Prospect East catchments — which cover most of the infill areas south of Sydney Harbour — require minimal additional infrastructure, so have a lower cost of around $1,000 per property.

Combining water and wastewater costs, as shown in Figure 12, our analysis shows most development south of the harbour has a cost of around $13,000–$20,000 per dwelling, while most other areas have a cost of around $21,000. In our modelling the highest-cost area was Hornsby, at $42,000 per dwelling. Areas in the North West also had significantly higher costs – $30,000 in Pennant Hills-Epping, and $40,000 in Baulkham Hills.

[25] Sydney Water's exhibited developer charges are lower than the numbers we have calculated because they do not always allocate the full cost of growth to new development. We assume that the infill dwellings are, on average, two-bedroom apartments. These dwellings are considered to use only about 50 per cent of the water and 75 per cent of the wastewater of a 'standard' detached house (equivalent tenement; Water Directorate, 2017)

Figure 12: Water and wastewater costs are very high in some areas

Water and wastewater infrastructure costs, $ per additional dwelling



Source: Sydney Water (2023); NSW Productivity Commission analysis.

3.3.3 Charging for the cost of connections will better signal where to build homes

Water costs in Sydney are unlike some of the other infrastructure types in that they impose minimal financial costs on government. Since 2008, new developments have not had to pay to connect to Sydney Water's water and sewerage networks. Instead, the costs of growth have been recovered from Sydney Water customers in the form of higher bills over the life of the assets.

In future, these costs will be recovered at the point of development, largely insulating existing customers from the costs of growth. Sydney Water's development servicing plans are due to be registered in the coming months, with charges gradually phased in over two years. This will:

- Encourage development in the areas that are most economically viable.
- Provide Sydney Water with more funding upfront, which will help it to deliver growth infrastructure with greater certainty.
- Contain growth in customers' bills by $200 a year in the longer run (Sydney Water, 2023).

3.4 School infrastructure is critical social infrastructure

The NSW Government also needs to ensure it provides adequate capacity for Sydney's children to learn. And school demand can be challenging to anticipate: it requires an understanding not just of the population of an area, but of the number and age of the children that are likely to live there over time.[26]

Under-provision and delayed provision of schools infrastructure are common concerns for people in growing areas. The media often reports schools being overcrowded before or shortly after opening (Baker and Gladstone, 2022).

As for other types of infrastructure, we model adding 2,500 hypothetical new households to an SA3. This would add an immediate demand for 733 additional primary school students and 325 secondary school students, which we would accommodate in nearby public comprehensive schools.[27] We do not consider the effect of primary school students moving into high schools in following years. We are only examining immediate impacts, and high school students tend to travel further than primary students to schools, diluting this impact.

For the purposes of this analysis, the economic cost of accommodating the additional students is the approximate cost of upgrading schools, where there is insufficient capacity to accommodate students within existing teaching spaces.[28] We measure the capacity of a school by comparing its current enrolment to its 'out of area cap' (the maximum enrolment before the school stops accepting students from outside its catchment).

Where students could fit within existing caps in their local area, we assume there would be minimal cost. If local enrolments are above capacity, we assume the government would first attempt to allocate students elsewhere in the SA3 to other schools with capacity (with an associated economic cost). If there is no capacity elsewhere in the SA3, we assume that existing schools are upgraded to accommodate more enrolments.

If there is insufficient land (per student) to construct additional buildings at existing schools in the SA3, the government would need to develop a new school. For this number of students, however, there is no SA3 where a new school would be needed on this basis.

3.4.1 Enrolling additional students costs less on the south side of the harbour

The cost of accommodating extra student enrolments is generally much higher on the north side of Sydney Harbour than on the south side, especially for primary schools. Suburban areas in the South and South-West, such as Sutherland, Cronulla, and Liverpool, also had higher costs for primary schools, as shown in Figure 13.

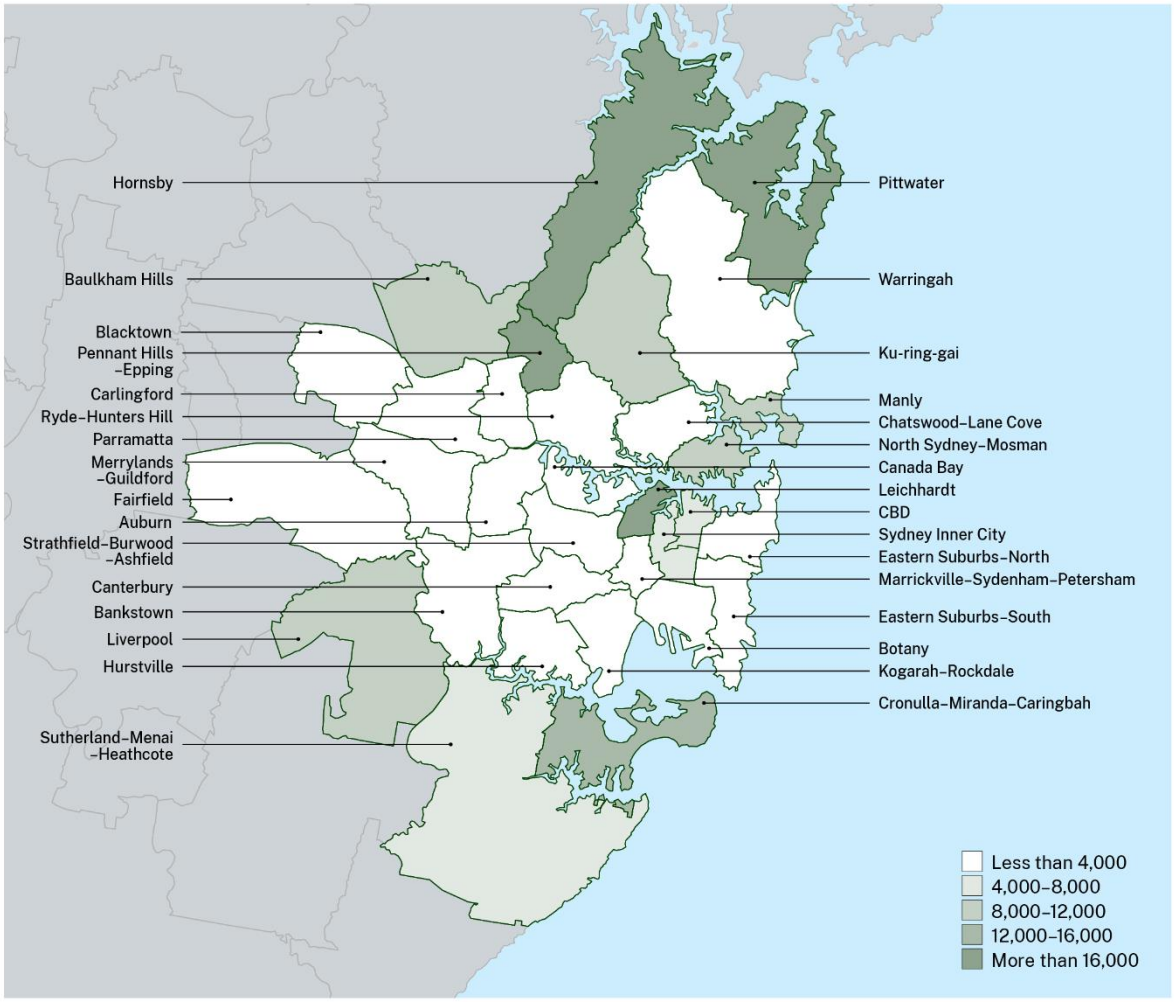
[26] Typically, new development will create a temporary bulge in school enrolments, as families tend to move shortly before they have children or when children are in early schooling. Very large increases in population in any one area might require entirely new schools, but temporary increases due to new families can be absorbed within existing schools. Overbuilding to address temporary crowding will leave underutilised capacity in the future.

[27] This analysis does not account for the increase in future secondary school costs from current primary students. In practice, more detailed school infrastructure demand modelling would account for this future demand.

[28] We model the cost of enrolling these students into comprehensive public schools. Ideally the students would be enrolled in schools within 1.5 km for primary schools, and 4 km for secondary schools. Where this is not possible, students would be added to other schools in the SA3, but an additional cost is applied to account for inconvenience of needing to travel further. We do not estimate the increase in ongoing costs (such as teachers, equipment, and building maintenance), which would be similar between areas.

Figure 13: Sydney's north has limited additional primary school capacity

Primary school infrastructure cost, $ per additional dwelling

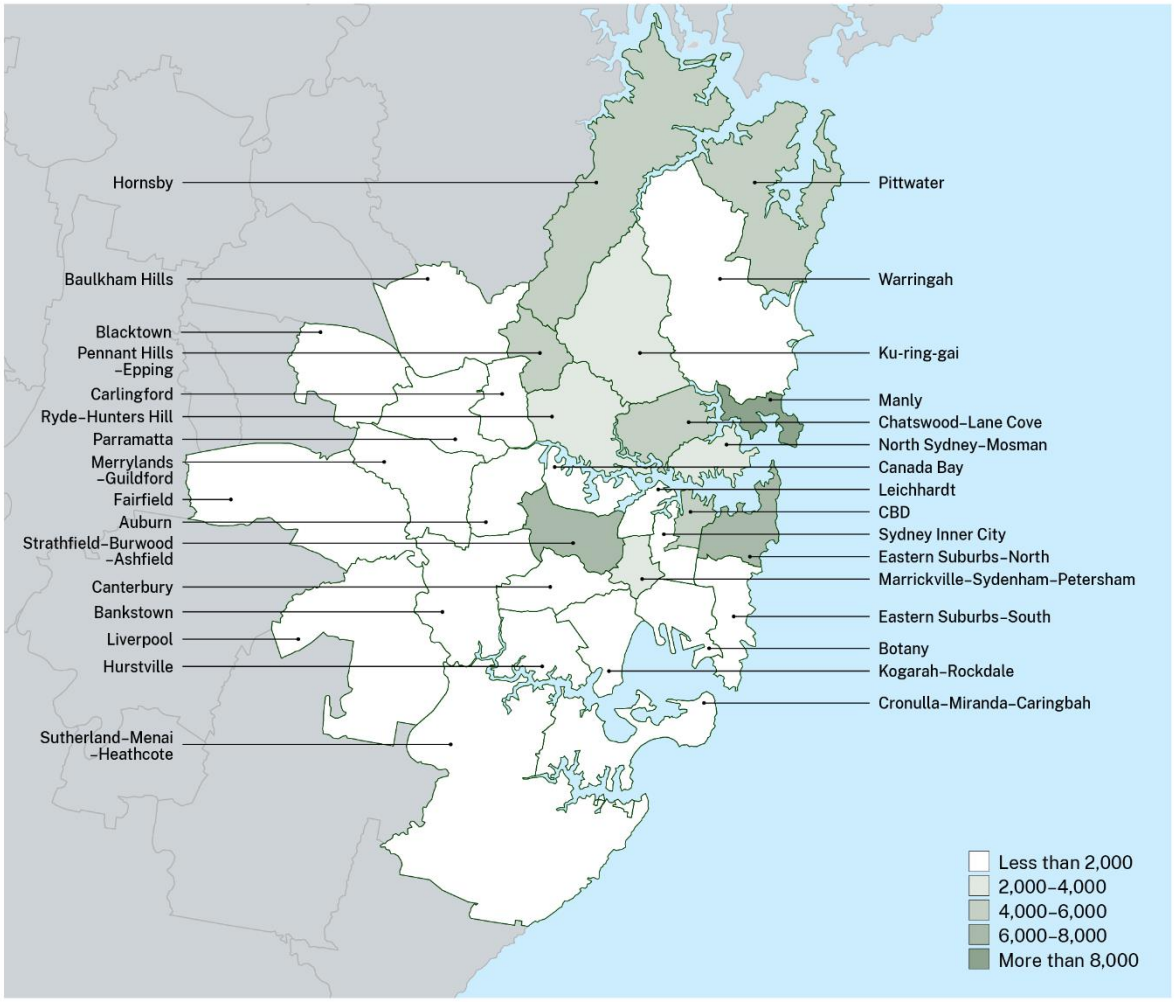


Source: Department of Education (2021), (2022); NSW Productivity Commission analysis.

For secondary schools, costs were also generally higher north of the harbour, as shown in Figure 14. Some isolated areas like Manly, the northern Eastern Suburbs, and Auburn also have higher costs because there are relatively few local high schools within these SA3s. In contrast, the cost in many areas of southern Sydney is zero (or near-zero) for secondary schools, because there is available local capacity to manage additional students without upgrades.

Figure 14: Secondary school capacity constraints cost less to fix

Secondary school infrastructure cost, $ per additional dwelling



Source: Department of Education (2021), (2022); NSW Productivity Commission analysis.

Considering primary and secondary school costs together, the highest-cost areas in our analysis are all in the north of Sydney including Pennant Hills-Epping, Manly, Pittwater, and Hornsby. The combined costs of primary and secondary places in these areas are more than $20,000 per additional dwelling. In comparison, the lowest-cost areas are in Fairfield, Canterbury-Bankstown, parts of the Inner West and South, and in the Eastern Suburbs, where costs are less than $3,000 per dwelling.

We identify two key factors for the much higher costs of schools in the North West compared to the south of Sydney:

- There are more schools in the denser, older areas of Sydney, where schools were designed to be within walking distance of homes. This is particularly true in some parts of the Inner West. For example, the Marrickville-Sydenham-Petersham SA3 has 0.65 public primary schools per square kilometre. In contrast, Chatswood-Lane Cove has 0.27 public primary schools per square kilometre and the Baulkham Hills SA3 has 0.19.
- Schools in the North West tend to have very high enrolments relative to their out-of-area caps, and so need more capacity to be added.

— For example, in the CBD, the average ratio between enrolments and the out-of-area cap for primary schools is 0.85, meaning schools in the area typically have spare capacity. In contrast, schools in the Baulkham Hills SA3 have an average ratio of 1.53, which means schools are already operating well above the capacity of their permanent buildings.

— Low enrolments in the Eastern Suburbs could be due to the very high private school enrolments in the area (around 60 per cent of secondary school students are in private schools, compared to around 35 per cent across the remainder of Sydney).

Our modelling indicates that every SA3 has sufficient land at existing secondary schools to allow for at least 2,000 additional students at existing schools. For primary schools, some areas — such as The Hills and Lane Cove-Chatswood — are nearing the point where there is minimal spare land to expand capacity at existing schools. Here, a relatively small increase in student numbers might require a whole new school to be built to fit the area/student benchmark in our model.

3.4.2 Utilising existing school capacity to manage costs

This analysis identifies that there is a material amount of spare school capacity across Greater Sydney. And it further suggests that population growth across these areas (mostly in the south of Sydney) would generate lower school-related costs.

These areas also benefit from a higher concentration of schools, which allows additional population to be distributed across more schools, and allows children to walk to school rather than needing to travel by bus or be dropped off by car.

Schools also have significant ongoing operating costs, including staffing, maintenance, and utilities. Some of these costs, such as the number of teachers, will be roughly the same however schools manage enrolment. Other costs, such as building maintenance, increase as more schools are built.

We have not included operating costs in our modelling, as these are unlikely to be significant at the margin. We do not foresee the need to construct new schools as a result of the additional households in our analysis.

3.4.3 Managing school capacity has broader challenges

Demand for schools can be highly unpredictable, due to parental preferences between schools, as well as for selective schools and private schools. It is also hard to match population growth to areas with school capacity. Building capacity to manage surges in population also risks creating unused capacity in the future, as population settles.

In practice, upgrading existing schools to accommodate growth in an area might be less cost-effective than constructing an entirely new school. Upgrading a school typically involves creating space for the expansion through the removal of existing teaching spaces, expanding and updating common spaces (e.g. libraries and playgrounds) and temporary disruptions (e.g. moving students into temporary teaching spaces offsite during construction).

3.5 Public open space

3.5.1 Access to quality open space is important

Residents derive a range of benefits from public open space, using it for recreation, exercise, and social purposes. Access to open space not only adds to the amenity of an area, but can improve the health of residents and the local environment (Box 6).

> *'Public open space is infrastructure that is essential for communities and creating great places to live. It encompasses parks, natural areas and linkages, waterways and foreshores, informal parklands, sports grounds and courts, playspaces, historical sites, and recreation trails for walking and cycling. It is found in every part of NSW — from remote regional towns, to new greenfield suburbs, and long-established urban centres. These spaces play a crucial ecological, economic, social and cultural role in our lives.'*
>
> NSW Public Open Space Strategy (DPE)

In general, proximity to a variety of high-quality public spaces is more important than requiring a certain amount of open space *per dwelling* (NSW Government Architect, 2021b).[29] Most open space (such as parkland) is quite versatile and is not capacity-constrained. So in estimating the marginal economic cost of accommodating growth from an open space perspective, we focus on the cost of ensuring access to a minimum area of open space within walking distance of homes.

Box 6: The Public Open Space Strategy

The NSW Government sets a coordinating vision for public open space policy across government, with five main objectives (DPE, 2022c):

1. better recognition for public open space
2. stronger First Nations involvement
3. coordinated planning, governance, policy, and funding
4. greater social, environmental, and economic value
5. better outcomes for regional NSW.

The open space access measure in this paper is simple and focuses on a small number of possible development locations within each SA3 area. More detailed strategic planning would identify the more specific needs of a location, and associated costs.

The NSW Department of Planning and Environment is developing improved baselines to guide public open space delivery. These baselines are specific to the public open space needs and the environments of greenfield, brownfield, and infill development. The baselines will consider:

- current and future population density
- distribution and quality of the existing public open space network
- projected growth and proximity to transport and social infrastructure
- a network-wide approach to open space planning and delivery, looking beyond the site alone.

They will offer a range of approaches to meet open space needs of a community.

[29] The NSW Government Architect's 2021 Draft Urban Design Guide recommends the following to be accessible within walking distance of a dwelling (for instance, a local park should be within 400 metres and a larger district park should be within 1,600 metres). For large developments, it recommends around 15 per cent of the land area of the development should be public green space. While it does not set per-dwelling quantity targets, it does reinforce the importance of quantity in achieving access to green space (for instance, for sporting facilities susceptible to capacity constraints).

3.5.2 Most areas of Sydney have reasonable access to open space

To estimate open space infrastructure costs, we have assessed the area of public open space within walking distance (1.6 kilometres) of each identified location, measuring it against the Draft Urban Design Guide's 15 per cent benchmark for large developments.

Where a location meets the benchmark, we consider there to be no cost, because there is spare capacity. Where a location does not meet the benchmark, we don't attempt to address the shortfall for existing residents. Instead, we estimate the cost of providing public open space for the additional dwellings as the lower of:

- the cost of purchasing eight square metres of land to improve access to public open space[30]; or
- the relevant public space contribution rate in the local government contribution plan[31].

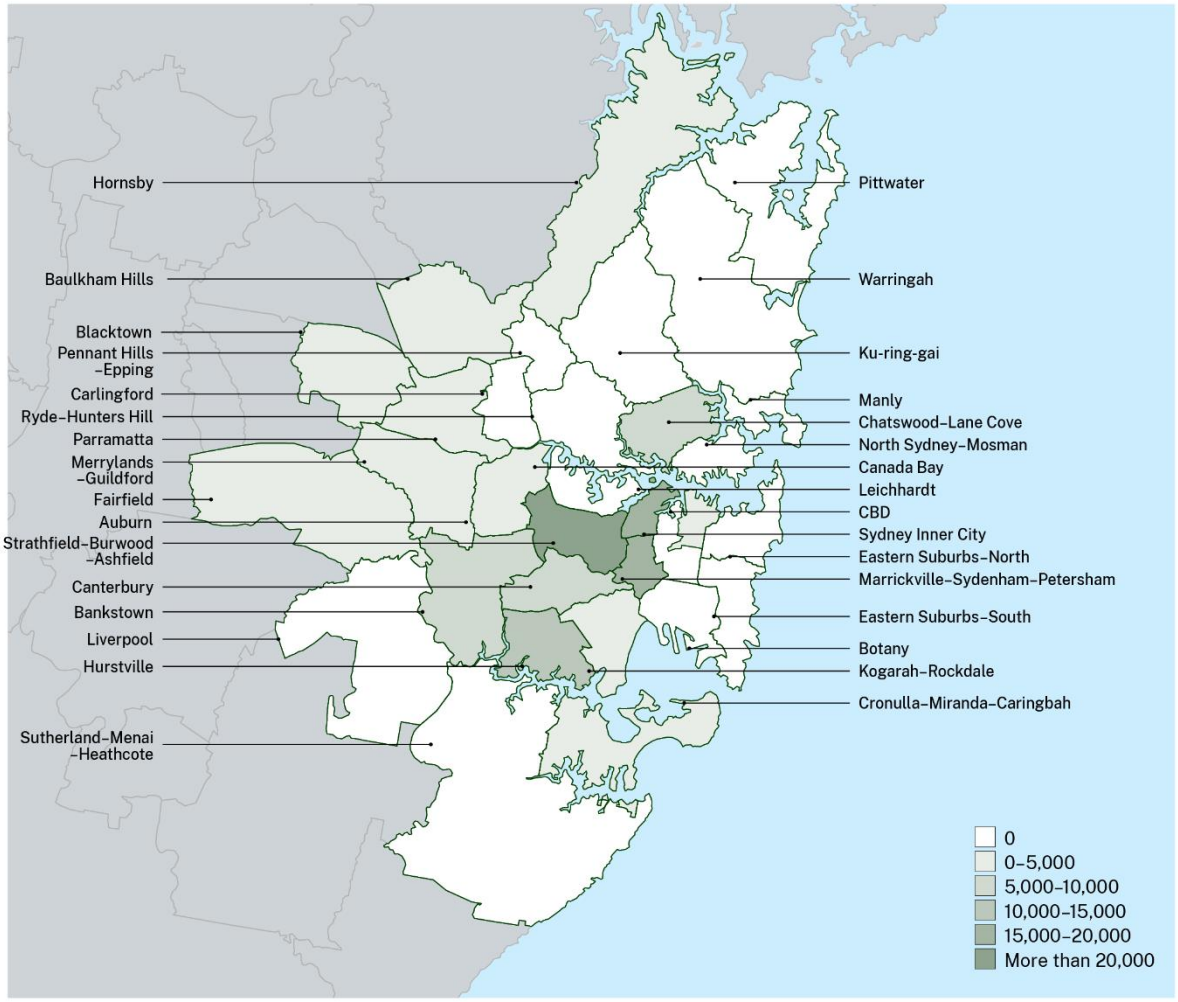
We find that most areas of Sydney meet or are near the minimum access standard. The Eastern Suburbs, Lower North Shore, Inner City (excluding the CBD), and several outer suburban areas had no open space costs. Other areas in southern, western, and north-west Sydney have costs between $2,000 and $10,000 per property.

[30] We use an estimate of eight square metres of land per dwelling as an approximate measure consistent with every dwelling being within a 200-metre distance to a small local park.

[31] Local infrastructure contributions plans made under section 7.11 and 7.12 of the Environmental Planning and Assessment Act.

Figure 15: Strathfield, Burwood, and Ashfield by far have the least available open space

Public open space costs, $ per additional dwelling



Source: NSW Productivity Commission analysis.

The SA3s with open space access well below the benchmarking are Strathfield-Burwood-Ashfield, Marrickville-Sydenham-Petersham, and Leichardt. These sections of the Inner West were constructed without many parks, and originally contained large industrial areas. In these areas, we estimate the cost open space to be $17,000 to $24,000 per dwelling.

Adding public open space in infill areas can be expensive. It is not feasible to create new major urban parks like Centennial Park, Sydney Park, or St Leonards Park which provide open space for large numbers of people. However, new housing can subsidise the creation of smaller open spaces, which will benefit both new and existing residents.

3.5.3 The financial cost of open space depends on locational objectives

Estimating the 'right' amount of public open space for a particular area is fraught. We have used a simple, access-based measure that can be consistently applied across the city. Analysis by DPE using different criteria has identified other areas with limited access to open space, including areas in the Inner South, Botany, and the Inner West.

When deciding on the appropriate access a development needs, governments might need to consider:

- Capacity constraints for different assets: Although most open space assets are not prone to congestion, others can get quite congested at times. Some areas may have a shortage of sport fields, for example, these are used intensively on weekend match days and on weeknights for training. Even if there was a sufficient area of open space in aggregate, a council might incur costs in redeveloping one type of open space into another.
- Varied quality of open space: In practice, policymakers will need to consider the quality of existing open space, and how it can be improved to the benefit of the community. For example, a small, well-designed park with a good playground will likely give people more amenity than an expanse of patchy grass next to a highway. The benefits from embellishing *existing* open space and planting street trees in infill areas are substantial and come with relatively little cost.[32]
- The needs of different types of residents: An area with mostly young professionals will likely need more dog parks, and an area with more children will require more playgrounds. The specific needs of current and future residents would affect the cost of adapting existing open space.
- Self-selection: All else being equal, people will gravitate toward places that suit their specific amenity preferences. Other public spaces and venues may to some degree substitute for open space in meeting households' needs: Marrickville residents may socialise at a microbrewery instead of a park; Pyrmont residents might go for a run along the foreshore instead of around an oval. Less open space may be acceptable in these circumstances, at least from an amenity perspective.
- Increased open space standards: This analysis looks at the cost of achieving a minimum standard. But governments may decide that it is in the public interest to increase public open space, either to encourage local residents to be more active, or to achieve environmental outcomes. This will likely achieve additional benefits, though at additional cost. The NSW Department of Planning and Environment, in partnership with NSW Treasury, developed a cost-benefit analysis framework to assist policymakers in making a business case for open space expenditure (DPE, 2022).

By its nature, though, open space is land-intensive, and land in infill areas is expensive; we estimate constructing Centennial Park today would cost upwards of $12 billion — comparable to major transport projects. Some of these costs can typically be recovered from beneficiaries through local developer contributions plans.

[32] The CIE estimates that street trees and embellishment have a benefit-cost ratio of 13 for infill at medium density and 26 at high density (CIE, 2023).

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Appendix A: Modelling results for all SA3s

Table 2: Modelled costs for all SA3s in alphabetical order, $ '000s/dwelling

SA3	Congestion	Water and wastewater	Train overcrowding	Primary schools	Secondary schools	Public open space	Total[33]
Auburn	42.7	13.3	5.1	2.6	0.4	0	**64.1**
Bankstown	57.0	13.3	5.2	0.7	0.1	5.3	**81.6**
Baulkham Hills	62.7	40.1	0.6	10.8	0	0.2	**114.4**
Blacktown	51.5	21.3	4.1	0.7	0	3.6	**81.2**
Botany	51.5	13.3	2.5	2.6	0	0	**69.9**
Canada Bay	48.8	13.3	4.1	1.9	0.5	0	**68.5**
Canterbury	65.2	13.3	3.5	0	0.1	6.3	**88.4**
Carlingford	68.8	19.5	1.7	3.0	1.2	0	**94.1**
CBD[34]	9.7	13.3	0.5	4.3	4.6	7.0	**39.5**
Chatswood - Lane Cove	24.2	19.5	2.2	2.6	5.7	5.2	**59.4**
Cronulla - Miranda - Caringbah	60.9	15.4	3.5	14.0	0	2.8	**96.6**
Eastern Suburbs - North	24.1	13.3	0.2	3.6	6.4	0	**47.5**
Eastern Suburbs - South	37.2	13.3	0.1	3	0	0	**53.6**
Fairfield	53.4	13.7	5.5	0	0	2.7	**75.2**
Hornsby	37.7	42.2	1.9	19.7	4.6	2.1	**108.3**
Hurstville	45.2	13.3	7.5	3.1	0.2	10.1	**79.4**

[33] Rows may not sum to total because of rounding.

[34] CBD is a 'synthetic' SA3 we used for analysis purposes by separating the Sydney (North) - Millers Point, Sydney (South) - Haymarket, Ultimo, Chippendale, Redfern, Darlinghurst, Surry Hills, and Potts Point - Woolloomooloo SA2s from the ABS Sydney Inner City SA3.

SA3	Congestion	Water and wastewater	Train overcrowding	Primary schools	Secondary schools	Public open space	Total[33]
Kogarah - Rockdale	41.6	13.3	8.6	1.3	0	4.8	**69.6**
Ku-ring-gai	44.9	19.5	2.4	11	2.9	0	**80.7**
Leichhardt	42.9	13.3	0.4	17.6	0.3	16.9	**91.4**
Liverpool	44.7	19.5	5.2	8.5	0	0	**77.8**
Manly	53.4	19.5	0	8.5	11.9	0	**93.3**
Marrickville - Sydenham - Petersham	30.8	13.3	4.5	1.2	2.7	16.6	**69.0**
Merrylands - Guildford	50.8	13.7	6.0	3.4	0.3	3.7	**77.9**
North Sydney - Mosman	17.9	19.5	1.4	10.9	3.0	0	**52.6**
Parramatta	37.2	16.4	7.1	0.3	0.2	2.7	**63.8**
Pennant Hills - Epping	54.5	30.5	2.6	19.9	4.8	0	**112.3**
Pittwater	52.6	21.6	0	19.9	5.2	0	**99.3**
Ryde - Hunters Hill	40.8	19.5	2.1	3.2	2.3	0	**67.8**
Strathfield - Burwood - Ashfield	42.3	13.3	4.4	2.5	7.4	23.5	**93.4**
Sutherland - Menai - Heathcote	57.5	18.5	5.5	6.6	0	0	**88.0**
Sydney Inner City	25.1	13.3	2.6	7.9	0	0	**48.9**
Warringah	63.8	19.5	0.2	1.7	0.9	0	**86.1**

Appendix B: Composition and allocation of the population shock

In our analysis we looked at the infrastructures costs of adding 2,500 new households into different areas of Sydney. We chose this number as it is roughly the size of a large infill housing development in Sydney. We considered this was a large enough shock to stress existing infrastructure, while not so large that it would justify significant changes to the configuration of the city's major infrastructure.

Determining characteristics of the shock

To determine the infrastructure needs of 2,500 additional dwellings we looked at the demographic characteristics of households in the 2021 Census who indicated they had not lived in Sydney 5 years ago. This included the number of workers and their occupations and the number of school age children.

From this data we estimated adding 2,500 new dwellings would mean:

- 6,488 additional people
- 3,441 additional workers
- 733 primary school age children
- 325 secondary school age children

Of these new residents, roughly 49% moved more overseas, 41% from elsewhere in NSW and 11% from interstate. These households have somewhat different infrastructure needs compared to average households. New households:

- are larger and younger, 2.6 persons on average compared to 2.5 for the existing population.
- have more primary school age children, but fewer secondary school age children.
- contain more workers, and those workers are more likely to work in lower paid occupations, such as labourers and care workers.

This approach does not take into account household formation for existing residents for example through families separating, or through new couples forming. We made this simplifying assumption based on the assumption that new residents are the main driver for the need for new housing. We also consider it unlikely this change would have significant impacts on our analysis.

Allocating shock to "Locations of Interest" within each SA3

To allocate the 2,500 additional households within each SA3, we first identified good potential locations, within each SA3, to add more housing around train stations, and other community centres.

Next, we ranked each location based on each location's "effective access to jobs". We calculated this using the formula:

$$EAJ = \sum_{All\ i} \frac{J_i}{T_i}$$

where for all SA2s in the ABS Greater Sydney Greater Capital City Statistical Area:

- J_i is the number of jobs in SA2 i
- T_i is the time taken to commute from the potential development location to the centroid of SA2 i starting at 8 am on a weekday, using Google Maps.

Based on these results we allocated the shock of 2,500 households between the three to four highest scoring locations of interest (LoI) within each SA3, in proportion to their relative EAJ scores.

As an example for the Eastern Suburbs North SA3, we identified seven locations. We allocated the population shock to the four highest locations.

Potential LoI	EAJ Index	EAJ Ranking	Percentage of population shock	Additional households
Edgecliff Station	63,369	1	31%	768
Bondi Junction Station	54,490	2	26%	661
Double Bay	46,767	3	23%	567
Waverley	41,561	4	20%	504
Bondi Road	35,483	5	0%	0
Bondi Beach	33,040	6	0%	0
Rose Bay	30,887	7	0%	0

Appendix C: Modelling Appendix

Congestion

We estimate the economic value of time lost to congestion for workers driving to their place of employment from different areas of Sydney. Broadly, our model:

- Looks at commuting destinations and travel mode preferences for residents of each "Location of Interest" based on the 2016 Census. This tells us, for each "Location of Interest", the share of workers who drive to work and where their place of work is.
- Uses Google Maps data to measure the congested and uncongested driving time for each itinerary between a "Location of Interest" and a place of employment.
- Based on this information, estimates how many additional drivers will be created by adding 2,500 homes in each SA3 as well as the amount of time they will lose to congestion, over the long-term. This lost time is then converted to an economic cost based on standard estimates for the value of time.

Our model assumes that the capacity of existing roads is fixed and new infrastructure is not constructed to reduce congestion. It is assumed the population of all other SA3s remain constant.

The model can be described as the sum of costs of across "Location of Interest" within each SA3:

$$congestion\ costs_{SA3} = \sum_{All\ i\ in\ SA3} S_i \times C_i \times T_C$$

where:

- S_i is the number of workers added to "Location of Interest" i
- C_i is the additional time lost to congestion from adding more workers to "Location of Interest" i
- T_C is the long-term cost per minute of additional time lost to congestion.

Breaking down further:

$$S_i = W \times p_i$$

where:

- W is the number of additional workers moving to an SA3 from adding 2,500 new homes, which we estimate to be around 3,441 workers (see Appendix B)
- p_i is the share of the N households allocated to "Location of Interest" i.

Next, C_i is the sum of all time lost to congestion for workers residing in "Location of Interest" i. We calculate this time for individual professional occupations and for individual itineraries between "Location of Interest" i and SA2 of employment.

Specifically, we first consider a worker residing in "Location of Interest" i and whose job is located in SA2 j. The congestion time lost by this worker is:

$$c_{i,j} = t_{i,j}^{peak} - t_{i,j}^{off-peak}$$

where:

- $t_{i,j}^{peak}$ is the time taken to drive from "Location of Interest" i to the centroid of SA2 j starting at 8 am on a weekday, based on Google Maps data
- $t_{i,j}^{off-peak}$ is the time taken to drive from "Location of Interest" i to the centroid of SA2 j starting at 11:59 pm on a weekday, based on Google Maps data.

We then use information on professional occupations, mode of transport, and place of work to calculate the total time lost to congestion by all workers residing in "Location of Interest" i:

$$C_i = \sum_{all\ x} \sum_{all\ j} \alpha_{i,x} \times \beta_{i,x,car} \times \gamma_{i,j,x,car} \times c_{i,j}$$

where:

- $\alpha_{i,x}$ is the percentage of workers who live in "Location of Interest" i and who work in occupation x (we use the eight ABS 1-digit occupation codes from 2016 Census)
- $\beta_{i,x,car}$ is the proportion of workers in "Location of interest" i, with occupation x, who drive to work
- $\gamma_{i,j,x,car}$ is the proportion of workers who live in "Location of Interest" i, work in occupation x, drive to work, and whose place of work is located in SA2 j based on 2016 Census data.

Finally T_C is a constant:

$$T_C = \omega \times \varphi_C \times Y_C \times (1 + \varepsilon) \times P$$

- ω is $0.33 per minute. This reflects the value of private travel time, based on 40% of average weekly earnings in NSW, assuming a 38h-week. Based on ABS AWE and Sydney CPI and Transport for NSW Economic Parameter Values guidelines.
- φ_C is 2.1. This is a factor to scale AM peak into daily total congestion. Based on Infrastructure Australia approximation that in Sydney, 7-9AM peak accounts for 32% of daily hours delay car and 4-6PM peak for 33%.
- Y_C is 336. This is a factor to scale daily congestion costs to yearly costs, based on Transport for NSW Economic Parameter Values guidelines.
- ε is 0.79. This is the incremental congestion delay an individual traveller imposes when entering traffic. Transport for NSW Economic Parameter Values guidelines.
- P is 23. This is a present value scaler, based on ABS and CBA guidelines assuming a AWE annual growth rate of 0.48% and 5% discount rate over 100 year horizon.

Note that, because T_C is a constant, any variation in congestion costs between different SA3s is solely due to differences in the distance travelled by workers from their new homes to their places of employment and the time they lose to congestion during their commute.

Train crowding

Similar to congestion above, we calculated train overcrowding using the formula:

$$overcrowding\ costs_{SA3} = \sum_{All\ i\ in\ SA3} S_i \times OC_i \times T_{OC}$$

where:

- S_i is the same as above
- OC_i is the additional train overcrowding from adding LoI i's share of the population shock
- T_{OC} is the long-term cost per minute time in congested train, based on willingness to pay to avoid congestion.

So,

$$OC_i = \sum_{all\ x} \sum_{all\ j} \alpha_{i,x} \cdot \beta_{i,x,train} \cdot \gamma_{i,j,x,train} \cdot OCT_{i,j,r} \cdot OCM_r$$

where:

- $\alpha_{i,x}$ is the same as above

- $\beta_{i,x,train}$ is the proportion of workers in location i occupation x who travel to work by train
- $\gamma_{i,j,x,train}$ is the proportion of workers who live in "Location of Interest" i, work in occupation x, take the train to work, and whose place of work is located in SA2 j based on 2016 Census data
- $OCT_{i,j,r}$ is for each train itinerary from LoI i to employment location j, the amount of time spent on an overcrowded train on each train line r
- $OCM_{i,j,r}$ is the crowding multiplier for the itinerary i to j.

To determine the amount of time commuters spend on overcrowded trains, we used Google Maps to determine the best train itinerary between LoI i and each employment SA2 j. From this we determined which rail lines[35], r, and which rail segments between stations y and z the commuter would travel on.

Breaking down further:

$$OCT_{i,j,r} = \sum_{All\ x,y} d_{y,z,r} \cdot SN_{y,z,r} \cdot ST_{y,z}$$

where:

- $d_{x,y,r}$ is a dummy variable, $\in \{0,1\}$, based on whether the rail segment between stations y, z occurs on the rail component of the itinerary between LoI i and employment location j while a commuter is traveling on rail line r.

  For example, an itinerary between Newtown station and the CBD, would travel on the rail segment between Redfern and Central on the T2 Inner West Line so the value of $d_{y,z,r}$ would be 1. However, the itinerary does not contain:

  — the segment between Central and Redfern going the other direction; or

  — the segment between stations which are not on the route for example between Paramatta station and Harris Park station; or

  — the same segment but on a different line, for example segment between Redfern and Central but on the T8 South Line.

  In each of these examples $d_{y,z,r}$ would equal 0.
- $SN_{y,z,r}$ is the percentage of the time the rail segment between stations y and z is standing room only, while travelling on rail line r, in the morning peak in September 2019, based on Transport for NSW data.
- $ST_{y,z}$ is the time taken to travel the rail segment between stations y and z, assuming no delays based on Google Maps data.

Our crowding multiplier, OCM_r, converts the time spent in a crowded train to the amount of additional time a commuter would be willing to travel to avoid being in an crowded train. This calculation on based the Average and Maximum Load Factors for each rail line (the average and highest recorded ratios of passengers to seats at peak times) as reported by Transport for NSW based on September 2019 ridership. Load Factors are then converted to an amount of additional time a customer would be willing to spend travelling to avoid crowding using Transport for NSW recommended crowding multipliers.

Finally, T_{OC} is the value of time in crowded trains:

$$T_{OC} = \omega \times \varphi_{OC} \times Y_{OC} \times P$$

- ω is the same as above.

[35] For example the T1 Northern Line or the T4 Eastern Suburbs Line.

- φ_{OC} is 1.85, a factor to scale AM peak into daily total crowding. Based on Transport for NSW survey of peak train loads 8-9AM relative to 5-6PM.
- Y_{OC} is 277, is a factor to scale daily congestion costs to yearly costs, based on Transport for NSW Economic Parameter Values guidelines.
- P is the same as above.

Schools

To determine the cost of managing additional students from the population shock we followed a three-step procedure:

1. We drew a circle around each LoI, 1.6km for Primary Schools and 4km around Secondary Schools.[36] Importantly, these schools don't need to be in the same SA3 as the LoI.

   If there is spare capacity in schools within the circle, we iteratively allocate students to schools with capacity, until all spare capacity is taken up. There is no cost for students allocated in this step.
2. If there are new students unallocated after step 1, we look at the capacity of schools elsewhere in the SA3. If there is capacity, we allocate students to these schools until there are no students left to allocate or there is no capacity left. We assign a smaller cost for students allocated in this step, equal to one quarter of cost of managing the student through a new classroom.
3. If there are new students unallocated after step 2, we assume additional classrooms will be required to manage the students at a higher cost. As an additional check we made sure there was adequate space for the additional classrooms without breaking a student per square metre ratio benchmark, which didn't occur anywhere in Sydney for the number of additional students we considered in our analysis.

Step 1:

For the first allocation step, we iteratively distributed students through a series of rounds, in the first round:

- We divided the students from 2,500 households (733 primary school, 325 secondary school) between the LoIs in each SA3 in the same proportion as discussed in Appendix B.
- For each LoI, we divided the shock of students by the number of schools within the circle. We then attempt to allocate that many students to the school. [37]
  - If a school has no available capacity, it is excluded.
  - If a school's available capacity is less than the share of students, it is allocated students up to its capacity. The school is excluded from future rounds and excess students are carried forward to be allocated to other schools in future rounds.
  - If the school's available capacity is greater than its allocation of students, it receives its allocation and its remaining available capacity can be allocated in future rounds.
- The available capacity for each school is determined by comparing each school's out-of-area cap in 2021 to its enrolment (Department of Education, 2021).
  - If a school is in the circle of multiple LoIs, its available capacity is shared between LoIs based on the relative proportion of additional dwellings allocated to the LoIs. For example, a school is shared between an LoI which received 25 per cent of the dwelling shock and one which received 30 per cent of the shock. The first LoI would receive 45 per cent of the school

[36] We choose these distances because they ensured all LoIs would have at least one school within the circle.

[37] We have allowed for fractional allocation of students at all steps for modelling simplicity.

capacity, $\frac{25\%}{(25\%+30\%)}$, and the second would receive 55 per cent of the school capacity $\frac{30\%}{(25\%+30\%)}$.

- For simplicity, available capacity for shared schools is not reallocated in future rounds.

In the second and subsequent rounds, any unallocated students in each LoI are divided between any remaining schools within the LoI with available capacity. The process in round 1 is repeated, until all students in the LoI are allocated, or all available capacity is exhausted for the schools in the LoI circle. If all students are allocated in all LoIs we stop here and the cost the cost is zero.

Step 2:

Unallocated students from all LoIs are collected together and compared to the remaining available capacity for all schools in the SA3 we are calculating, including schools which were not used in Step 1. However, schools from Step 1 in other SA3s are excluded.

- If there is no remaining available capacity in the SA3 we are measuring we moved to Step 3
- If the remaining available capacity is not zero, but less than the number of unallocated students:
  - Students are allocated until the available capacity in the SA3 is filled
  - Remaining students are carried over to step 3
- If the remaining available capacity in the SA3 is greater than the number of students left to allocate, all students are allocated and we stop here.

Students allocated in Step 2 creates a cost of $16,950 per primary school student and $22,884 per secondary student (one quarter the new classroom cost in step 3).

Step 3:

Any unallocated students from step 2 are assumed to necessitate the construction of new classrooms. Any remaining primary student attracts a cost of $67,800, and any remaining secondary student attracts a cost of $91,538.

These costs are based on an assessment of the per student cost of recent upgrade projects undertaken by Schools Infrastructure NSW.

Water and wastewater

For water and wastewater, we drew on data from Sydney Water's draft Development Servicing Plans (DSPs), released in April 2023. The DSPs compare the projected future capital and operational costs, as well as population growth for different areas of Sydney. We used a long-run marginal cost approach, where we estimated each additional dwelling's incremental contribution to Sydney Water's future capital and operational infrastructure needs.

We calculated the cost based on the formula:

$$Water\ and\ wastewater\ cost\ SA3 = \sum_{All\ i\ in\ SA3} N \times p_i \times \left(\frac{C_{w,i} + O_{w,i}}{\propto \times ET_{w,i}} + \frac{C_{s,i} + O_{s,i}}{\beta \times ET_{s,i}} \right)$$

where:

- N is 2,500, the number of new dwellings added in the SA3
- p_i is the share of the D households allocated to "Location of Interest" i
- $C_{w,i}$, $C_{s,i}$ are the present value of uncommissioned capital assets required to service future growth in the relevant water w, and wastewater s DSPs for where LoI i is located
- $O_{w,i}$, $O_{s,i}$ are the present value of incremental operating and maintenance costs from growth in the relevant water w, and wastewater s DSPs for where LoI i is located

- $ET_{w,i}$, $ET_{s,i}$ are the present value of future "Equivalent Tenements"[38] in the relevant water, w, and wastewater, s, DSPs for where LoI i is located
- α, β are scaling factors relating the number of water and wastewater Equivalent Tenements an additional two-bedroom apartment creates. We set α to equal 0.5 and β to 0.75. This is to reflect that we expect most infill dwellings to be attached rather than detached dwellings.

Public open space

For public open space access, we calculated costs based on the amount of additional land (or equivalent developer contributions) required to meet an open space benchmark of 15 per cent of developable land in the local area being available as public open space. Broadly, our procedure is as follows:

1. We drew a 1,600m circle around each LoI, equivalent to roughly a 20 minute walking distance.
2. Using DPE land zoning data we determined the land area within the circle which was zoned for public open space (RE1 zone) and the amount of land zoned for residential uses (R1-5 zone).
3. We calculated the ratio of RE1 zoned land area to the area of RE1 zoned land plus the area of residential zoned land. If this ratio in an LoI is less than 15 per cent, we calculated the cost of providing public open space to meet the need of new residents using the formula:

$$Open\ space\ cost\ SA3 = \sum_{All\ i\ in\ SA3} d_i \times N \times p_i \times \min(LV_i \times LPD, CR_i)$$

where:

- d_i is a dummy variable, $\in \{0,1\}$, set to 0 if the "Location of Interest" i meets the 15% open space metric and set to 1 if it has less than 15% public open space
- N is 2,500, the number of new dwellings added in the SA3
- p_i is the share of the D households allocated to "Location of Interest" i
- LV_i is the per square metre unimproved value of residential land in the postcode where the LoI is located, based on 2022 data from the NSW Valuer General
- LPD is the additional land we calculated would be required to ensure appropriate access to public open space for a new high-density dwelling, roughly 8 sqm per dwelling [39]
- CR_i is the per dwelling contribution rate for public open space land and embellishment for the relevant Local Infrastructure Contribution plan for the LoI. [40]

[38] Equivalent tenements represent the service needs for a single detached house.

[39] The 8 sqm of land per dwelling metric is an approximate measure of accessibility to green space, consistent with assuming that every dwelling is within a 200 metre distance to a small local park.

[40] Local infrastructure contributions plans made under section 7.11 and 7.12 of the Environmental Planning and Assessment Act.

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